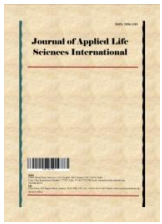

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Effect of Port Activities on the Physicochemical and Microbiological Quality of Surface Water in Warri and Onne Port Terminals, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author DNO designed the study, while author EMA performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript managed the analyses of the study and literature searches under the strict supervision of authors DNO and SAN. All authors read and approved the final manuscript.

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ABSTRACT

Activities around the port terminals such as cargo handling, and others has environmental implications both inside and outside the port area which may in turn pose severe risks to the environment and water resources resulting to adverse effect on the physicochemical and microbiological quality of the water body. Hence this study was aimed at determination of the effect of port activities on the physicochemical and microbiological quality of surface water at Warri and Onne Port terminals. Surface water samples were collected during wet and dried season between January to June from Onne and Warri port terminals, using sterile containers and transported in an ice packed container to Department of Microbiology laboratory of the Rivers State University for microbiological and physicochemical analyse using standard methods. Statistical analyses were carried out using ANOVA and All pairs tukey-kramer. Results of the Physicochemical Characteristics of the surface water of the dry season ranged as follows; pH (5.6±0.15 to

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6.08±0.22),Temperature (27.6±4.278 to 30±1ºC), Electric conductivity (14168±1.90to 2138±27.871 µs/cm), Total dissolved solid (2622±1.70 to 974.2±9.09 mg/l),Total suspended solid (7.6±0.54 to 111±21.284 mg/l), Dissolved oxygen (2.08±0.19 to 2.68±0.31 mg/l), Biological oxygen demand (0.78±0.19 to 1.2±0.45 mg/l), Chemical oxygen demand (1.56±0.38 to 2.4±0.90 mg/l),Turbidity (0.2±0 to 1.36±0.336 NTU),Bromine (0.3±0.01 to 0.6±0 mg/l), Chlorine (<0.001±0 to 0.3±0 mg/l),Nitrate (0.32±0.15 to 5.98±0.74 mg/l), Sulphate (3.32±0.75 to 694±1.9 mg/l) Phosphate (0.634±0.42 to 2.316±0.44 mg/l), similar trends were recorded during the wet season. There were significant differences (P<0.05) between the wet and dry seasons. The mean values of the microbiological results ranged from 1.6±0.77 x 10^6 to 5.6±2.17 x 10^6 cfu/ml (Total heterotrophic bacterial count), 0.8 ±2.51 x 10^4 to 5.6±2.77 x 10^4 cfu/ml (Total heterotrophic Fungal count), 0.2 ±1.14 x 10^4 to 3.6 ±1.52 cfu/ml (Hydrocarbon utilizing Bacteria counts) 0.3 ±1.52 x 10^4 to 1.2 ±2.05cfu/ml (Hydrocarbon utilizing Fungal counts), 0.2±0.71x 10^4 to 0.6±0.89 x 10^4cfu/ml (*Salmonella* spp.). 0.4±0.55 x 10^4 cfu/ml (*Shigella* spp), 0.3 ±2.19 x 10^4 to 1.6±5.13 x 10^4 cfu/ml (*Vibrio* spp.) 1.6 ±14.7 x 10^4 to 2.1±6.39 x 10^4 cfu/ml *Staphylococci* spp), 3.9±0.81 x 10^4 to 4.6 ±1.79 x 10^4cfu/ml (total coliform), 1.8±0.44 x 10^4 to 2.7 ±1.03 x 10^4cfu/ml (feacal coliform). Higher counts were recorded during the wet season compared to dry season. In this study, nine bacteria isolates belonging to the genera and species:- *E.coli, Vibrio, Pseudomonas, Klebsiella, Bacillus sp., Shigella, Staphylococcus, Salmonella,* and *Proteus,* Six fungal isolates, namely, *Penicillium* sp *Candida* sp, *Mucor* sp, *Aspergillus, Rhizopus* spp, and *Yeast* were obtained. The results obtained in this study Port terminal houses several companies with beehive of activities which generate various industrial wastes which causes adverse environmental effects which consequently are major atmospheric and water pollution around port terminals. Therefore, proper waste management system should be maintained to avoid emergence of virulent pathogens.

Keywords: Port activitie physico-chemistry; surface water; environment; microorganisms and pollution.

1. INTRODUCTION

Maritime industry activities, particularly ship operations are the prime factor causing maritime pollution due to the generation of waste products. Other port activities like shipping, dredging, ballast water discharges, storage and transportation of hazardous materials generate several wastes such as industrial effluents, sewage, urban and river runoff, natural seepage, offshore oil production, ships, and others into the environment thus, causing pollution of coastal water and the sounding environment [1] soil [2] and water source [3].

The wastes disposal into the sea, especially plastics remains for several years without decomposition causing blockage of water bodies, affecting the physiochemical quality of the receiving water body especially the dissolved oxygen in the water, thus causing an imbalance in the ecosystem [4]. These wastes generated by these port activities are leached through runoffs into the sea/ surface water bodies and these constitute pollution [5].

Activities around the port terminals such as cargo handling, operation in the field of maritime navigation, Emission from ships has environmental implications both inside and outside the port area which may in turn pose severe risks to the environment and water resources resulting to adverse effect on the physicochemical and microbiological quality of the water body. For example, accidents during oil transportation and ballast water tank transfers are harmful to aquatic species between different places in the ocean [3]. This effect results in stemming from ballast water handling, oil spills and fouling by ships due to discharges from vessels and waste from hazardous cargoes, all of which potentially produce negative effects on the environments particularly the marine ecosystems. Such operations within the physical environment can increase urban congestion affecting both air and water pollution leading to emergence of certain diseases [2].

These conditions in addition to surface water flows, in several directions are essential in determining the water quality status of the river [6]. However, River water quality assessment depends on the pH and temperature which are vital as they influence reactions in water and the concentrations of other water quality parameters [7].

The surface water contains dissolved solids which possesses physical characteristics such as odor, taste and temperature. The natural quality

of surface water depends upon the physical environment, the origin, and the movement of water. As the water moves through the hydrological cycle, various chemical, physical and biological processes change its original quality through reactions with soil, rock and organic matter. Natural processes and human activities cause the changes in surface water and groundwater quality, directly or indirectly. Many waterborne infectious diseases are linked with faecal pollution of water sources and results in faecal oral route of infection [8].

One of the major problems with the use of surface water contaminated with microbes is the infectious disease such as viral hepatitis, polio, typhoid and paratyphoid fever, amebic and bacillary dysentery, botulism, cholera, schistosomiasis, salmonellosis, primary amoebic meningoencephalitis and giardiasis. The causative organism of these diseases are present in the faeces and urine of infected persons and when discharged may gain entrance into any body of water that may ultimately serve the purpose for drinking and other domestic uses, [9]. These organisms may also be present in the environment [10].

Persons with improper sanitation, hygiene and poor water supply are at greater risk of contracting water borne diseases. [11]. Poor quality water destroys the crop production and infects our food which in turn affect human life through food chain [12,13], Untreated water and faecal contamination of surface water can serve as the major vehicle of pathogen spread and other environmental health hazard. Hence this study was aimed at investigating the effect of port activities on the physiochemical and microbiological quality of surface water at Warri and Onne Port terminals.

2. MATERIALS AND METHODS

2.1 Description Area of Study

The study area is Onne in Eleme L.G.A Rivers State and Warri in Delta State. Onne where one of the two prominent Nigerian ports for oil and gas exploration are sited. It is bordered by the Alode, Ebubu and Ngololo Creek, a tributary of Bonny River. Warri is a city in Delta State, Nigeria. It is an oil hub in Southern Nigeria and houses the Warri port where several port activities are carried out. It served as the colonial capital of the then Warri Province. The location of Warri port terminal makes the port an ideal spot for landing, swamping and low water activity nearby. Fig. 1 shows the sampled locations at Warri and Onne Port terminals in Niger Delta.

2.2 Sample Collection

Surface water samples were collected from Onne and Warri port terminals at five different stations with sterile containers. Surface water samples were collected during sampling in both ports between January to June over a period of six months covering both wet and dried seasons. Each sample bottle was rinsed with the appropriate water sample before the final collection. The sterile bottles were filled with surface water and transported in an ice packed cooler to the Department of Microbiology Research Laboratory of the Rivers State University for analyses.

2.3 Microbiological Analyses of Water Samples

2.3.1 Serial dilution

One millilitre each of the water samples were separately added to 9 ml of normal saline (diluents). After thorough shaking, further 10-fold (v/v) serial dilutions were made by transferring 1 ml of the original solution to freshly prepared normal saline diluents to a range of 10^{-4} dilutions [14].

2.3.2 Inoculation and incubation

Aliquots (0.1 ml) of various dilutions were inoculated to surface dried appropriate medium in triplicates using the spread plate method. The inocula were spread on the plates with flamed bent glass spreader and incubated at 37□ C for 24 hours.

2.3.3 Enumeration and isolation of bacterial colonies

2.3.3.1 Total Heterotrophic Bacteria (THB)

Total Heterotrophic Bacteria was enumerated as described by Prescott et al. [14]. Bacterial Colonies that appeared on the nutrient agar plates which were inoculated in duplicate with an aliquot of 0.1ml from 10^{-4} dilutions were counted and the mean expressed as cfu/ml for the samples. While discrete colonies on the nutrient agar plates that were inoculated with an aliquot of 0.1ml from the direct samples were sub cultured on freshly prepared nutrient agar plate in order to isolate pure cultures.

The colony forming unit per millilitre was calculated using the formula below:

$$\text{CFU/ml} = \frac{\text{number of colonies}}{\text{Dilution x volume plated}}$$

2.3.3.2 Total Coliform Counts (TCC)

Total Coliform Counts was enumerated as described by Prescott et al. [14]. Bacterial Colonies that appeared on the MacConkey agar plates which were inoculated in duplicate with an aliquot of 0.1ml from 10^{-2} dilutions and incubated 37□ C for 24 hours were counted and the mean expressed as cfu/ml for the samples [15]. While discrete colonies on the nutrient agar plates that were inoculated with an aliquot of 0.1ml from the direct samples were sub cultured on freshly prepared nutrient agar plate in order to isolate pure cultures.

2.3.3.3 Feacal coliform counts

Feacal Coliform counts was enumerated as described by Prescott et al. [14]. Bacterial Colonies that appeared on the Erosin Methylene Blue (EMB) agar plates which were inoculated in duplicate with an aliquot of 0.1ml from 10^{-2} dilutions and incubated 45.2□ C for 24 hours, were counted and the mean expressed as cfu/ml for the samples [15]. While discrete colonies on the nutrient agar plates that were inoculated with an aliquot of 0.1ml from the direct samples were sub cultured on freshly prepared nutrient agar plate in order to isolate pure cultures.

2.3.3.4 Total Salmonella-Shigella Counts (SSC)

This was determined with the *Salmonella-Shigella* agar using the spread plate method as described by Prescott et al. [14]. Zero point one (0.1ml) milliliter from 10^{-2} of the serially diluted samples was inoculated onto sterile pre-dried *Salmonella-Shigella* agar plates in duplicates. The inocula were then spread evenly on the surface of the media using a sterile spreader. The plates were then incubated at 37°C for 24 hours, after which the colonies that developed were counted and the mean total *Salmonella-Shigella* counts were recorded.

2.3.3.5 Total Vibrio species count

Total *Vibrio* count was determined with the Thiosulphate Citrate Bile Salt (TCBS) agar using the spread plate technique as described by Prescott et al. [14]. Zero point One (0,1ml) milliliter from 10^{-2} of the serially diluted samples was inoculated onto sterile pre-dried TCBS agar plates in duplicates. The inocula were then spread evenly on the surface of the media using a sterile spreader. The plates were then incubated at 37°C for 24 hours, after which the colonies that developed were counted and the mean total *Vibrio* counts were recorded.

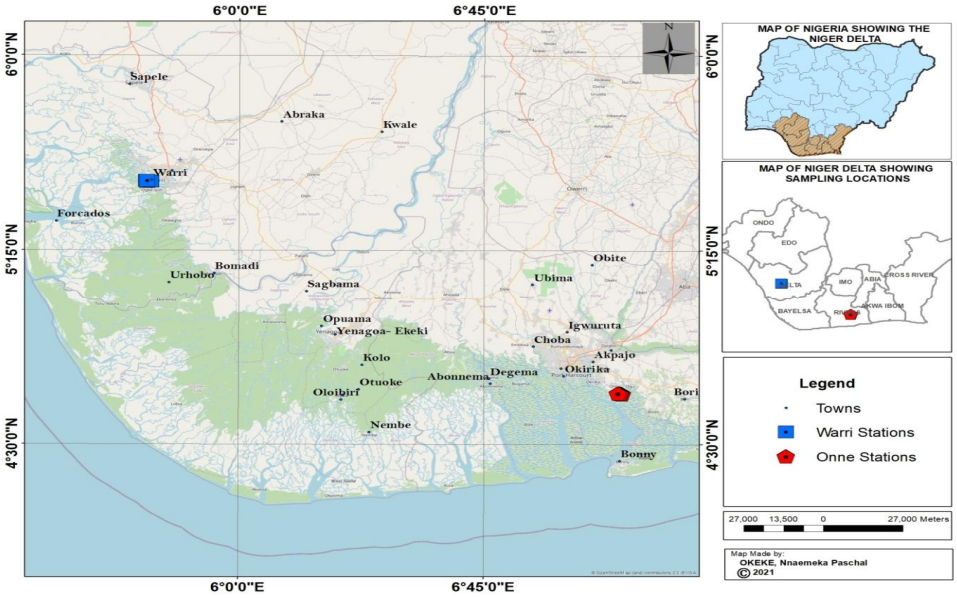

Fig. 1. Niger delta showing the sampled points in Warri and Onne port Terminals

2.3.3.6 Total Heterotrophic Fungal counts (THF)

This was determined using the Sabround Dextrose Agar (SDA) amended with Tetracycline to suppress bacterial growth [16,17]. The spread plate technique as described by Prescott et al. [14] was adopted. An aliquot of 0,1ml from 10^{-2} dilution of the serially diluted samples was inoculated onto pre-dried SDA agar plates in duplicates. The inocula were then spread evenly on the surface of the media using a flamed bent spreader. The plates were then incubated at room temperature (25^{o}C) for 5 days after which the colonies that developed were counted and the mean total Fungi counts were recorded accordingly.

2.3.3.7 Enumeration of hydrocarbon utilizing microorganisms

The vapour phase transfer method as modified by Obire et al. [18] was adopted in estimating the population of hydrocarbon utilizing microorganisms using the spread plate techniques on Mineral salt Medium (MSM). This method employed the use of sterile filter paper saturated with 1ml of sterilized crude oil which served as the only source of carbon. The filter paper was aseptically placed onto the inside cover of the inverted Petri dishes before incubating [19]. Aliquots of 0.1 ml from dilutions of 10^{-2} were inoculated onto the media in duplicates. For the enumeration of the hydrocarbon degrading bacteria, the medium was supplemented with fungusol to prevent the growth of fungal contaminants. On the other hand, the Mineral Salts Medium supplemented with Tetracycline to inhibit the growth of bacteria was used for the enumeration and isolation of oil degrading fungi. The plates were incubated at room temperature (25^{o}C) for 5 days before enumeration. Mineral salt agar was constituted as adopted by Obire et al. [18].

2.4 Purification of Isolates

After incubation, pure isolates were obtained by picking (with sterile inoculating loop) distinct culturally and morphologically different colonies from the various plates. These were subjected to streaking on sterile nutrient agar plates until pure distinct colonies were formed.

2.5 Identification of Bacterial Isolates

Pure bacterial isolates were identified by the method described by Collins et al. [20] and Cheesbrough [21]. Pure bacterial isolates were subjected to genomic identification and Biochemical tests. which include oxidase test, Catalase test, Indole test, methyl red test, Voges Proskauer test, Starch hydrolysis test, Urease test, Citrate test, Sugar fermentation test and Triple sugar Iron agar test. Bacterial isolates were identified with reference to the Bergey's Manual of Determinative Bacteriology [22].

2.6 Physicochemical Characteristics of Water

Temperature, Electrical Conductivity, Total Dissolved Solids (TDS), Turbidity, and pH were determined in-situ using field/laboratory scientific digital simultaneous multi-parameter measurement meter (U=10, Horiba, LA-920. Kyota, Japan). After adequate calibration, the probe was rinsed with distilled water before being dipped into each sample and the display allowed to stabilize before the values for the respective parameter were recorded.

2.7 Total Dissolved Solids (TDS) (APHA 2510B)

This was measured using the HANNA (H199300) meter. The meter was calibrated using the 1000uS/cm, conductivity standard. The key mode was pressed until TDS mode was displayed. The probe was then rinsed with some portion of the water sample before being immersed into the sample. Trapping of air bubbles around the temperature sensor was avoided. The reading was allowed to stabilize before measurement was recorded in mg/l.

2.8 Total Suspended Solids (TSS) (ASTM D1868)

TSS was determined using the HACH (DR 2800) meter. Five hundred millilitre (500ml) of the water sample was blended at high speed for 2 minutes. The blended sample was poured into a 600ml beaker and stirred. Then 25ml of the blended sample was poured into a sample cell. Another sample cell was filled with distilled water and used as blank. The blank was placed in the cell holder and zeroed by closing the light shield. The prepared sample cell was then swirled to remove gas bubbles and suspend any residue, and then placed into the cell holder. The light shield was then closed and reading in mg/l was taken.

2.9 Chemical Oxygen Demand (COD) (APHA 508)

It is a measure of the oxygen reducing capabilities of a medium due to chemical reaction was determined using APHA 508 method. Fifty millilitre (50ml) of the water 4sample was measured into a 250ml conical flask. It was then diluted to 100ml by adding 50ml of distilled water and 2ml of 10% NaOH solution was then added immediately. The content was heated to near boiling point before being brought down after which 10ml of 0.01N KMnO4 was then added to it and allowed to boil again for 10mins. Immediately it was brought down, 10ml of 10N H_2SO4 and 10ml of 0.01N oxalic acid ($C_2H_2O_42H_20$) were added. The resulting colourless content of the conical flask was titrated with 0.01N $KMnO_4$ to an end point colour of faint purple. COD was then calculated using the formula:

$$COD = \frac{\text{VI}-\text{V2X8X1000XN}}{\text{V3}}$$

2.10 Biological Oxygen Demand (BOD_5) (APHA 5210B)

Prior to sampling, the sampling bottles were rinsed with distilled water. Samples were collected in 250ml amber-coloured bottles which were filled to the brim to exclude air, stoppered tightly and conditioned in a cool ice-chest.

This is a measurement of how much oxygen is in an aqueous solution to support aquatic life due to biological activity. This was determined in accordance with APHA 5210B method. The samples were incubated at 20^{o}C for 5 days. Dissolved oxygen was measured initially after incubation and the BOD_5 was calculated from the difference between initial and final dissolved oxygen (DO).

2.11 Statistical Analyses

Statistical analyses were carried out using one-way ANOVA and all pairs tukey-kramer.

3. RESULTS AND DISCUSSION

Water physicochemical properties, which serve as a measure of water contamination are usually evaluated to determine the quality of the water body. Management of water is done to ensure that contaminants that gets into it do not exceed the set or permissible limits, thus, the quality of water is related to the expected use of the water for fishing, recreation, or wild life [23]. In this study the physicochemical parameters of the surface water at Onne and Warri port terminals were evaluated in two different seasons (dry and wet seasons). The seasonal variation of the physicochemical parameters showed that the pH is one of the most important parameters commonly measured in natural and wastewaters to ascertain their quality status. Generally, pH values measured in the present study are indicative of slightly acidic water (5.6±0.15 to 6.08±0.22 for the dry season, and 6.68±0.22 to 6.72±0.24 for the wet season). The mean pH values of the dry season were frequently below the acceptable range of 6.5 - 8.5 prescribed by the regulatory agency [24]. The acidic nature of the water samples possible reflects the presence of high levels of free CO_2 in the waters which could be attributed to the various port activities in the study area. An important problem associated with acidic nature of surface waters is that these waters favours the mobility of non-biodegradable and hazardous trace elements within them [25].

The results of the pH obtained from the surface water of Warri port terminal and Onne port terminals for both seasons were within the 6.5-8.5 NSDWQ [24] permissible limits despite the significant differences recorded between the seasons in the two terminals. This implied that the pH of both terminals was not adversely affected. The variation in the pH of both terminals in their respective seasons could also be due to the geochemical activities carried out in these terminals. This is in consonance with Obunwo and Chukwudi [26], who reported that variations in pH in Warri terminal were due to the inherent geochemical properties of the formations of chemicals being carried. The pH of water is a property that plays vital role in different microbial functions since it has the tendency to impact on the enzymes, hormonal balance, proteins, growth as well as control the metabolism of microorganisms and dissolution of minerals [27]. Similarly, the temperatures of the two terminals in the different seasons were within the NSDWQ [24] limits of 33□C. Temperature is another factor that affect the biotic components inherent in the water body. Fishes and microorganisms are affected by the temperature and dissolved oxygen [23].

Temperature as recorded in the water samples of both seasons are reasonably warm with consistent temperatures, ranging from 26±0 to 26.6±0.54 ºC during the wet season, and from

27.6±4.278 to 30±1ºC during the dry season. The range values are normal for water in the tropics, and are attributed to weather conditions of the study area – which is characterized by hot dry season and cold wet season [28,29]. The difference in the water temperature between the wet and dry seasons were, expectedly, statistically ($p<0.05$) significant (Tables 1 & 2). Conversely, the recorded mean water temperature for each of the seasons showed variations within very narrow limit.

Electrical conductivity of the sampled water during the wet season ranged from 870±1.70 to 1847.2±2.30 µs/cm while that of the dry season ranged from 14168±1.90 to 2138±27.871 µs/cm (Table 2). EC values measured during the dry season are higher than those of the wet seasons. The most likely EC reflect the effect of dilution during the wet season. Akpan et al. [29] explained that precipitation, fresh water discharge and low temperature conditions do not favour high concentration of ionized substances in water.

The mean dissolved oxygen concentration measured during the wet season ranged from 0.8±0.25 to 3.0 ±0 3.68±0.311 mg/L, while that for the dry season was 2.08±0.19 to 2.68±0.311 mg /L, Moreover the values are frequently below the 14 mg/L limit set by the Nigerian standard for drinking water quality [24]. The observed low dissolved oxygen values possibly reflects early indication of undesirable conditions in the physical, chemical and biochemical factors within the water bodies.

Biological Oxygen Demand (BOD), which is a measure of the biological activities in a water body, gives an indication of the organic load of water bodies, especially those receiving organic effluent. BOD mean values for Onne and Warri surface water ranged from 0.8±0.25 to 1.02±0.444 mg/L, for the wet season (Table 1 & 2), and from 0.78±0.19 to 1.2±0.453 mg/L, with mean value of 6.14 mg/L for the dry season. Very low BOD of 0.78±0.19 mg/L was observed during the dry season sampling at Onne port terminal. Ephraim and Ajayi [25] interpreted low BOD values as an indication of limited levels of organic matter decomposition requiring oxygen from the water. The mean values for Bromine, Chlorine, Nitrate, Sulphate and Phosphate obtained from surface water of Onne port terminal showed significant ($p=0.05$) difference between the two seasons (Table 2). While Warri samples had no significant difference (Table 1). The values were higher during the dry season in both locations.

The turbidity of the two terminals in the two seasons are below the permissible limits of 15 NTU, While the TSS of the Onne port were within the limits, the sample from Warri port terminals were above the limits in the two seasons. Previous study has highlighted the effect of TDS on water body as it hinders the penetration of light thereby inhibiting the ability of algae which are the primary producers to photosynthesize [23]. The values of TDS and TSS obtained in this study are higher than the values reported by Amaku and Akani [23]; Obunwo and Chukwudi [26]. The high values obtained in this study could be attributed to the various port activities in the study area.

Results of mean microbial count of water samples from the five locations of Onne and Warri port terminals during wet and dry seasons are presented in Table 3. and 4. The mean values obtained from Onne and Warri port terminal during the dry season ranged from 1.6±0.77 x10^6 to 4.4±1.2 x 10^6 cfu/ml (total heterotrophic bacterial count), 0.8 ±2.51 x 10^4 to 1.6±0.65 x 10^4 cfu/ml (THFC), 0.3 ±1.52 x 10^4 to 0.5±0.59 x 10^4 cfu/ml (HUFC), 0.2 ±1.14 x 10^4 to 0.3±1.34 x 10^4 cfu/ml (HUBC),. 0.2±0.71x 10^4 to 0.7 ±0.09 x 10^4 cfu/ml (*Salmonella* spp), *Shigella* spp. 0.4±0.05 x 10^4 to 0.4±0.05 x 10^4 cfu/ml (*Shigella* spp.), 0.3 ±2.19 x 10^4 to 0.5 ±0.3 x 10^{4c} cfu/ml (*Vibrio* spp.), 1.6 ±14.7 x 10^4 to 2.1±6.39 x 10^4 cfu/ml (*Staphylococcus* spp.) 3.9±0.81 x 10^4 to 4.6 ±1.79 x 10^4 cfu/ml (coliform count), 1.8±0.44 x 10^4 to 2.7 ±1.03 x 10^4 cfu/ml (feacal coliform). However higher counts were recorded during the wet season compared to dry season this trend may depend on the sources of various waste discharge and its constituents which have the ability to influence the microbial load, most of the waste product that are discharged into the surface water during wet season may be through erosion, runoffs or direct discharge of wastes into the river which may carry in suspension many microbes to warrant the higher counts in the wet season. The result is in correlation with the work reported by Mandri and Lin [30], Ogbonna [31], who worked on surface water during both dry and wet season and obtained similar results. These could be attributed to certain physiochemical factors of water like temperature, pH, dissolved oxygen, etc. which favours some organisms during wet season [32].

Table 1. Seasonal variation of physicochemical properties of surface water samples from Warri port terminal

Parameters	Unit	Season		t-test	Sig. Diff.
		Dry	Wet		
pH	°C	6.08±0.228[a]	6.68±0.217[d]	**0.0027***	6.5-8.5
Temperature	µs/cm	27.6±4.278[d]	26±0[d]	0.4272	20-33 °C
Electric conductivity	mg/l	2138±27.871[d]	870±170c	**<0.0001***	500 µs/cm
Total dissolved solid	mg/l	974.2±9.09[e]	450±28.258[d]	**<0.0001***	1000mg/l
Total suspended solid	mg/l	111±21.284[d]	95.6±18.461 [d]	0.2564	0.100 mg/l
Dissolved oxygen	mg/l	2.68±0.311[d]	3.68±0.311[a]	**0.0010***	14 mg/l
Biological oxygen demand	mg/l	1.2±0.453[d]	1.02±0.444 [d]	0.5433	<5 mg/l
Chemical oxygen demand	NTU	2.4±0.906[d]	2.04±0.888 [d]	0.5433	10mg/l
Turbidity	mg/l	1.36±0.336[a]	0.78±0.13[a]	**0.0070***	5.00 NTU
Bromine	mg/l	<0.001±0 [d]	<0.001±0 [d]	1.0	1.0 mg/L
Chlorine	mg/l	<0.001±0 [d]	<0.001±0 [d]	1.0	5 mg/L
Nitrate	mg/l	0.32±0.148[c]	0.32±0.148[c]	1.0	10.00 mg/l
Sulphate	mg/l	3.32±0.75[a]	3.32±0.75[a]	1.0	100.00 mg/l
Phosphate	mg/l	0.634±0.421[a]	0.634±0.421[a]	1.0	100.00 mg/l

Means with same alphabet across the column shows no significant difference at (p≥0.05) (NSDWQ, 2008) = Nigerian standard for drinking water quality

Table 2. Seasonal variation of physicochemical properties of water from Onne port terminal

Parameters	Unit	Season		t-test	NSDWQ [24]
		Dry	Wet		
pH	°C	5.6±0.15	6.72±0.24	**<0.0001***	6.5-8.5
Temperature	µs/cm	30±1	26.6±0.54	**0.0002***	20-33 °C
Electric Conductivity	mg/l	14168±1.90	1847.2±2.30	**0.0035***	500 µs/cm
Total Dissolved Solid	mg/l	2622±1.70	917.2±2.70	**<0.0001***	1000mg/l
Total suspended solid	mg/l	7.6±0.54	1.4±0.548	**<0.0001***	0.100 mg/l
Dissolved Oxygen	mg/l	2.08±0.19	3±0.6	**0.0114***	14 mg/l
Biological Oxygen Demand	mg/l	0.78±0.19	0.8±0.25	0.8921	<5 mg/l
Chemical Oxygen Demand	NTU	1.56±0.38	1.6±0.51	0.8921	10mg/l
Turbidity	mg/l	0.2±0	0.14±0.05	**0.0400***	5.00 NTU
Bromine	mg/l	0.6±0	0.2±0	**<0.0001***	1.0 mg/L
Chlorine	mg/l	0.3±0	0.1±0	**<0.0001***	5 mg/L
Nitrate	mg/l	5.98±0.74	0.262±0.06	**<0.0001***	10.00 mg/l
Sulphate	mg/l	694±1.9	250±2.01	**0.0080***	100.00 mg/l
Phosphate	mg/l	2.316±0.44	0.844±0.21	**0.0002***	100.00 mg/l

Means with same alphabet across the column shows no significant difference at (p≥0.05) [24] = Nigerian standard for drinking water quality

In this study, nine bacteria belonging to the genera *E. coli, Vibrio, Pseudomonas, Klebsiella, Bacillus, Shigella, Staphylococcus, Salmonella, Proteus,* (Fig. 2) and six fungal isolates, namely, *Penicillium*, *Candida*, *Mucor*, *Aspergillus, Rhizopus* and *Yeast* were isolated from the samples analysed over the sampling period. Even though, most of them may not be pathogenic, their presence in the wastewater system is universally accepted to indicate faecal contamination, and possible presence of other pathogenic organisms [33].

E. coli is a subgroup of faecal coliforms used as an indicator of faecal contamination. Although vast majority of *E. coli* are completely harmless, some strains of the isolated bacteria have acquired genetic capabilities which enable them to encode virulence factors [34]. Pathogenic *E. coli* strains cause diverse forms of

bacterial induced illnesses with symptoms ranging from mild diarrhoea to severe complication and even death [35]. Fig. 3 shows the percentage occurrence of the bacterial species isolated in this study across the sampled locations.

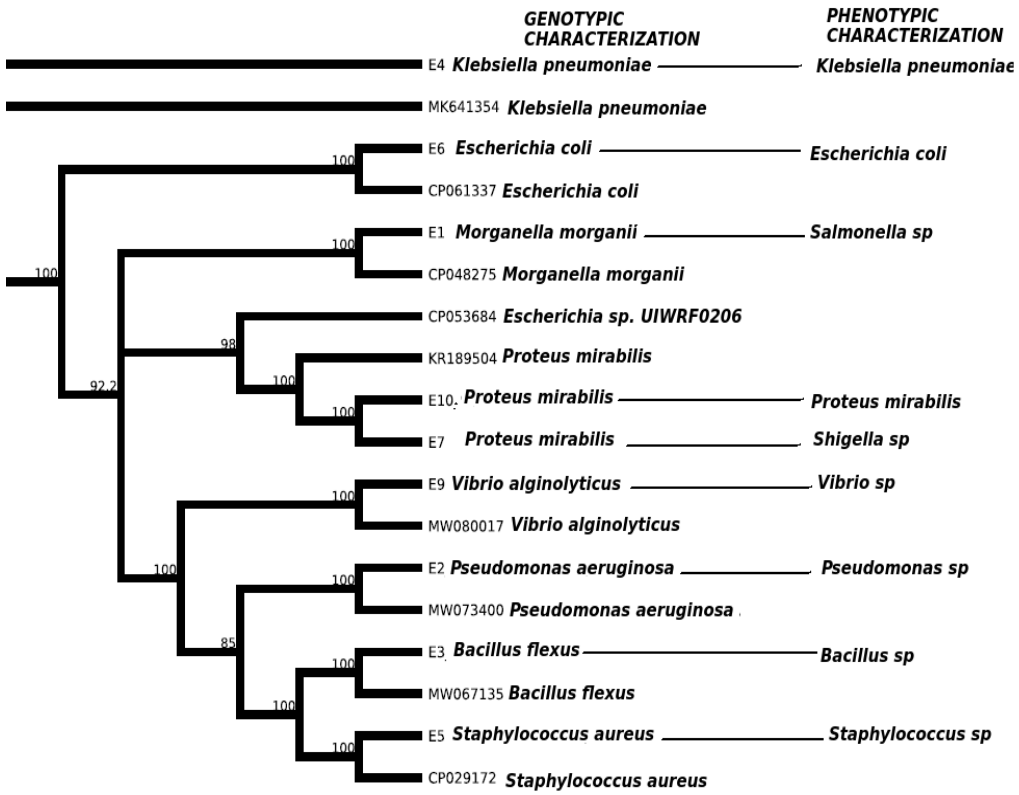

Fig. 2. Bacterial isolates identified using genotypic and phenotypic characterization

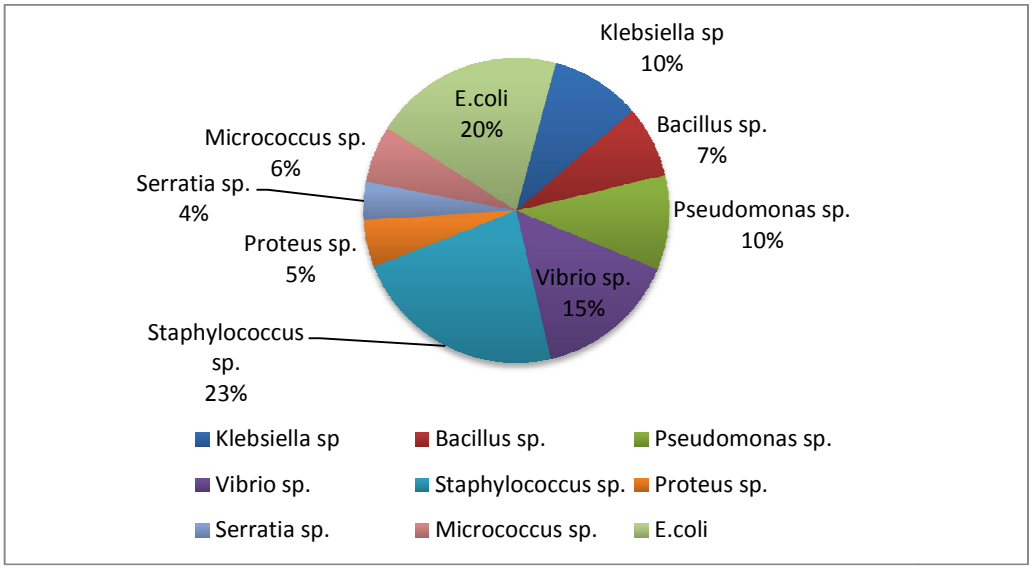

Fig. 3. Percentage occurrence of the bacterial isolates in water across the five sampling points

Table 3. Seasonal Variation of the mean microbial count of water samples from Warri Port terminal during wet season

Parameters	Unit	Warri Seasons		t-test	NSDWQ [24]
		Wet	Dry		
Total Heterotrophic Bacteria	cfu/ml	$5.6\pm2.17 \times 10^{6a}$	$4.4\pm1.2 \times 10^{6d}$	**0.0004***	100
Total Heterotrophic Fungi	cfu/ml	$5.6 \pm2.77 \times 10^{4b}$	$1.6\pm0.65 \times 10^{4f}$	**0.0002***	10.0
Hydrocarbon Utilizing Bacteria	cfu/ml	$3.6\pm1.52 \times 10^{4c}$	$0.3\pm1.34 \times 10^{4a}$	**0.0006***	0
Hydrocarbon Utilizing fungi	cfu/ml	$1.2\pm2.05 \times 10^{4d}$	$0.5\pm0.59 \times 10^{4c}$	**0.0004***	0
Salmonella	cfu/ml	$0.4\pm0.84 \times 10^{4a}$	$0.2\pm0.71 \times 10^{4b}$	**0.0002***	0
Shigella	cfu/ml	$2.6\pm0.39 \times 10^{4d}$	$0.4\pm2.35 \times 10^{4e}$	**<0.0001***	0.0
Vibrio	cfu/ml	$1.6\pm0.13 \times 10^{4c}$	$1.6\pm5.13 \times 10^{4d}$	**0.00211***	0.0
Staphylococci count	cfu/ml	$2.8\pm1.8 \times 10^{4d}$	$2.1\pm6.39 \times 10^{4a}$	**0.0051***	0.0
Total Coliform	cfu/ml	$5.4\pm1.48 \times 10^{4f}$	$3.9\pm0.81 \times 10^{4d}$	**0.00302***	0.0
Feacal coliform	cfu/ml	$2.5\pm0.71 \times 10^{4d}$	$1.8\pm0.44 \times 10^{4a}$	**0.0086***	0.0

Means with same alphabet across the column shows no significant difference at (p≥0.05) NSDWQ [24]= Nigerian standard for drinking water quality

Table 4. Seasonal variation of the mean microbial count of water samples from Onne Port terminal

Parameters	Unit	Onne Seasons		t-test	NSDWQ [24]
		Dry	Wet		
Total Heterotrophic Bacteria	cfu/ml	$3.9\pm2.77 \times 10^{6a}$	$1.6\pm0.77 \times 10^{6b}$	**0.0004***	100
Total Heterotrophic Fungi	cfu/ml	$0.8 \pm1.55 \times 10^{4b}$	$0.5 \pm2.51 \times 10^{4d}$	**0.0008***	10.0
Hydrocarbon Utilizing Bacteria	cfu/ml	$0.2 \pm1.14 \times 10^{4c}$	$0.3 \pm1.14 \times 10^{4c}$	**0.0006***	0
Hydrocarbon Utilizing fungi	cfu/ml	$0.3 \pm1.52 \times 10^{4d}$	$0.5 \pm1.48 \times 10^{4a}$	**0.0009***	0
Salmonella	cfu/ml	$0.7 \pm0.09 \times 10^{4a}$	$0.6 \pm0.89 \times 10^{4d}$	**0.0002***	0
Shigella	cfu/ml	$0.4\pm0.55 \times 10^{4d}$	$0.4 \pm0.53 \times 10^{4a}$	**<0.0001***	0.0
Vibrio	cfu/ml	$0.5 \pm6.3 \times 10^{4c}$	$0.3 \pm2.19 \times 10^{4d}$	**<0.0001***	0.0
Staphylococci	cfu/ml	$5.6 \pm2.4 \times 10^{4a}$	$1.6 \pm14.7 \times 10^{4b}$	**0.0005**	0.0
Total Coliform	cfu/ml	$7.4 \pm1.3 \times 10^{4c}$	$4.6 \pm1.79 \times 10^{4b}$	**0.0222***	0.0
Feacal coliform	cfu/ml	$3.6 \pm1.17 \times 10^{4d}$	$2.7 \pm1.03 \times 10^{4c}$	**0.0043**	0.0

Means with same alphabet across the column shows no significant difference at (p≥0.05) [24] = Nigerian standard for drinking water quality

4. CONCLUSION AND RECOMMEN DATIONS

There have been increasing detrimental impacts on the environment including pollution of the freshwater ecosystems. This is further exacerbated with high population of pathogens in the water resulting in variation in physiochemical characteristics of surface water bodies. Seafood consumption pre-disposest a public health risk through the food chain. These conditions may also affect wildlife, which uses surface water for drinking or as a habitat. The most significant contaminant when it comes to human health are microorganisms that come into water from human and animal excreta, mainly due to the unhygienic disposition of wastewater.

Therefore, proper waste management approach and personal hygiene should be maintained during operation at port terminals to avoid cross contamination of the environment.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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