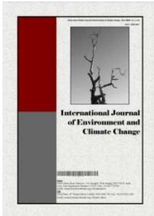

International Journal of Environment and Climate Change

9(11): 671-681, 2019; Article no.IJECC.2019.055
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

The Effects of an Industrial Wastewater Effluent on the Seasonal Variations of Ekerekana Creek, Rivers State Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author COO designed the study, wrote the protocol and took part in supervision of the work. Author BAB performed the statistical analysis, managed part of the literature searches and handled the discussion aspect of the work. Author OAO wrote the first draft of the manuscript, managed part of the literature searches and participated in managing the analyses of the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2019/v9i1130148
Editor(s):
(1) Dr. Wen-Cheng Liu, Professor, Depertment of Civil and Disaster Prevention Engineeirng, National United University, Taiwan.
Reviewers:
(1) Oguegbu, Ozioma Onyinye, Nnamdi Azikiwe University Awka, Nigeria.
(2) Roberto Flores, Universidad Autonoma del Estado de Morelos, Mexico.
Complete Peer review History: http://www.sdiarticle4.com/review-history/51569

Original Research Article

Received 15 July 2019
Accepted 20 September 2019
Published 25 October 2019

ABSTRACT

The effects of industrial wastewater from Port-Harcourt Refinery Company Limited on Ekerekana Creek, Rivers state were studied. This study was carried out in July and December 2015. Analyses focused on Lead, Cadmium, Copper, Chromium, pH, Phosphate, Nitrate, Temperature, Dissolve Oxygen, BOD_5 and Total Hydrocarbon Content as some of the parameters of interest. Sterilized yellowish-brown bottles were used to collect samples from each location and fixed with concentrated HNO_3 before transporting to the laboratory in iced coolers. Water samples from the different stations were analyzed using standard laboratory methods. Statistical Package for the Social Sciences (IBM- SPSS$^{(C)}$) version 19.0, statistical package for windows and MS Excel was used in the analysis of data. The test of homogeneity of variance in Means of the variables was carried out using the one way ANOVA. Results obtained showed that for heavy metals concentrations, Cadmium varied between 0.03 mg/L and 0.70 mg/L (0.39 ±0.06), Lead varied between 0.09 mg/L and 0.65 mg/L (0.29 ±0.04), Chromium between 0.04 mg/L and 0.46 mg/L

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(0.23 ±0.03) and Copper 0.10 mg/L and 0.90 mg/L (0.45 ±0.06) respectively. Others include pH which varied between 5.7 and 6.8 (6.15 ±0.07), Dissolved Oxygen 3.40 mg/L and 6.40 mg/L (4.75 ±0.22). BOD and Turbidity varied between 6.20 mg/L and 9.90 mg/L (7.77 ±0.29) and 8.60NTU and 11.20NTU (9.80 ±0.20) respectively. General results show that station 2 (discharge point) had maximum concentrations of heavy metals and other contributory parameters, and their values were higher than World Health Organization (WHO) and National Environmental Standards and Regulation Enforcement Agency (NESREA) standards. The test of homogeneity of variance in means of the physical and chemical parameters revealed significant spatial inequality $F_{(161.45)} > F_{crit(4.49)}$ at $P = .05$ across the sampling stations.

Keywords: Industrial wastewater; Ekerekana creek; Port Harcourt refinery; Okrika LGA.

1. INTRODUCTION

Clean uncontaminated water is essential for life and health. In many regions of the world, such as parts of Asia and Africa, the scarcity of water limits development and challenges health [1]. The earth's supply of freshwater available for our use is limited. We acquire water for our domestic, industrial and agricultural needs either from surface or groundwater. Natural waters are a part of a continuing cycle. Water resources have been the most exploited natural resource by man. Of the total amount of about 1500 million km^3 of water in the hydrosphere, about 95% of it is sea water, 4% is frozen as snow in mountains and cold regions, and only 1% is available for human activity as freshwater [2]. Nigeria is endowed with generous resources of water bodies which provide sustenance for the fishery industries, transportation, irrigation, recreation and for domestic uses. Changes in the physical or chemical properties of water that could harm living organisms or make it unfit for its intended uses is termed pollution. Different regulations put in place to protect the marine environment and other water bodies in Nigeria have not been effective in controlling the indiscriminate dumping of effluent into open water bodies [3]. Refining of crude oil into petroleum products for energy is essential to human development. This process generates a lot of wastewater, solids, heavy metals and gaseous pollutants into the environment. Large scale contamination might occur during chemical processes. These contaminants constitute pollution if discharged into the immediate environment without treatment [4].

Over the years, Ekerekana Creek in Okrika Local Government Area, Rivers state has served as the recipient water body for discharged refinery effluent. The levels of chemical contaminants in the treated refinery wastewater have always been a cause of worry to the community and environmentalists as a possible cause of environmental pollution.

The levels of these effluents have been found to be in concentration above acceptable and permissible levels [5,6,7]. Effluents from industries were found to alter the physical, chemical and biological nature of receiving water bodies [8].

It is evident that both the waste and process water of Port Harcourt refinery are treated in a water treatment plant, but the level of treatment can only be ascertained through the analysis of the discharged effluent at different points of their exit into the adjoining environment. This is important because the level of environmental pollution has risen to a state that threatens and endangers the health and survival of humans and other living things. This situation has led to loss of biodiversity of assorted species [9].

It is therefore necessary to carry out continuous assessment of pollutants in water bodies within this region.

2. MATERIALS AND METHODS

2.1 Study Area

Okrika is located between latitude 4º44' 0" N, 7° 5' 0" E in Rivers state Niger Delta area of Nigeria, as shown in Fig. 1. The Niger Delta is one of the world's largest deltas and has a vast coastal plane covering some estimated 40,000-70,000 square kilometers in the central part of southern Nigeria [10]. Rivers state is bound to the south by the Atlantic Ocean, to the west by Bayelsa state, to the north by Imo state and to the east by Abia and Akwa Ibom states. This region is known for oil exploration, but they are also actively involved in fishing, commerce, administration, banking and finance, information, land and marine transportation, academia, manufacturing, sand mining and farming [11]. The Niger Delta lies mainly in the wet equatorial climatic region (Koppen's A*f* Climate) but in its northern extremities the climate could be best described as tropical wet-and-dry climate (Koppen's A*w* Climate). Because of its nearness to the equator, cloud cover is high during the rainy season, characterized by frequent precipitation that reaches up to 300-450 cm annually. There is usually a long wet season that last from March to September, and mean monthly temperature ranges between 24 and 27ºC, while humidity is about 80%. The geology of the area is of the earlier deposits of the marine sediments of the Lower and Upper Cretaceous age, which constitutes the economically important structure where petroleum was formed and deposited. The soil type could be classified as coarse, loamy, highly weathered and moderately acidic with low soluble salt content.

The Niger Delta is one of the seven relief regions which make up Nigerian. About 95% of the total area is wetland and is characterized by a network of creeks and small rivers which drain into short swift coastal rivers. The major drainage systems of the Niger Delta include those of the Niger, Ase, Ethiope, Warri, Orashi, Sombreiro, New Calabar and the Imo rivers [12]. The waters of the Niger Delta are warm all year round with a temperature range of 22-30ºC. Very few parts of this area have been spared from human interference through urban and industrial developments. Hence there are very few areas of pristine natural and luxuriant vegetation while others have been reduced to secondary growths. The pristine vegetation is characterized by thick mangrove forest of the red specie.

2.2 Field Sample Collection

Three (3) main sampling stations were selected in the Creeks; station 1 upstream of the river located on 7º5'33.68'' E and 4º45'35.84''N, station 2 effluent discharge point into the river 7º5'39.95''E and 4º45'19.86''N, and station 3 downstream of the river 7º5'41.24''E and 4º45'02.94''N respectively as shown in Fig. 1. Each sampling station was further sub-divided into three, where triplicate water samples were collected from the sub-stations, using yellowish-brown bottles fitted with screw stoppers and labeled 1_A, 1_B, 1c, 2_A, 2_B, 2c, 3_A, 3_B and 3c respectively. Samples were immediately transported to the lab in iced-packed coolers. Samples were collected at low tide at about 30 cm depth for physico-chemical properties during the peak of the rainy season (July) and at the peak of the dry season (December).

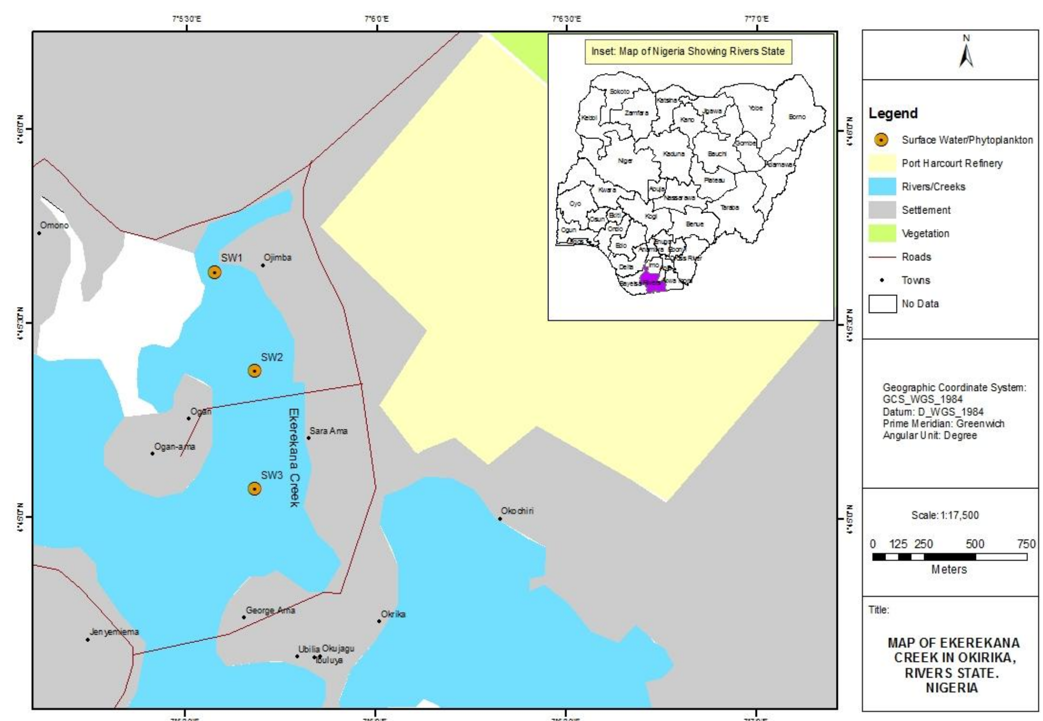

Fig. 1. Map of Ekerekana Creek Okrika showing the study area, Rivers State and Nigeria

2.3 Laboratory Analysis and *In-Situ* Measurements

All glassware were washed with detergent and hot water and afterwards rinsed with distilled water. Analytical grade reagents used include concentrated HNO_3 as preservative for samples, KCl solution (0.01M) for calibration of conductivity meter, distilled water for rinsing equipment and dilution of samples, Buffer solutions (pH = 4.0 & 7.0) to standardize the pH meter. For heavy metals, (Calcium, Lead, Copper and Cadmium) they were determined using Atomic Absorption Spectrometer (model AA6800 – SHIMADZU), pH was measured *in situ* using a pH meter (Mettler Toledo 320 model) American Public Health Association [13], the conductivity of the samples were determined *in situ* using conductivity meter American Public Health Association APHA (2510B), temperature was determined in-situ by the use of 0-100ºC mercury –in – glass thermometer, Dissolved oxygen (DO) was also measured *in situ* by a DO meter, turbidity levels were measured in Nephelometric units (NTUs) using the HACH 2100A turbidity meter. Phosphate in water was determined by automation using a multi-parameter photometer (Hanna Instrument H183200), nitrate level was determined by reading the absorbance at 500 nm wavelength using HACH DR 2010 UV-visible spectrometer, BOD was determined by conventional methods according to American Public Health Association APHA, using the BOD bottles and total hydrocarbon content of the water samples were determined by mixing 10ml of the sample with 20 ml of toluene and determined with spectrometer.

2.4 Statistical Analysis

Descriptive statistics was used in the analysis of data and the test of homogeneity of variance in means of the physical and chemical parameters across the sampling stations was explored using the one-way ANOVA.

3. RESULTS

3.1 Spatial Variation in Parameters Analyzed

For heavy metals concentrations, station 2 recorded the highest concentration of all the heavy metals analyzed across the stations. Among all the heavy metals in this study, Cadmium and Chromium showed least concentrations of 0.05 mg/l and it was during the rainy season in station 1. Comprehensive results for heavy metals in this study are presented in Figs. 2-5 respectively.

Total Hydrocarbon (THC) for this study revealed that station 2 had the highest result 4.25 mg/l during the dry season as presented in Fig. 6.

For nutrient content, least result 0.02mg/l was recorded for phosphate across the season in station 1 and 1.48 mg/l was recorded as the highest for nitrate in station 2 as presented in Figs.7 and 8. Results for temperature, pH and dissolved oxygen are presented in Figs. 9, 10 and 11 respectively.

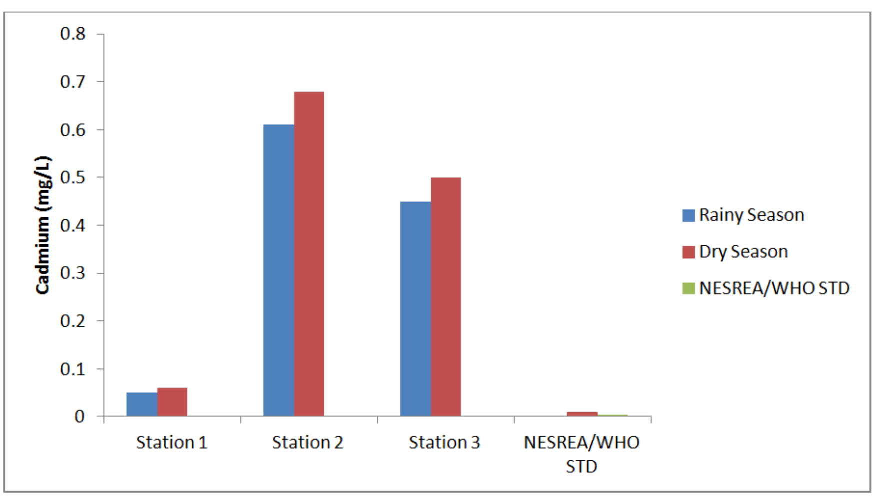

Fig. 2. Spatial variation in mean cadmium concentration across the seasons

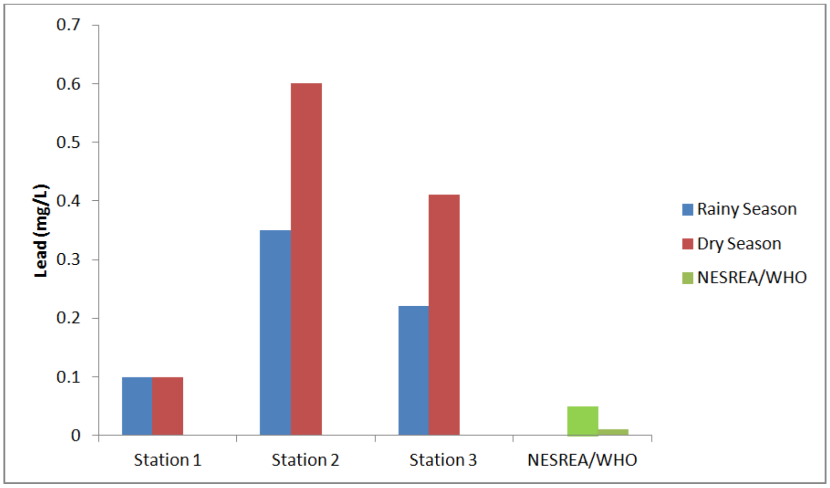

Fig. 3. Spatial variation in mean lead concentration across the seasons

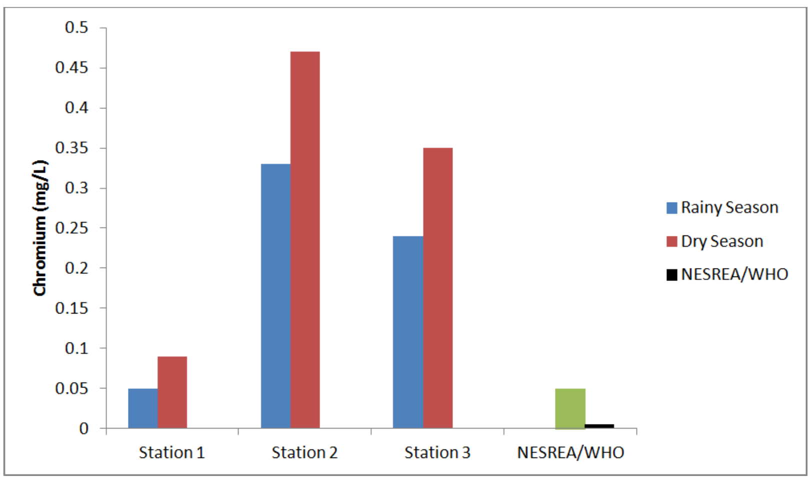

Fig. 4. Spatial variation in mean chromium concentration across the seasons

Turbidity had highest value (11.07 NTU) at station 2 and least value (8.82 NTU) at station 1(Fig. 12). For BOD highest value (9.73 mg/l) was recorded at station 2, while least value (6.23 mg/l) was recorded at station 1 (Fig. 13).

4. DISCUSSION

In this study, heavy metals concentrations under investigation believed to be of petroleum origin were generally higher than both National Environmental Standards and Regulation Enforcement Agency [14] and World Health Organization [15] standards. Except for Copper which was lower than WHO standard across the stations and seasons, and Chromium which was at par with NESREA standard at station 1 during the rainy season, Lead and Cadmium recorded higher concentrations than WHO and NESREA standards. The high concentrations discovered in the water samples could therefore be connected to crude oil contamination from petroleum refining and improper treatment of the discharged effluent into the neighboring environment. Discharge of oil contaminated effluent into surrounding water bodies in the creeks is a perennial activity and its impact is suspected to be negative on the immediate ecosystem. This position is in agreement with the works of other authors such as [16,17,18,19]. The minimum pH at which this was experienced (5.60) is acidity and encourages mineralization of heavy metals in solution. pH values in this study were below both NESREA and WHO standards except in station 1 during the rainy season. This may be due to upstream

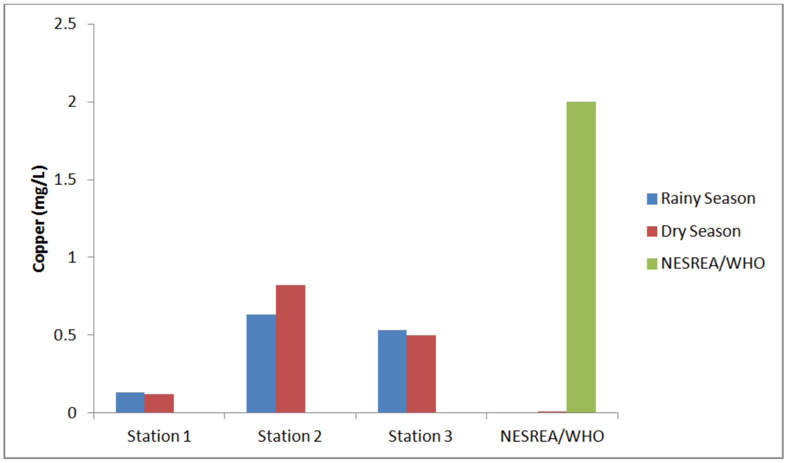

Fig. 5. Spatial variation in the mean copper concentration across the season

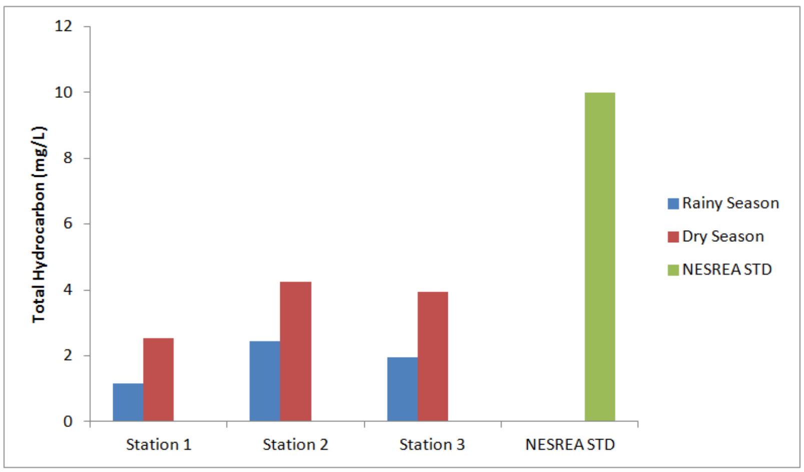

Fig. 6. Spatial variation in mean total hydrocarbon across the seasons

location of station 1from discharge point. Streams that directly receive effluents from petrochemical areas have been reported to be more acidic [20]. Results recorded in this study were similar to those recorded by several other authors [21,22,23]. Studies by Arimoro et al. [24] gave a pH range of 6.60-8.22, and they agreed that the study indicates that the water was slightly acidic with occasional slight alkaline condition. The implication of this is bioaccumulation of heavy metals in man due to his position in the food chain. Although, heavy metals in the work of Otokunefor et al. [25], were below detectable limits. This may be as a result of very high pH (8.47) recorded in their work which encouraged immobilization of heavy metals and settling in sediment. Temperature plays a vital role in the rate of chemical reactions and the nature of biological activities, thus governing the assimilative capacity of aquatic systems. Temperatures in this study were within WHO standards (20-32ºC) and lower than NESREA standard (40ºC). Studies carried out by Marcus and Ekpete [26] gave year average temperature as 27ºC which corroborated the present study. The temperature in this study could be attributed to over-hanging macrophytes, a dominant feature of the studied area which prevents sunlight from reaching the water, this is in agreement with [27]. Turbidity is an important operational parameter in process control and can indicate problems with treatment processes, particularly coagulation/ sedimentation and filtration [28]. In this study, results for turbidity across the stations were twice higher than NESREA standard (5NTU). Studies by Makinde et al. [29] revealed result (6.91NTU) higher than NESREA standard. Asuquo and Etim [30],

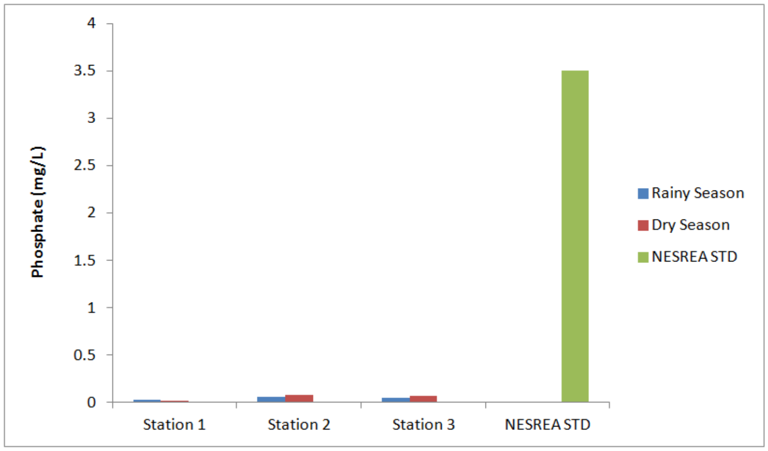

Fig. 7. Spatial variation in mean phosphate concentration across the seasons

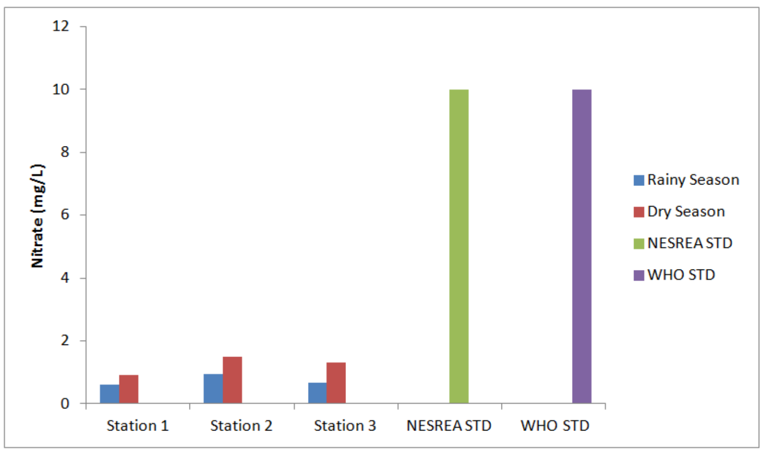

Fig. 8. Spatial variation in mean nitrate concentration across the seasons

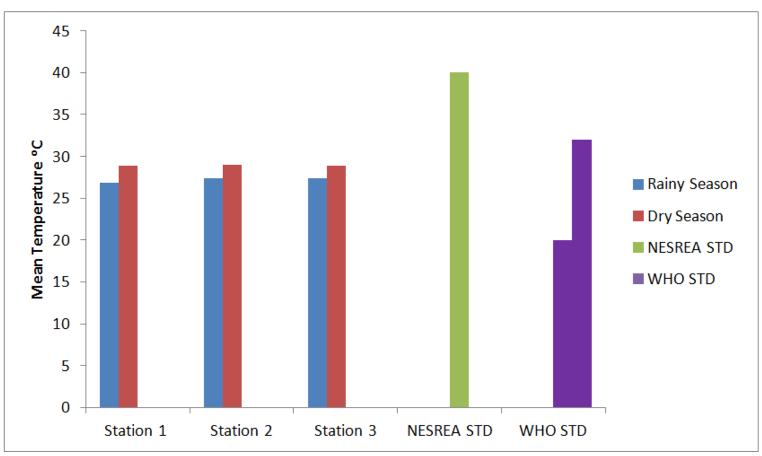

Fig. 9. Spatial variation in mean temperature across the seasons

reported that high turbidity could result from the presence of colloidal particles arising from clay and silt during rainfall or from discharges of sewage and industrial waste or the presence of large number of microorganisms. Although, considerable amount of organic contamination enter the system from municipal urban life, this affects the system thus resulting in synergistic action. These organic materials eventually get broken down by bacteria, which require oxygen for the decomposition process, leading to depletion of dissolved oxygen, hence the low dissolved oxygen and high BOD values in this work. In general, discharge of untreated or incompletely treated industrial effluents into the river from the Port Harcourt Refinery may be largely responsible for this pollution because of the values recorded at the point of effluent discharge. This conforms to reports by Quinby et al. [31] that low DO indicates a high BOD_5 values. According to WHO [32], unpolluted waters typically have BOD values of 2 mg/l or less and the least value of BOD in this work was 6.23 mg/l an indication of pollution. Arimoro et al. [24] in similar studies recorded relatively high BOD values of mean 26.28 and 18.65 mg L^{-1} corroborating this work. Phosphate concentration was lower than NESREA standard, while Nitrate level was lower than both NESREA and WHO standards, an indication of microorganism assimilation during the continuous breakdown of pollutants. Mean THC in this study were generally lower than NESREA standard for surface water discharges. Studies on aquatic ecosystems in the Niger Delta indicated high levels of oil and grease in areas prone to oil spills [33]. Divergent results may be due to partial or incomplete treatment of the effluent before discharge into the receiving water bodies.

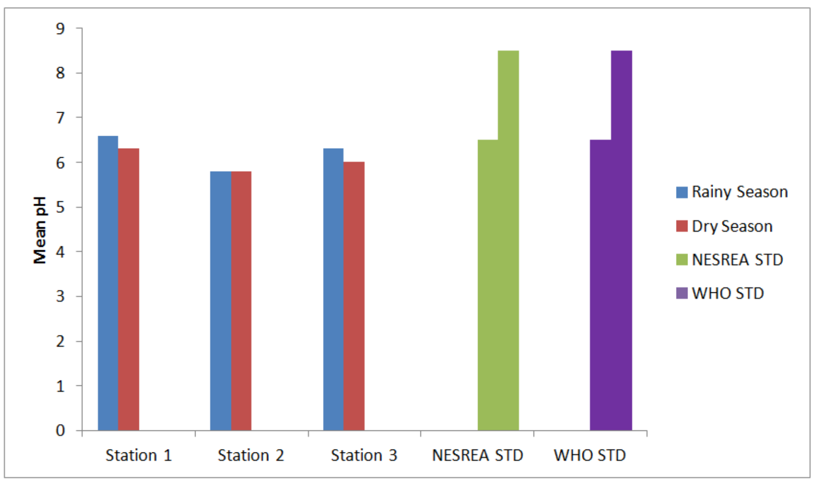

Fig. 10. Spatial variation in mean ph across the seasons

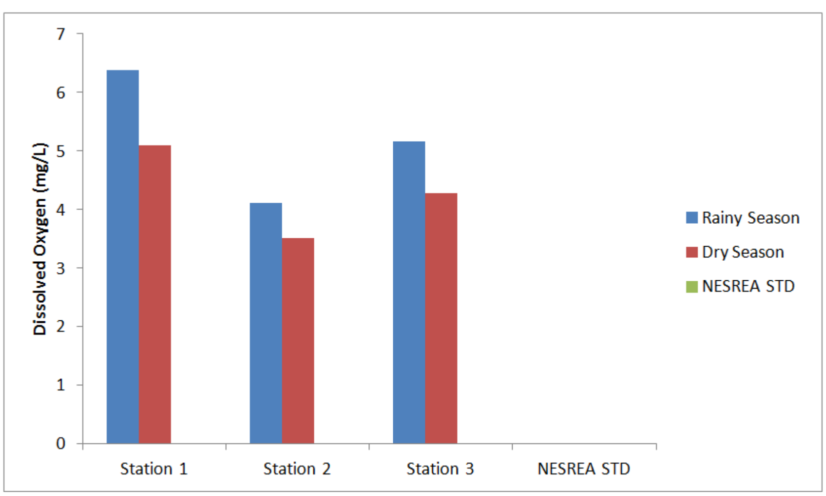

Fig. 11. Spatial variation in mean dissolved oxygen across the seasons

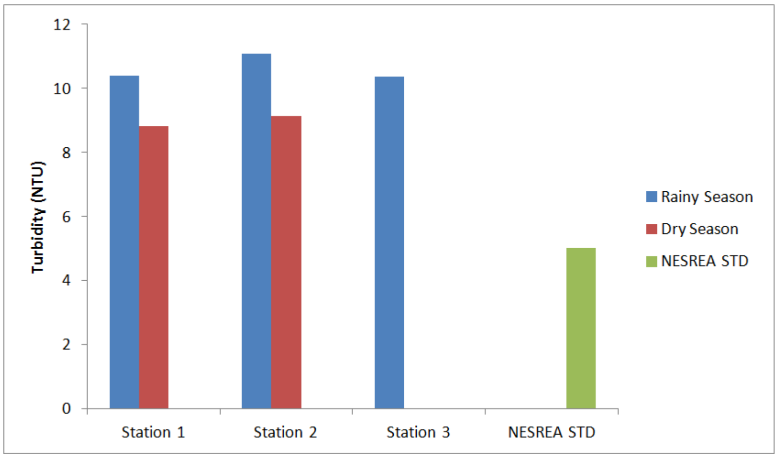

Fig. 12. Spatial variation in mean turbidity across the seasons

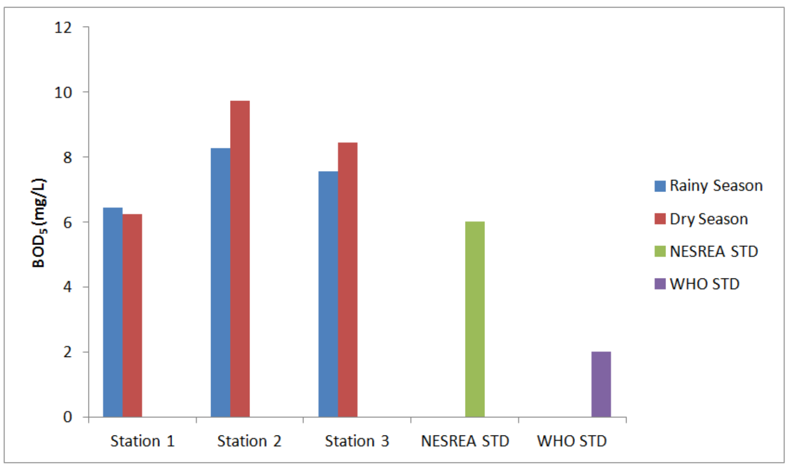

Fig. 13. Spatial variation in mean bod$_5$ across the seasons

5. SUMMARY, CONCLUSION AND RECOMMENDATION

From the outcome of this work, the Port Harcourt Refinery Company could be implicated as mostly responsible for the levels of pollution recorded in this study. The study has identified that considerable amount of pollutants were left in its wastewater and discharged into the receiving water bodies without proper treatment adversely affecting the ecological conditions of the neighboring environment. With more untreated or partially treated industrial effluent from the Port Harcourt Refinery into the Creeks, the prospects of increasing pollution is high, so also is an increased risk to public health particularly to the various communities settling along its banks and catchment areas. General results in this study revealed that pollution was more at the discharge point than at upstream, an indication of water pollution from the refinery. The presence of the studied pollutants in concentrations higher than the acceptable standards of regulatory agencies (WHO, 1984; NESREA, 2007) calls for caution to prevent dwindling health of the people.

There is need for continuous monitoring by the local regulatory agencies to ensure that this company treats its effluent in line with modern acceptable technologies, guidelines and standards before discharging into the receiving water bodies. Further studies should focus on the impact on primary productivity and bio-accumulation in marine organisms.

COMPETING INTERESTS

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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http://www.sdiarticle4.com/review-history/51569