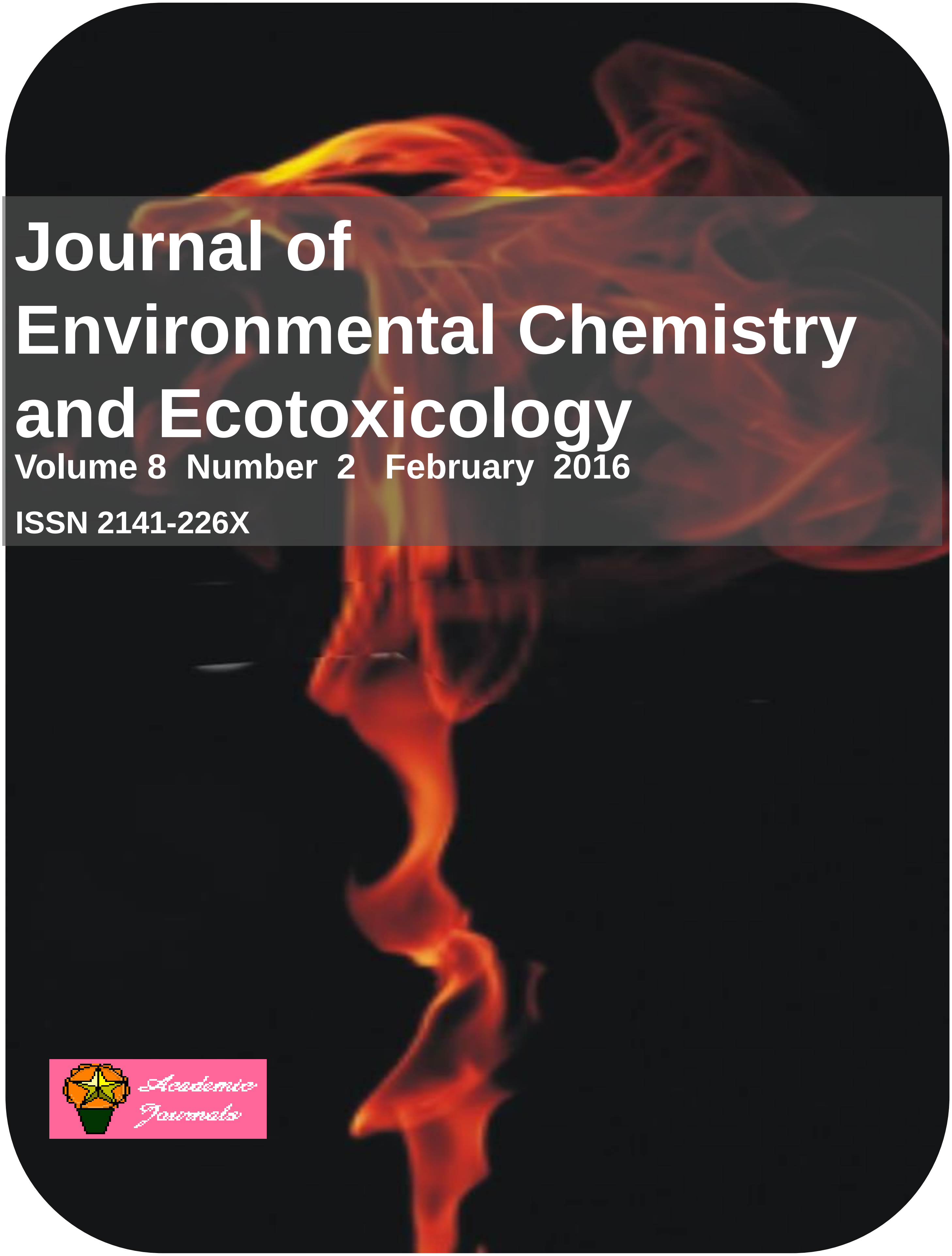

Journal of Environmental Chemistry and Ecotoxicology

Volume 8 Number 2 February 2016

ISSN 2141-226X

Academic Journals

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academicJournals

Vol. 8(2), pp. 9-13, February, 2016
DOI:10.5897/JECE2015.0368
Article Number: 372EF1857453
ISSN 2141-226X

http://www.academicjournals.org/JECE

Journal of Environmental Chemistry and Ecotoxicology

Full Length Research Paper

Physicochemical properties of the effluents of Forcados Terminal in Warri, Delta State

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Received 13 November 2015; Accepted 4 January 2016

Physicochemical properties of the effluent samples from Forcados Terminal in Warri, Delta State were studied from May 2008 to June 2009. Effluent samples were collected from the two Barge Jetties A and B and Two Saver Pits 1 and 2 inside the tank farm. A total of 96 effluent samples were collected throughout the study period. Physicochemical properties of the effluent samples were determined using Hach methods as recommended by the American Public Health Association (APHA) and American Society for Testing and Material (ASTM). The results of the physicochemical parameters tested showed that most of the physicochemical parameters complied with their respective Department of Petroleum Resources (DPR) and Federal Ministry of Environment (FEMENV) limits for near shore environments while values of turbidity, total dissolved solids (TDS), salinity, and electrical conductivity (EC) were above statutory requirements. There was statistical difference at $p \leq 0.05$ in the levels of the physicochemical parameters analysed. The range of values obtained for physicochemical parameters analysed was from 4.86 to 8.09 pH, 22.7 to 28.8°C temperature, 7.5 to 27 NTU turbidity, 81 to 37,500 µmhos/cm EC, 19.15 to 18,800 mg/L TDS, 4.6 to 19.6 mg/L total suspended solids (TSS), 10.35 to 7,735 mg/L salinity, 4.7 to 8.05 mg/L dissolved oxygen (DO), 1.35 to 6.75 mg/L biochemical oxygen demand (BOD), 0.006 to 4.80 mg/L NH_4, 0.002 to 1.46 mg/L $P0_4$, 0.001 to 0.01 mg/L H_2S. Turbidity, TDS, EC, and salinity had levels above DPR statutory requirements.

Key words: Forcados Terminal, effluents, water quality, compliance.

INTRODUCTION

Some parameters are used to measure physical, chemical, and biological properties in water. Water quality should be related to the anticipated beneficial use of the water, such as for fish and wildlife. Water should be managed so that no contamination at one location will be detrimental to its use at another location (Clesceri et al., 1997). It is essential to monitor parameters during hydrocarbon pollution in ecosystems.

Effluents are liquid waste materials with by-products of human activities, such as liquid industrial discharge or sewage (ISO 14001, 2000). Nature has an amazing ability to cope with small amounts of water wastes and pollution, but it would be dangerous or detrimental if the billions of gallons of water waste and sewage produced

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everyday are not treated before releasing them back to the environment. Treatment plants reduce pollutants in waste water to a level nature can handle. Our water should be kept clean for purposes of its use in the fishing industry, sports, wild life habitats, recreation, and health (Kakulu and Osibanjo, 1991). Whenever industrial wastewater is discharged into a body of surface water, care must be taken to avoid damaging any sensitive ecosystem and to ensure that no long-term accumulation of pollutants occurs in the sediments and that the overall use of the water in question is not impaired. The survival of organisms used for biomonitoring is determined by the values of such parameters. The rates of biological and chemical processes depend on temperature (Haarstad and Maehlum, 1999). They reported that temperature affects the oxygen content of water. Oxygen levels become lower as temperature increases, therefore photosynthesis in aquatic plants, the metabolic rates of crustaceans and the sensitivity of aquatic organisms decrease. Dissolved oxygen (DO) is a basic requirement needed for healthy crustaceans. Crustaceans suffer if DO concentrations are below 3 to 4 mg/L. Larvae and juvenile crayfish are more sensitive and require even higher concentrations of DO (Van der Oost, 2003).

pH is the negative logarithm of hydrogen ion concentration. It is a major factor in all chemical reactions associated with formation, alteration, and dissolution of minerals (Yao and Byme, 2001). The level of acidity of the water is important to the aquatic species and most aquatic species are adapted to neutral conditions. Ammonia is a nutrient required for life. It is a form of nitrogen found in water. However, researchers (Clesceri et al., 1997) reported that above certain concentrations, it can be toxic to crustaceans. At high concentrations, fish deaths occur; some fish (such as, juvenile fish) are more sensitive to ammonia concentrations. Salinity is a concentration of dissolved salts in the water; aquatic animals are adapted to a range at which they live. Some fish, such as sunfish, cannot survive in salt water or salty condition. High levels of total dissolved solids (TDS) limit the industrial and agricultural use of water (Ansa-Asare, 1992). High total suspended solid (TSS) levels also increase turbidity in water, which prevents light from reaching aquatic plants and animals (Kakulu and Osibanjo, 1991). The objective of this research is to monitor the physicochemical parameters of Forcados Terminal by comparing the levels of the parameters obtained with Department of Petroleum Resources/Federal Ministry of Environment (DPR/FMENV) standards.

MATERIALS AND METHODS

Study area

Forcados Terminal lies within the provisional surface coordinate of E: 310300 m and N: 162090 m in the Western Niger Delta Sedimentary basin. Lithological features are consistent with that of the Benin formation typical of most areas in the Niger Delta. It is within Oil Mining Lease (OML) 45 in the Greater Forcados Off-take. It is located in the swamps of the southern bank of the Forcados River, 47 km west of Warri Town in the Delta area of Nigeria. The terminal provides crude oil dehydration, storage, and export facilities primarily for the Western Division of the NNPC/SHELL/ELF/AGIP joint venture operated by the Shell Petroleum Development Company of Nigeria Ltd (SPDC) and other producers in the area. Forcados Terminal consists of two zones, the Core Zone and Secondary Zone. There are two sewage plants, one located at the Core Zone which treats sewage from the offices inside the storage tank area and one located at the Secondary Zone that treats sewage from the residential quarters. The sewage plant at the Core Zone is chemically treated while the sewage plant at the Secondary Zone is biologically treated. There are two saver pits (Saver Pit 1 and Saver Pit 2) located within the Core Zone. Effluents from the two saver pits meet at a point of final discharge to the recipient environment, Forcados River and then to the Atlantic Ocean.

Sample collection

Effluent samples from Forcados Terminal in Warri Delta State were collected from May 2008 to June 2009. Four effluent samples were collected biweekly from the two Barge Jetties A and B and two Saver Pits 1 and 2 inside the tank farm. A total of 96 effluent samples were collected throughout the study period.

Sampling, preservation, and transportation were carried out in accordance with the recommended methods as contained in APHA (2002). Samples were collected with the aid of clean 1 L water sampling cans. The Saver Pits 1 and 2 effluent samples were collected from the storage tank of the Tank Farm situated at the Core Zone, while the Barge effluents A and B were collected from the Main Jetty situated at the Secondary Zone where there are lots of ship and vessel settlers moving in and out of the Terminal. Control surface water samples were collected 500 m away from the sampling points, far away from the terminal, to avoid control sampling areas that may be contaminated by the effluent discharge (Figure 1).

Experimental

The temperature, PH, conductivity, and turbidity were determined using digital meters. TDS and TSS measurements were carried out by using the conductivity/TDS meter (HACH DR/2010 Spectrophotometer Hand Book, 1997).

The American society for testing and materials as adopted by HACH M 8332 (ASTM, 1986) was used to determine the DO and ammonia. Biochemical oxygen demand (BOD) was determined in accordance with American public health association 5210B Winkler’s Dilution method (APHA, 1995).

Statistical analysis

The software package SPSS version 17.0 was used to analyze physicochemical properties of the effluents of Forcados Terminal. Means were calculated and compared. One-way analysis of variance was used to find the levels of significance of the considered parameters. A further mean separation using mean plots to analyze the inequality in means across the sample locations was done.

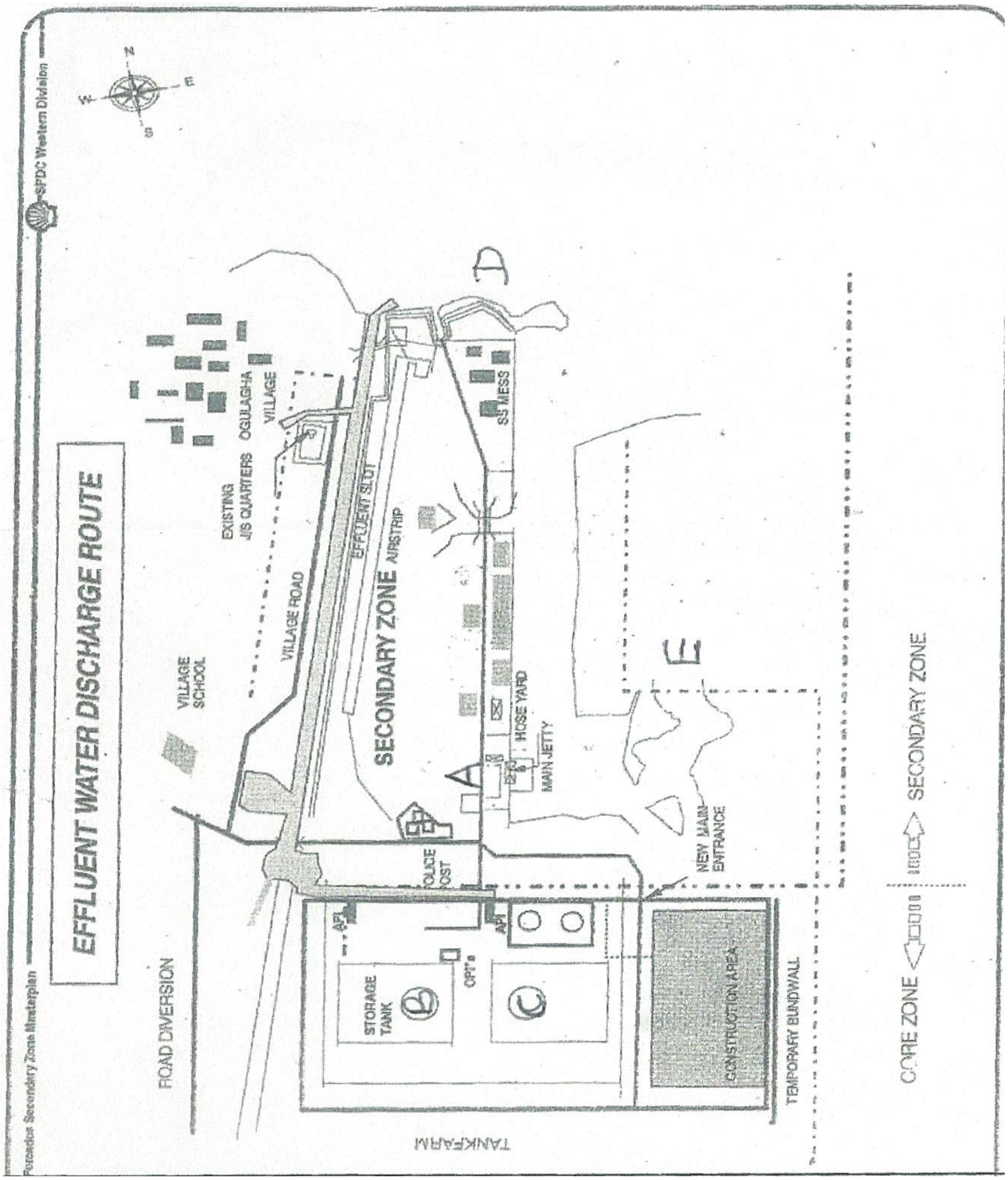

Figure 1. Map of effluent water discharge route of Forcados Terminal. A- Barge jetties A and B; B- Saver pit 1; C- Saver pit 2; D- Beginning of Effluent discharge; E- End of Effluent discharge.

RESULTS AND DISCUSSION

Table 1 shows the comparison of physicochemical parameters of effluents of Forcados Terminal with DPR/FEMENV standards. All other values of the parameters were within DPR/FEMENV standard except the values of turbidity, TDS, salinity, and electrical conductivity which are above statutory limits.

Physicochemical properties of the effluents from Forcados Terminal were investigated. The results obtained were used to assess the effectiveness of the treatment of the Forcados Terminal by monitoring the physicochemical parameters of the effluent samples.

The pH of all the samples collected both in the rainy and dry season months from the Barge Jetties A and B and Saver Pits 1 and 2 of Forcados Terminal was within the permissible limits of the DPR and FMENV (Table 1). The pH is important to microorganisms, because it affects the functioning of virtually all enzymes, hormones, and proteins which control metabolism, growth, and development; pH is also a major factor in all chemical reactions associated with formation, alteration, and

Table 1. Comparison of physicochemical parameters of effluents samples with DPR/FMENV standards.

Parameter	Minimum	Maximum	Average value	DPR/FMENV
pH	4.86	8.29	6.6	6.5-8.5
Temp (°C)	22.7	28.826	-	25-30
Turbidity (NTU)	7.5	27	17	15
THC (mg/L)	BDL	BDL	-	20
TPH (mg/L)	BDL	BDL	-	20
TDS (mg/L)	19.15	18,800	9410	5,000
TSS (mg/L)	4.6	19.612.1	-	50
Salinity (mg/L)	10.35	7,735	3873	2,000
DO (mg/L)	4.7	8.05	6.3	3.0 (minimum)
BOD (mg/L)	1.35	6.75	4.1	10
NH4 (mg/L)	0.00	4.80	4.8	10
EC (µhos/cm)	81	37,500	18790	2000
$P0_4$ (mg/L)	0.00	1.46	1.46	<2 mg/L
H_2S (mg/L)	0.01	0.01	0.01	<2 mg/L

BDL: Below detectable limit; EC: electrical conductivity.

dissolution of mineral (Yao and Byme, 2001). The metabolism of many aquatic organisms is catalysed by acids and bases; therefore, depend on the pH of the water.

The temperature of all the samples taken *in situ* throughout the study period was within the DPR and FMENV limits (Table 1). The temperature of surface water governs to a large extent, the biological species present and their rates of activities. Higher order species, such as fish, are affected dramatically by temperature and DO levels which are a function of temperature. The observed temperature range of 22.7 to 28.8°C is consistent with that reported by Adesemoye et al. (2006).

The turbidity values of most of the samples (7.5 to 27 NTU) were higher than the 15 NTU DPR/FMENV limits (Table 1). This may have to do with the nutrient load of the effluents. The highest value of 27 NTU was recorded in February which is the peak of dry season. However, in June (rainy season), the effluent samples collected from Saver Pit 1 and Barge Jetty A had values of 7.5 and 8.5 NTU, respectively which were below the acceptable DPR limits and are indicative of dilution.

TDS and salinity were above the DPR and FMENV limits of 5000 and 2000 mg/L, respectively. TDS may be of organic (algae, zooplankton, and bacteria) or inorganic (clay, silt, calcium, bicarbonates, chloride, etc.) origin (Carvallo et al., 1999). TDS reduces light penetration, hence, reducing the ability of algae to photosynthesize. The interplay of hydrographic forces leaves a large quantity of materials in the effluents and causes some level of population of organisms in the effluents. The discharge of such effluent to a fresh water environment should be discouraged except there is further dilution before discharge.

TSS, which is the filterable particles in the effluent, had values (4.6 to 19.6 mg/L) below the recommended DPR maximum (50 mg/L) (Table 1). High TSS can cause an increase in the surface water temperature, because the suspended particles absorb heat from sunlight. TSS values of the effluent samples from the Barge Jetties and Saver Pits of Forcados Terminal were noticed to be lower than the DPR and FMENV recommended maximum. This could be as a result of the effective effluent treatment capability of Forcados Terminal as observed during the study. TDS values obtained from Barge Jetties effluent samples were noticed to be high. This could be as a result of human activities around the Barge Jetties as the boats that convey people in and out of the Forcados Terminal habour around the Barge Jetties. High TDS usually affects the refractive capacity of the water body and light dispersion pattern, apart from having a significant effect on the heat capacity of the system.

Total hydrocarbon (THC) and total petroleum hydrocarbons (TPH) of all effluent samples were below detectable limits. This is attributable to the very effective effluent treatment plant at the terminal. THC is an index to measure the carbon-containing compounds in a medium. It serves as a means of determining the level of organic contamination in a given environment. Sverdrup et al. (2003) reported that high organic carbon content increases the growth of microorganisms which then leads to the depletion of oxygen supply.

The conductivity of a medium is an indication of its ability to conduct an electric current. It is usually assessed by the presence of total concentration of ions, temperature, etc. Conductivity values higher than the 1250 µs/cm European Economic Community (EEC) maximum for domestic water (Mentode l'exploitant de leau etde l'assainissesment, 1986) were obtained from all the effluent samples of the Barge Jetties A and B and Saver Pits 1 and 2. These high conductivities results might be due to increased decomposition and mineralization of some organic matter. Higher conductivity range from 32,000 to 37,500 µhos/cm was obtained from all the effluent samples of the Barge Jetties A and B and Saver Pits 1 and 2 between January and February 2009. Only ionized substances contribute to conductivity of water (Adesemoye et al., 2006).

The DO levels showed a wide range of fluctuation between 4.7 and 8.05 mg/L in the rainy season (May to October) and 5.3 and 6.7 mg/L in dry season (November to April). DO levels of below 2.0 mg/L are indicative of environmental stress (Clark, 1986). The values observed in the effluents in this study were higher than the DPR minimum and lower than the 10 mg/L maximum, thus they are capable of sustaining marine/estuarine life when discharged into the water bodies.

BOD_5 is a measure of the oxygen requirement for the biochemical degradation of organic materials and the oxygen used to oxidize inorganic material, such as sulphides, ferrous ions, and nitrogen.

Observed values of BOD_5 were significantly below the acceptable limits (Table 1). This suggests that most available oxygen is used for biodegradation of waste within the environment; hence, very small amount was left for biochemical activities. BOD_5 depicts the amount of putrescible organic matter degradable by microbial metabolism on the assumption that the water has no bactericidal or bacteriostatic effects (A.P.H.A, 1995). Interesting changes were observed in the fluctuation of ammonia (NH_3). Low values below 1.0 mg/L were recorded from July 2008 to May 2009, while an average value of 4.8 mg/L was obtained for Saver Pit 1 in June 2008. This fluctuation was found to depend on the varied composition of waste effluent samples. Effluents high in nitrogenous compounds release ammonia as the major by-products (Cushing, 1975).

Phosphate, hydrogen sulphide, and phosphorus concentrations in the effluent samples were below 1.5 mg/L which is within the acceptable limit (<2 mg/L) (Table 1). Nutrients, including phosphate and nitrate are chemical substances required by microorganisms for growth. A wide variety of materials and trace elements can be classified as nutrients and are required in macro quantities for growth (Peavy et al., 1985).

CONCLUSION

This research was intended to evaluate the physicochemical properties of effluent samples of Forcados Terminal, thereby establishing the quality of the aqueous effluent samples of Forcados Terminal and checking the level of compliance with the regulatory limits. The conclusions from this research are as follows:

(1) Most of the parameters tested for complied with their respective DPR limits for near-shore environments.

(2) Turbidity, TDS, salinity and electrical conductivity had levels above statutory requirements.

RECOMMENDATION

Periodic monitoring should be given to the Forcados treatment plants in order to maintain their efficiency. It may be necessary for the DPR to review the guidelines to include highly saline environments, such as obtainable at Forcados Terminal with regard to parameters like TDS, salinity, turbidity, and EC.

Conflicts of Interests

The authors have not declared any conflicts of Interests.

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