Assessment of the Impact of Petroleum Depot Effluents on a Nearby River Quality

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Abstract

The possible effects of the petroleum depot effluents on the river water quality were examined. Twelve-monthly water sampling (June, 2015 to May, 2016) were taken from upstream and downstream of the river. Physicochemical parameters such as pH, temperature, turbidity, total dissolved solid (TDS), total suspended solid (TSS), total solid (TS), biochemical oxygen demand (BOD), dissolved oxygen (DO), total alkalinity, electrical conductivity (EC), total hardness, phosphate, sulphate, nitrate, chloride and heavy metals were determined using standard methods. The pH, temperature, TDS, TSS, TS, BOD, total alkalinity and chloride concentrations exceeded the guidelines values of WHO, SON and EPA during the dry season and within the permissible limits during the rainy season. The EC, total hardness, sulphate and nitrate were within the range of standards while phosphate and turbidity exceeded the permissible standard values throughout the sampling period. Pearson correlation coefficient of ions showed that there was a significant correlation at the 0.01 probability level. Therefore, the metals and anions are from a common source. Atomic Absorption Spectrophotometric results showed that concentration of Cd and Ni exceeded standard values, 0.005 and 0.1 mg/L respectively during the dry season while Pb and Cr exceeded the permissible limits, 0.01 and 0.05 mg/L during the rainy season. Copper was within the permissible limit 0.5 mg/L while Zn exceeded the permissible limit 0.05 mg/L throughout sampling periods. The levels of Pb, Cd, Zn, Ni, and Cr in the river are particularly high enough to cause public concerns.

Keywords: Heavy metals, Pearson correlation, permissible limits, physicochemical parameters, % violation

Introduction

Petroleum depots are generally located in the remote areas (OISD, 2012). Experience shows that with the passage of time, it gets surrounded by residential and/or industrial installations due to possible gains. However, as human dependency on crude-oil increases the dangers that accompanied it also increases (Abdus-Salam et al. 2010). Leakages and spills associated with loading and offloading of petroleum products in these depots as well as washing of oil storage tanks has adverse impact on the environment (Rasmussen, 1976). The indiscriminate discharge of effluents by the petroleum depot into the environment causes degradation of the aquatic ecosystem located near their installations. Crude oil is a complex mixture of several polycyclic aromatic compounds, heavy metals, anions, other hydrocarbons and additives. Nigeria crude oils were studied and shown to contain relatively high concentrations of some heavy metals, Fe, Zn, Cu and Pb (Owamah, 2013). The refined petroleum products show higher toxicity compared to crude oil since metal speciation is altered and new metals added to the matrix during the refining processes (Uzoekwe and Oghosanine, 2011).

Ever since the beginning of the existence of the universe, water has been an inevitable resource to all living things on earth. Although, water is abundant on earth in the form of oceans, seas, rivers, lakes and wells, large proportion of this water is not in the state suitable for human or animal consumption (Giwa et al. 2009). Water pollution is a serious problem for the entire world. All water pollution is dangerous to the health of living organisms, but sea and river pollution can be especially detrimental to the health of humans and animals. Rivers and seas are used as primary sources of potable water by populations all over the world (Mbaneme et al. 2013). Industrial wastewaters are continually being discharged indiscriminately into surface waters resulting in impairment of water quality (Sarkodie et al. 2014). This has led to pure and hygienic water scarcity, disruption of socio-economic activities and poor aesthetic quality of most of the water bodies polluted by the industrial activities.

It had been observed that toxicity from oil pollution can lead to respiratory illness, kidney disease, neurological diseases etc in humans (Ndubuisi and Asia, 2007). Effluents from petroleum companies are one of the largest sources of water pollution and one with the most lethal composition of toxins (Mishra and Jhansi, 2013). The waters that are being in contact with petroleum and its derivatives contain oil, hydrocarbons, sulfides, ammonia and large quantities of inorganic salts (Mukherjee et al. 2011). As a result, these toxic substances shift from one compartment within the aquatic environment to another including the biota often with detrimental effects, through sufficient bioaccumulation. They accumulate and are passed on at successive greater concentration of predators higher up in the food chain (Akporido and Asagba, 2013). It became necessary to carry out environmental assessment of the water of the area suspected of receiving the pollutant from the point of discharge from time to time, in order to evaluate the level of contaminants and to know the remediation techniques to implore in the purification of affected environments.

Materials and Methods

Study area

The oil depot studied (**Table1**) is located between latitude (8°34'60") N and longitude (4°43'0") E in Oke-Oyi, Ilorin East local government area, Kwara State, Nigeria. The sampling locations map (upstream and downstream), latitude and longitude were recorded using global positioning system (GPS) and Google earth (**Figure 1**).

Table 1: Sampling points and locations.

Sampling points	Location	
	Latitude	Longitude
Upstream	8º34' 4.40" N	4º41'2.75" E
Downstream	8º33'33.34" N	4º41'33.52" E

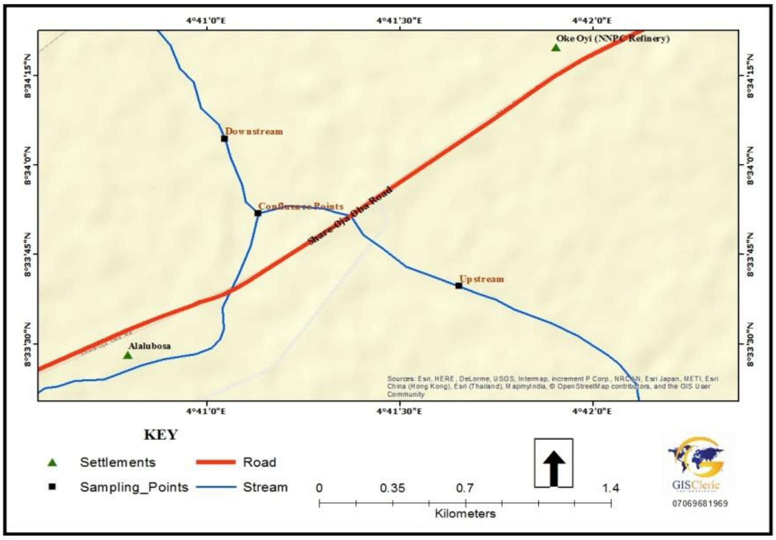


Figure 1: Map showing sampling points

Sampling and preservation

Water samples were collected from the upstream and downstream of the river into 1 L high density polyethylene (HDPE) plastic vials pre-treated with 4 M HNO_3 and properly rinsed with de-ionized water followed by doubly distilled water before use. Water samplings were carried out on monthly basis for 12 months between June, 2015 and May, 2016. Samples for metals analysis were collected separately and preserved immediately with 2 mL concentrated HNO_3 per 1 L sample. Samples handling and preservation were carried out in accordance with standard methods (APHA, 1995).

Water analysis

The pH, temperature, turbidity and conductivity of the water samples were measured with pH-meter, thermometer, turbidimeter and conductivity meter respectively which were previously calibrated before use. These parameters were determined *in situ* immediately after samples were collected. The total dissolved solid (TDS), Total suspended solid (TSS), total solid (TS), Dissolved oxygen (DO), Biochemical oxygen demand (BOD), Total alkalinity (TA) and Total hardness (TH) were determined using standard methods. Chloride, nitrate, sulphate and phosphate concentrations were determined by Mohr's, sodium salicylate (colorimetric), turbidimetric and ascorbic acid methods respectively (APHA-AWWA & WEF, 2005). Water samples were digested with aqua regia, HCl/HNO_3 (3:1) to release metals in a measurable form by atomic absorption spectrophotometer (APHA-AWWA & WEF, 2005).

Data analysis

Data obtained from physical and chemical measurements were subjected to descriptive statistical analysis, Pearson correlation coefficient and Box plot analyses. The mean values were compared with the water quality criteria of World Health Organization (WHO), Standard Organisation of Nigeria (SON) and Environmental Protection Agency (EPA). The Pearson correlation coefficient ($P < 0.01$) and Box plot analyses were used to establish relationship trend between parameters, pollution sources and the extent of the petroleum depot effluents into the river.

Results and Discussion

The average values of physicochemical parameters determined in this study are reported in **Table 2** for the two sampling points. The values obtained were compared to WHO, EPA and SON standards in order to obtain the percentage violation reported in Figure 2. The pH values ranged from 4.2 to 7.8 for upstream with a mean value of 6.4 ± 1.17 while the downstream ranged from 5.1 to 8.5 with an average of 7.05 ± 0.79. Both sampling points have low pH during the dry season and early rainy season with 50 - 100% percentage violation compared to the rainy season. This difference could be attributed to the presence of acidic constituents of water resulting from the microbial utilization of hydrocarbon pollutants in the ecosystem studied (Antai et al. 2016). According to Swingle (2000), organic waste reduces the pH of water and sediment to acidic level. It was observed that the temperature of the river water reduces with increase in the amount of rainfall. Temperature ranged from 24.5 to 37 ^oC with a mean temperature of the upstream as 29.45 ± 3.98 ^oC while the downstream mean temperature was 29.79 ± 3.61 ^oC. The fluctuation in river water temperature usually depends on the season, geographic location, sampling time and temperature of effluents entering the stream (Flura et al. 2016). The total dissolved solid (TDS), total suspended solid (TSS) and total solid (TS) for all the sampling points have no violation during the rainy season whereas, the values for the dry season varied from 50% to 100% violation of the standard values. The TDS for upstream ranged from 38 to 2125 mg/L with an average of 508.02 ± 409.16 mg/L while the downstream ranged from 40 to 1300 mg/L with an average value of 500.08 ± 306.33 mg/L. TSS for the upstream ranged from 21 to 775 mg/L with a mean concentration of 180.09 ± 114.29 mg/L while the downstream ranged from 17 to 2780 mg/L with a mean value of 94.58 ± 75.21mg/L. TS for upstream ranged from 59 to 2900 mg/L with a mean concentration of 1032.91 ± 492.67 mg/L while the downstream ranged from 57 to 3390 mg/L with a mean concentration of 803.17 ± 314.48 mg/L. Gebreyohannes et al. (2015) also reported the same trend in similar environment. Electrical conductivity (EC) values were within permissible limits throughout the sampling periods. The upstream of the river had higher turbidity values compared to the downstream of the river. This might be due to daily disturbance of the river by different anthropogenic activities.

The Dissolved Oxygen (DO) ranged from 7.2 to 26 mg/L for the upstream with mean value of 16.34 ± 6.37 mg/L while the downstream ranged from 0.97 to 25 mg/L with mean DO of 16.81 ± 6.77 mg/L. The DO exceeded standard values for both sampling points during the rainy season while the DO was low during the dry season. This was due to increase in temperature and presence of degradable organic matter (Uzoekwe and Oghosanine, 2011) from the depot effluents to the receiving river body. The low DO during the dry season may affect the aquatic habitats in the water and also cause an adverse effect on the villagers using the river water for consumption and domestic use. Biochemical Oxygen Demand (BOD) for the upstream ranged from 0.25 to 17 mg/L with mean concentration of 7.67 ± 5.99 mg/L while the downstream ranged from 0.79 to 12.4 mg/L with an average concentration of 6.27 ± 3.11 mg/L (**Table 2**). The BOD of the upstream was higher than the downstream due to high organic loads in the river water which may be attributed to the washing of locust beans (*Parkiabiglobosa)* into the river. Increased levels of BOD decrease the dissolved oxygen content in the river water (Ubwa et al. 2013). Hence the water is not fit for consumption and it may cause ailment to those villagers using it as a source of water. Total alkalinity (TA) for the upstream ranged from 24 to 366 mg/L with an average concentration 91.64 ± 65.72 mg/L while downstream ranged from 22 to 270 mg/L with a mean concentration 66.42 ± 43.29. The TA was within the standard values except June 2015 and March 2016 upstream (Table not shown), which may be due to the weathering of rocks, waste discharge from the villagers' activities and microbial decomposition of organic matter in the water body during these months. Aziz and Fakhrey (2016) also reported that TA was highest in March and it exceeded permissible limits as reported in this present study. Total Hardness (TH) was within the permissible limits throughout the sampling periods.

The nitrate levels in the upstream ranged from 1.83 to 8.7 mg/L with a mean concentration of 5.36 ± 2.43 mg/L while downstream ranged from 1.41 to 8.58 mg/L with an average concentration of 3.968 ± 2.53 mg/L. Uzoekwe and Oghosanine (2011) reported this same trend for nitrate concentration to be within permissible limits with refinery discharge been 0.87 mg/L, the values obtained for upstream and downstream are 0.35 mg/L and 0.25 mg/L respectively. Phosphate concentration in the river upstream ranged from 1.06 to 18.31 mg/L with a mean of 5.48 ± 5.13 mg/L while downstream ranged from 0.5 to 8.43 mg/L with a mean concentration of 3.238 ± 3.00 mg/L. Phosphate concentrations exceeded the permissible limits with 100% violation throughout the sampling periods except April, 2016 which had 50% violation of standards (**Figure 2**). Continuous entry of domestic sewage rich in phosphate additive is responsible for increase of phosphate (Sahoo et al. 2016). The upstream sulphate concentration ranged from 8.2 – 95.59 mg/L with mean of 43.05 ± 33.70 mg/L while downstream ranged from 6.73 to 157.93 mg/L with a mean concentration of 50.4 ± 50.69 mg/L. Sulphate contents of the river were within the WHO highest permissible limits of 250 mg/L. This result is in agreement with the result obtained by Muniyan and Ambedkar (2011). Chloride concentration in surface water serves as an indicator of pollution caused by industrial or domestic waste (Noortheen et al. 2016). The upstream of the river ranged from 21 to 349.98 mg/L with an average concentration of 74.71 ± 97.06 mg/L while the downstream ranged from 18.99 to 167.95 mg/L with a mean concentration of 53.92 ± 50.44 mg/L. The chloride concentrations in the river were within the permissible limits except March 2016 (upstream) and this may be attributed to the high temperature, less rainfall and a load of pollutants discharged into the river.

Copper concentrations fell within permissible limits while zinc, lead and chromium were higher than standard values for both sampling points. Cadmium and nickel were above permissible limits during the dry season and within the acceptable values during the rainy season. Concentration of copper ranged from0.015 to 0.02 mg/L in upstream with a mean concentration of 0.058 ± 0.041 mg/L while downstream ranged from 0.02 to 0.17 mg/L with an average value of 0.059 ± 0.046 mg/L. A high load of Cu was reported earlier for similar environmental media (Etchie et al. 2011). Zinc concentration ranged from 0.13 to 1.645 mg/L with an average concentration of 0.465 ± 0.523 mg/L in upstream of the river while downstream ranged from 0.1 to 1.645 mg/L with a mean concentration of 0.374 ± 0.431 mg/L. Zinc exceeded WHO standard of 0.01 - 0.05 mg/L and EPA standard of 0.05 mg/L throughout the sampling periods. Adewuyi et al. (2011) also reported that, Zn had the highest metal burden which exceeded the standard values for surface water around and within the vicinity of petroleum depot. Chromium concentration ranged from 0.1 to 0.836 mg/L with a mean concentration of 0.450 ± 0.323 mg/L while the downstream of the river ranged from 0.08 to 1.303 mg/L with an average value of 0.462 ± 0.381 mg/L. Chromium content of the upstream was below detectable limits while that of the downstream gave values higher than permissible limits in July 2015, October 2015 and February 2016. Lead concentration for upstream of the river ranged from 0.17 to 1.021 mg/L with a mean concentration of 0.524 ± 0.454 mg/L while downstream ranged from 0.231 to 2.38 mg/L with an average concentration of 1.158 ± 1.105 mg/L. High concentration of lead during the rainy and late dry season can be attributed to runoff from the depot effluents and automobile from the road that cut across the river (Manikandan et al. 2016). Concentration of cadmium ranged from 0.05 to 1.912 mg/L with a mean concentration of 0.521 ± 0.927 mg/L in the upstream of the river while downstream of the river ranged from 0.01 to 27.246 with a mean value 5.472 ± 12.172 mg/L. The cadmium concentrations detected during dry season have 100% violation of the standard values. Nickel concentration was below detectable limits throughout the sampling period except October and November 2015. The downstream of the river gave a concentration of 0.191 mg/L in October 2015 while both upstream and downstream gave 0.682 and 0.556 mg/L respectively in November 2015. These concentrations were far above the maximum contamination level. The concentration of heavy metals for both upstream and downstream of the river in mg/L was in the order of Cd > Zn >Pb> Cr > Ni > Cu.

Descriptive statistical analysis parameters computed include mean, minimum, maximum, standard deviation and standard error of mean. From **Table 3**, the pH, temperature and DO have minimum mean values in February, 2016, which may be attributed to the dried up of the upstream of the river where no sample was obtained that month while other physicochemical parameters such as TDS, TSS and TS in October, 2015 and BOD, EC, TH and TA in November, 2015 have minimum average values during the rainy season. Turbidity had its minimum mean value in April,

2016. The maximum mean concentration for most parameters were obtained during the dry season and early rainy season throughout the twelve-monthly sampling period, DO had its highest mean value in October, 2015, which may be attributed to the increase in dilution, tide and flow rate of the river.

Table 4 shows that nitrate had its highest mean value during the rainy season in October, 2015 while other anions have their highest mean concentration during the dry season, March and April 2016. From **Table 5**, the maximum mean concentrations for copper and lead were in the month of May, 2016, chromium and nickel were in the month of November, 2015 while cadmium and zinc were in the month of February and April, 2016 respectively. It was observed that the summary of the metal analysis also showed a significant difference in the measure of dispersion and central tendency of high concentration value for dry and rainy seasons of sampling. Box plot variation of concentration of the anions and heavy metals for the sampling points across the river also showed a wide variation pattern for anions and heavy metals during the dry season while the rainy season have little or no difference in the variation pattern from the extracted mean. Therefore, it is noteworthy that the seasons of sampling have a very huge effect on the concentration of the parameters studied.

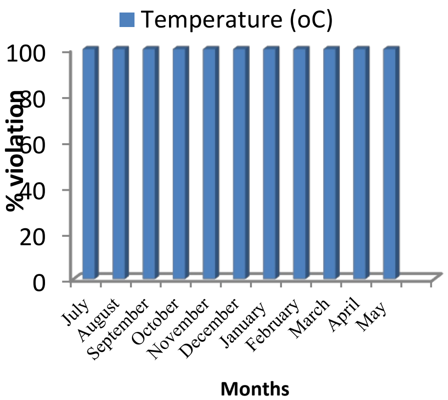
From the Pearson correlation coefficient of ions over the sampling time (**Table 6**). It was revealed that there was a significant correlation ($P<0.01$) among phosphate, nitrate and nickel; chloride and phosphate; zinc and sulphate; copper and lead; cadmium and chromium; indicating that the metals and anions are from a common source. This common source is supposed to be partly due to the depot wastewater, geogenic and other anthropogenic means through villager's use of the water as their main source of water resource for domestic use.

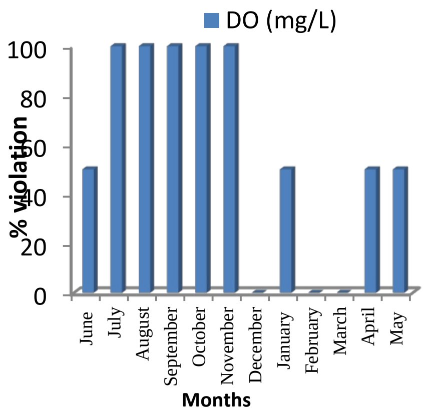
Table 2: Average values of the physicochemical parameters of water samples from June 2015 to May 2016

Parameters	Upstream	Downstream	WHO Standard	SON Standard	EPA Standard
pH	6.40 ± 1.17 (4.2 - 7.8)	7.05 ± 0.79 (5.1 - 8.5)	6.5 – 7.5	6.5 – 8.5	6.5 – 8.5
Temp. (^oC)	29.45 ± 3.98 (24.5 - 37)	29.79 ± 3.61 (24.5 - 37)	25	Ambient	NS
DO (mg/L)	16.34 ± 6.37 (7.2 - 26)	16.81 ± 6.77 (0.97 - 25)	15	NS	NS
BOD (mg/L)	7.67 ± 5.99 (0.25 - 17)	6.27 ± 3.11 (0.79 - 12.4)	10	NS	NS
TDS (mg/L)	508.02 ± 409.16 (38 - 2125)	500.08 ± 306.33 (40 - 1300)	1000	500	500
TSS (mg/L)	180.09 ± 114.29 (21 - 775)	94.58 ± 75.21 (17 - 2780)	80	NS	NS

TS (mg/L)	1032.91 ± 492.67 (59 - 2900)	803.17 ± 314.48 (57 - 3390)	1500	1500	NS
EC (µS/cm)	193.43 ± 218.75 (37 - 666)	150.13 ± 103.31 (50.7 - 362)	1500	1000	4.7-5.8
Turbidity (NTU)	177.18 ± 126.09 (19 - 1048)	65.35 ± 49.43 (6 - 174)	5	5	5 – 25
TH (mg/L)	76.55 ± 57.15 (22 - 192)	74.25 ± 45.98 (18 - 140)	500	150	NS
TA (mg/L)	91.64 ± 65.72 (24 - 366)	66.42 ± 43.29 (22 - 270)	200	NS	NS
NO_3^- (mg/L)	5.36 ± 2.43 (1.83 - 8.7)	3.968 ± 2.53 (1.41 - 8.58)	10	10	10
PO_4^{3-} (mg/L)	5.48±5.13 (1.06 - 18.31)	3.238 ± 3.00 (0.5 - 8.43)	0.5	0.01 – 0.03	NS
SO_4^{2-} (mg/L)	43.05 ± 33.70 (8.2 - 95.53)	50.40±50.69 (6.73 - 157.93)	200	100	250
Cl^- (mg/L)	74.71 ± 97.06 (21 - 349.98)	53.92 ± 50.44 (18.99 - 167.95)	250	250	250
Cu (mg/L)	0.058 ± 0.041 (0.015 - 0.02)	0.059 ± 0.046 (0.02 - 0.17)	0.5	1	1.3
Pb (mg/L)	0.524 ± 0.454 (0.17 - 1.021)	1.158 ± 1.105 (0.231 - 2.38)	0.01	0.01	0.015
Zn (mg/L)	0.465 ± 0.523 (0.13 - 1.645)	0.374 ± 0.431 (0.1 - 1.645)	0.01-0.05	3	0.05
Cd (mg/L)	0.521 ± 0.927 (0.05 - 1.912)	5.472 ± 12.172 (0.01 - 27.246)	0.003	0.003	0.005
Cr (mg/L)	0.45 ± 0.323 (0.1 - 0.836)	0.462 ± 0.381 (0.08 - 1.303)	0.05	0.05	0.1
Ni (mg/L)	0.682	0.374 ± 0.258 (0.191 - 0.556)	0.07	0.02	0.1

NS: Not Stated





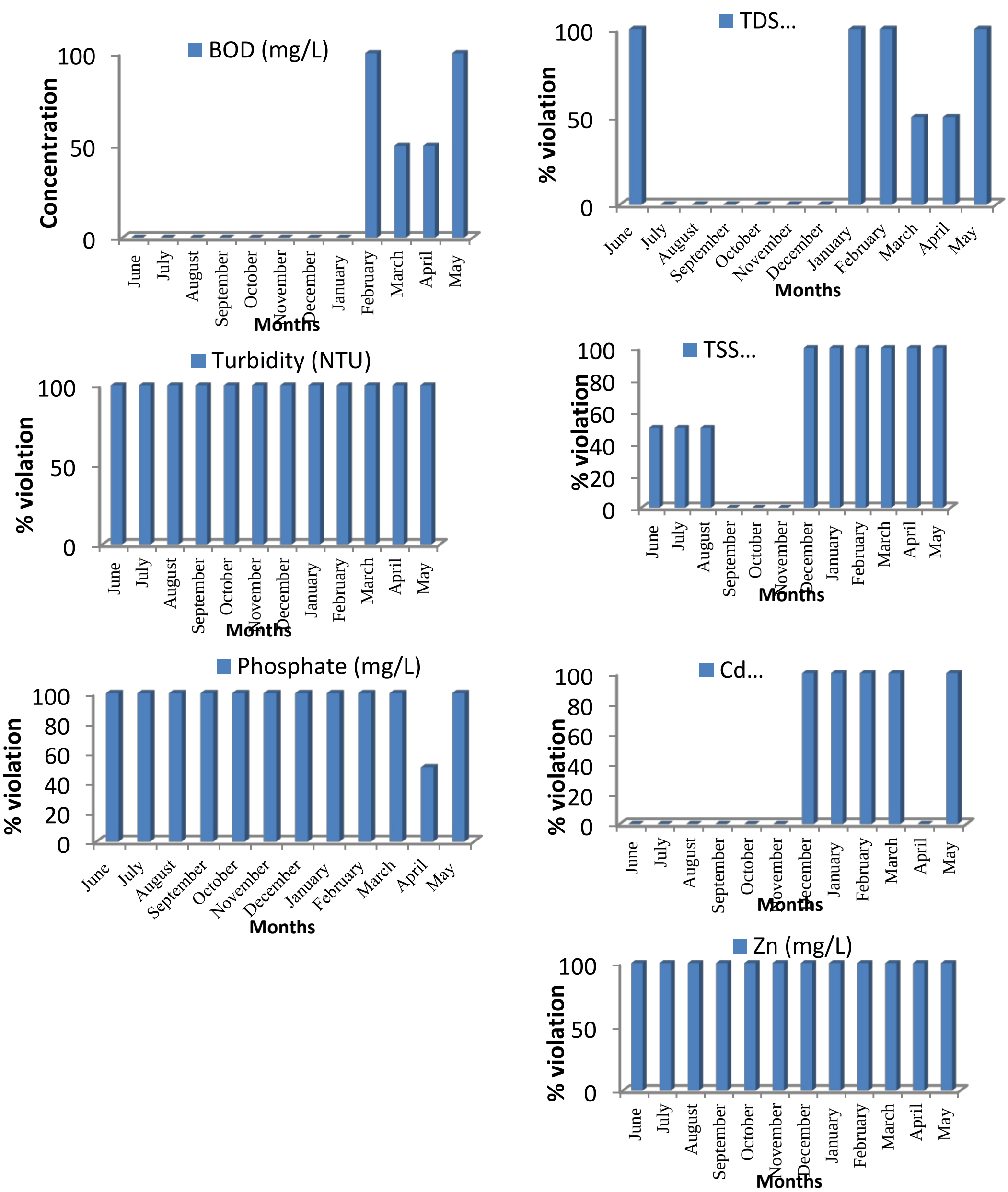


Figure 2: Graphs of summary of the percentage violation of the guideline values of water sample monitoring from June, 2015 to May, 2016

Table 3: Summary of physicochemical parameters for the months of June 2015 to May 2016

Months		pH	Temperature	DO	BOD	TDS	TSS	TS	EC	Turbidity	TH	TA
Jun-15	Mean	4.95	36	15.6	6.905	1545	85	1630	426	117.7	164	318
	Minimum	4.8	35	13.2	6.44	980	60	1040	362	61.4	136	270
	Maximum	5.1	37	18	7.37	2110	110	2220	490	174	192	366
	Std. Deviation	0.21213	1.41421	3.39411	0.65761	799.0307	35.35534	834.386	90.50967	79.62022	39.59798	67.88225
	Std. Error of Mean	0.15	1	2.4	0.465	565	25	590	64	56.3	28	48
Jul-15	Mean	6.8	29.75	16.7	5.97	340	56	396	215.5	45	102	60
	Minimum	6.7	29.5	14.2	5.76	270	22	360	161	12	96	42
	Maximum	6.9	30	19.2	6.18	410	90	432	270	78	108	78
	Std. Deviation	0.14142	0.35355	3.53553	0.29698	98.99495	48.08326	50.91169	77.07464	46.66905	8.48528	25.45584
	Std. Error of Mean	0.1	0.25	2.5	0.21	70	34	36	54.5	33	6	18
Aug-15	Mean	6.85	28.25	18.3	5.82	170	65	235	51.05	154	67.5	67.5
	Minimum	6.7	28	16.6	4.19	90	40	180	48.8	151	61	63
	Maximum	7	28.5	20	7.45	250	90	290	53.3	157	74	72
	Std. Deviation	0.21213	0.35355	2.40416	2.30517	113.1371	35.35534	77.78175	3.18198	4.24264	9.19239	6.36396
	Std. Error of Mean	0.15	0.25	1.7	1.63	80	25	55	2.25	3	6.5	4.5
Sep-15	Mean	7.2	26.25	20.25	5.17	175	35	210	59.75	96	41	50
	Minimum	7.1	25	17.2	3.9	70	30	110	56.9	95	40	38
	Maximum	7.3	27.5	23.3	6.44	280	40	310	62.6	97	42	62
	Std. Deviation	0.14142	1.76777	4.31335	1.79605	148.4924	7.07107	141.4214	4.03051	1.41421	1.41421	16.97056
	Std. Error of Mean	0.1	1.25	3.05	1.27	105	5	100	2.85	1	1	12
Oct-15	Mean	6.85	24.75	24.7	2.735	39	19	58	50.15	52.5	32	25
	Minimum	6.8	24.5	23.4	0.25	38	17	57	46.9	52	26	24
	Maximum	6.9	25	26	5.22	40	21	59	53.4	53	38	26
	Std. Deviation	0.07071	0.35355	1.83848	3.51432	1.41421	2.82843	1.41421	4.59619	0.70711	8.48528	1.41421
	Std. Error of Mean	0.05	0.25	1.3	2.485	1	2	1	3.25	0.5	6	1
Nov-15	Mean	7.45	24.75	21.05	1.455	195	51	246	45.3	59	20	24
	Minimum	7.1	24.5	17.3	0.79	190	50	242	39.9	58	18	22
	Maximum	7.8	25	24.8	2.12	200	52	250	50.7	60	22	26
	Std. Deviation	0.49497	0.35355	5.3033	0.94045	7.07107	1.41421	5.65685	7.63675	1.41421	2.82843	2.82843
	Std. Error of Mean	0.35	0.25	3.75	0.665	5	1	4	5.4	1	2	2

Dec-15	Mean	7.05	29	7.8	4.38	168	145	313	97.85	41.51	44	37
	Minimum	7	28	7.2	3.98	121	120	241	65.2	8.42	32	36
	Maximum	7.1	30	8.4	4.78	215	170	385	130.5	74.6	56	38
	Std. Deviation	0.07071	1.41421	0.84853	0.56569	66.46804	35.35534	101.8234	46.17407	46.79633	16.97056	1.41421
	Std. Error of Mean	0.05	1	0.6	0.4	47	25	72	32.65	33.09	12	1

Jan-16	Mean	8	34	18.8	5.225	1712.5	432.5	2145	110.5	533.15	55	67
	Minimum	7.5	31	12.6	2.59	1300	90	1390	70	18.3	52	50
	Maximum	8.5	37	25	7.86	2125	775	2900	151	1048	58	84
	Std. Deviation	0.70711	4.24264	8.76812	3.72645	583.3631	484.3682	1067.731	57.27565	728.1079	4.24264	24.04163
	Std. Error of Mean	0.5	3	6.2	2.635	412.5	342.5	755	40.5	514.85	3	17
Feb-16	Mean	3.85	17	0.485	5.3	305	1390	1695	130	19.25	70	39
	Minimum	0	0	0	0	0	0	0	0	0	0	0
	Maximum	7.7	34	0.97	10.6	610	2780	3390	260	38.5	140	78
	Std. Deviation	5.44472	24.04163	0.68589	7.49533	431.3351	1965.757	2397.092	183.8478	27.22361	98.99495	55.15433
	Std. Error of Mean	3.85	17	0.485	5.3	305	1390	1695	130	19.25	70	39
Mar-16	Mean	5.5	29.75	10.8	11.3	960	235	1195	479.5	42	128	135
	Minimum	4.2	29.5	9.1	7.2	380	200	580	293	13	80	68
	Maximum	6.8	30	12.5	15.4	1540	270	1810	666	71	176	202
	Std. Deviation	1.83848	0.35355	2.40416	5.79828	820.2439	49.49747	869.7413	263.7508	41.01219	67.88225	94.75231
	Std. Error of Mean	1.3	0.25	1.7	4.1	580	35	615	186.5	29	48	67
Apr-16	Mean	6.35	32.25	17.7	11.1	1295	180	1475	231	12.5	104	52
	Minimum	5.1	31.5	13.5	5.2	890	80	970	125	6	68	24
	Maximum	7.6	33	21.9	17	1700	280	1980	337	19	140	80
	Std. Deviation	1.76777	1.06066	5.9397	8.34386	572.7565	141.4214	714.1779	149.9066	9.19239	50.91169	39.59798
	Std. Error of Mean	1.25	0.75	4.2	5.9	405	100	505	106	6.5	36	28
May-16	Mean	6.65	29	17.4	14.6	786.5	115.5	902	68.05	194	39	28
	Minimum	6.6	29	13.6	12.4	680	80	760	37	158	26	22

	Maximum	6.7	29	21.2	16.8	893	151	1044	99.1	230	52	34
	Std. Deviation	0.07071	0	5.37401	3.11127	150.6137	50.20458	200.8183	43.91133	50.91169	18.38478	8.48528
	Std. Error of Mean	0.05	0	3.8	2.2	106.5	35.5	142	31.05	36	13	6
Total	Mean	6.4583	28.3958	15.7987	7.0119	640.9167	234.0833	875	163.7208	113.8842	72.2083	75.2083
	Minimum	0	0	0	0	0	0	0	0	0	0	0
	Maximum	8.5	37	26	17	2125	2780	3390	666	1048	192	366
	Std. Deviation	1.70036	7.05257	7.14054	5.81001	663.4726	564.7109	943.7566	166.109	208.1589	51.66782	85.52395
	Std. Error of Mean	0.34708	1.4396	1.45756	1.4525	135.4308	115.2711	192.6435	33.90685	42.49025	10.54665	17.4575

Table 4: Summary of anions for the months of June, 2015 to May, 2016

Months		NO_3^{2-} (mg/L)	PO_4^{3-} (mg/L)	SO_4^{2-} (mg/L)	Cl^- (mg/L)
Jun., 2015	Mean	3.72	5.58	97	145.955
	Minimum	1.83	2.73	92	123.96
	Maximum	5.61	8.43	102	167.95
	Std. Deviation	2.67286	4.03051	7.07107	31.10563
	Std. Error of Mean	1.89	2.85	5	21.995
	WHO maximum permissible limit	10	0.5	200	250
	SON maximum permissible limit	10	0.03	100	250
	EPA maximum permissible limit	10	NS	250	250
Jul., 2015	Mean	2.11	2.815	56	96.97
	Minimum	1.73	2.49	27	58.98
	Maximum	2.49	3.14	85	134.96

	Std. Deviation	0.5374	0.45962	41.01219	53.72597
	Std. Error of Mean	0.38	0.325	29	37.99
	WHO maximum permissible limit	10	0.5	200	250
	SON maximum permissible limit	10	0.03	100	250
	EPA maximum permissible limit	10	NS	250	250
Aug., 2015	Mean	2.26	3.115	19.25	23.49
	Minimum	1.79	3.09	16	18.99
	Maximum	2.73	3.14	22.5	27.99
	Std. Deviation	0.66468	0.03536	4.59619	6.36396
	Std. Error of Mean	0.47	0.025	3.25	4.5
	WHO maximum permissible limit	10	0.5	200	250
	SON maximum permissible limit	10	0.03	100	250
	EPA maximum permissible limit	10	NS	250	250
Sep., 2015	Mean	2.46	0.995	10	26.99
	Minimum	1.41	0.93	8	23.99
	Maximum	3.51	1.06	12	29.99
	Std. Deviation	1.48492	0.09192	2.82843	4.24264
	Std. Error of Mean	1.05	0.065	2	3
	WHO maximum permissible limit	10	0.5	200	250
	SON maximum permissible limit	10	0.03	100	250
	EPA maximum	10	NS	250	250

	permissible limit				
Oct., 2015	Mean	6.865	7.88	9.33	20.99
	Minimum	5.51	7.69	8.73	18.99
	Maximum	8.22	8.07	9.93	22.99
	Std. Deviation	1.91626	0.2687	0.84853	2.82843
	Std. Error of Mean	1.355	0.19	0.6	2
	WHO maximum permissible limit	10	0.5	200	250
	SON maximum permissible limit	10	0.03	100	250
	EPA maximum permissible limit	10	NS	250	250
Nov., 2015	Mean	8.64	7.785	7.465	40.99
	Minimum	8.58	7.56	6.73	33.99
	Maximum	8.7	8.01	8.2	47.99
	Std. Deviation	0.08485	0.3182	1.03945	9.89949
	Std. Error of Mean	0.06	0.225	0.735	7
	WHO maximum permissible limit	10	0.5	200	250
	SON maximum permissible limit	10	0.03	100	250
	EPA maximum permissible limit	10	NS	250	250
Dec., 2015	Mean	5.7	1.385	57.365	20.5
	Minimum	5.44	1.11	56.73	20
	Maximum	5.96	1.66	58	21
	Std. Deviation	0.3677	0.38891	0.89803	0.70711
	Std. Error of Mean	0.26	0.275	0.635	0.5

	WHO maximum permissible limit	10	0.5	200	250
	SON maximum permissible limit	10	0.03	100	250
	EPA maximum permissible limit	10	NS	250	250
Jan., 2016	Mean	5.225	5.41	43.665	22.5
	Minimum	3.05	1.29	29.33	21
	Maximum	7.4	9.53	58	24
	Std. Deviation	3.07591	5.82656	20.27275	2.12132
	Std. Error of Mean	2.175	4.12	14.335	1.5
	WHO maximum permissible limit	10	0.5	200	250
	SON maximum permissible limit	10	0.03	100	250
	EPA maximum permissible limit	10	NS	250	250
Feb., 2016	Mean	1.305	0.355	53.065	30.49
	Minimum	0	0	0	0
	Maximum	2.61	0.71	106.13	60.98
	Std. Deviation	1.84555	0.50205	75.04524	43.11937
	Std. Error of Mean	1.305	0.355	53.065	30.49
	WHO maximum permissible limit	10	0.5	200	250
	SON maximum permissible limit	10	0.03	100	250
	EPA maximum permissible limit	10	NS	250	250
Mar., 2016	Mean	4.88	10.56	45.265	193.45

	Minimum	1.87	2.81	15.4	37
	Maximum	7.89	18.31	75.13	349.9
	Std. Deviation	4.25678	10.96016	42.23549	221.25371
	Std. Error of Mean	3.01	7.75	29.865	156.45
	WHO maximum permissible limit	10	0.5	200	250
	SON maximum permissible limit	10	0.03	100	250
	EPA maximum permissible limit	10	NS	250	250
Apr., 2016	Mean	4.78	1.84	126.73	23.59
	Minimum	4.46	0.5	95.53	19.19
	Maximum	5.1	3.18	157.93	27.99
	Std. Deviation	0.45255	1.89505	44.12346	6.22254
	Std. Error of Mean	0.32	1.34	31.2	4.4
	WHO maximum permissible limit	10	0.5	200	250
	SON maximum permissible limit	10	0.03	100	250
	EPA maximum permissible limit	10	NS	250	250
May, 2016	Mean	6.825	2.245	14.07	88.07
	Minimum	5.85	2.05	12.87	86.17
	Maximum	7.8	2.44	15.27	89.97
	Std. Deviation	1.37886	0.27577	1.69706	2.68701
	Std. Error of Mean	0.975	0.195	1.2	1.9
	WHO maximum permissible limit	10	0.5	200	250

	SON maximum permissible limit	10	0.03	100	250
	EPA maximum permissible limit	10	NS	250	250
Total	Mean	4.5642	4.1638	44.9337	61.1654
	Minimum	0	0	0	0
	Maximum	8.7	18.31	157.93	349.9
	Std. Deviation	2.62892	4.20203	42.75363	74.74326
	Std. Error of Mean	0.53663	0.85774	8.72705	15.2569

Table 5: Summary of heavy metals for the months of June, 2015 to May, 2016

Months		Cu (mg/l)	Pb (mg/l)	Zn (mg/l)	Cd (mg/l)	Cr(mg/l)	Ni (mg/l)
Jun., 2015	Mean	0.098	0	0.3555	0	0.04	0
	Minimum	0.098	0	0.139	0	0	0
	Maximum	0.098	0	0.572	0	0.08	0
	Std. Deviation	0	0	0.306177	0	0.056569	0
	Std. Error of Mean	0	0	0.2165	0	0.04	0
	WHO maximum permissible limit	0.5	0.01	0.05	0.003	0.05	0.07
	SON maximum permissible limit	1	0.01	3	0.003	0.05	0.02
	EPA maximum permissible limit	1.3	0.015	0.05	0.005	0.1	0.1
Jul., 2015	Mean	0.039	0	0.167	0	0.435	0
	Minimum	0.039	0	0.153	0	0.35	0
	Maximum	0.039	0	0.181	0	0.52	0
	Std. Deviation	0	0	0.019799	0	0.120208	0

	Std. Error of Mean	0	0	0.014	0	0.085	0
	WHO maximum permissible limit	0.5	0.01	0.05	0.003	0.05	0.07
	SON maximum permissible limit	1	0.01	3	0.003	0.05	0.02
	EPA maximum permissible limit	1.3	0.015	0.05	0.005	0.1	0.1
Aug., 2015	Mean	0.128	1.076	1.069	0	0.5265	0
	Minimum	0.119	0.985	0.978	0	0.311	0
	Maximum	0.137	1.167	1.16	0	0.742	0
	Std. Deviation	0.012728	0.128693	0.128693	0	0.304763	0
	Std. Error of Mean	0.009	0.091	0.091	0	0.2155	0
	WHO maximum permissible limit	0.5	0.01	0.05	0.003	0.05	0.07
	SON maximum permissible limit	1	0.01	3	0.003	0.05	0.02
	EPA maximum permissible limit	1.3	0.015	0.05	0.005	0.1	0.1
Sep., 2015	Mean	0.1395	0.229	0.286	0	0.289	0
	Minimum	0.121	0.194	0.276	0	0.223	0
	Maximum	0.158	0.264	0.296	0	0.355	0
	Std. Deviation	0.026163	0.049497	0.014142	0	0.093338	0
	Std. Error of Mean	0.0185	0.035	0.01	0	0.066	0
	WHO maximum permissible limit	0.5	0.01	0.05	0.003	0.05	0.07
	SON maximum permissible limit	1	0.01	3	0.003	0.05	0.02

	EPA maximum permissible limit	1.3	0.015	0.05	0.005	0.1	0.1
Oct., 2015	Mean	0.0715	0.103	0.3205	0	0.06	0.7705
	Minimum	0.063	0	0.259	0	0	0
	Maximum	0.08	0.206	0.382	0	0.12	1.541
	Std. Deviation	0.012021	0.145664	0.086974	0	0.084853	1.089652
	Std. Error of Mean	0.0085	0.103	0.0615	0	0.06	0.7705
	WHO maximum permissible limit	0.5	0.01	0.05	0.003	0.05	0.07
	SON maximum permissible limit	1	0.01	3	0.003	0.05	0.02
	EPA maximum permissible limit	1.3	0.015	0.05	0.005	0.1	0.1
Nov., 2015	Mean	0.0785	0	0.247	0	0.6505	1.7535
	Minimum	0.059	0	0.212	0	0.465	1.575
	Maximum	0.098	0	0.282	0	0.836	1.932
	Std. Deviation	0.027577	0	0.049497	0	0.262337	0.252437
	Std. Error of Mean	0.0195	0	0.035	0	0.1855	0.1785
	WHO maximum permissible limit	0.5	0.01	0.05	0.003	0.05	0.07
	SON maximum permissible limit	1	0.01	3	0.003	0.05	0.02
	EPA maximum permissible limit	1.3	0.015	0.05	0.005	0.1	0.1
Dec., 2015	Mean	0.0585	0	0.246	0.0415	0	0
	Minimum	0	0	0.238	0.022	0	0
	Maximum	0.117	0	0.254	0.061	0	0

	Std. Deviation	0.082731	0	0.011314	0.027577	0	0
	Std. Error of Mean	0.0585	0	0.008	0.0195	0	0
	WHO maximum permissible limit	0.5	0.01	0.05	0.003	0.05	0.07
	SON maximum permissible limit	1	0.01	3	0.003	0.05	0.02
	EPA maximum permissible limit	1.3	0.015	0.05	0.005	0.1	0.1
Jan., 2016	Mean	0	0	0.385	0.0205	0	0
	Minimum	0	0	0.307	0.02	0	0
	Maximum	0	0	0.463	0.021	0	0
	Std. Deviation	0	0	0.110309	0.000707	0	0
	Std. Error of Mean	0	0	0.078	0.0005	0	0
	WHO maximum permissible limit	0.5	0.01	0.05	0.003	0.05	0.07
	SON maximum permissible limit	1	0.01	3	0.003	0.05	0.02
	EPA maximum permissible limit	1.3	0.015	0.05	0.005	0.1	0.1
Feb., 2016	Mean	0	0	0.274	13.623	0.6515	0
	Minimum	0	0	0	0	0	0
	Maximum	0	0	0.548	27.246	1.303	0
	Std. Deviation	0	0	0.387495	19.265831	0.92136	0
	Std. Error of Mean	0	0	0.274	13.623	0.6515	0
	WHO maximum permissible limit	0.5	0.01	0.05	0.003	0.05	0.07
	SON maximum permissible limit	1	0.01	3	0.003	0.05	0.02

	EPA maximum permissible limit	1.3	0.015	0.05	0.005	0.1	0.1
Mar., 2016	Mean	0	0	0.3145	0.961	0	0
	Minimum	0	0	0.28	0.01	0	0
	Maximum	0	0	0.349	1.912	0	0
	Std. Deviation	0	0	0.04879	1.344917	0	0
	Std. Error of Mean	0	0	0.0345	0.951	0	0
	WHO maximum permissible limit	0.5	0.01	0.05	0.003	0.05	0.07
	SON maximum permissible limit	1	0.01	3	0.003	0.05	0.02
	EPA maximum permissible limit	1.3	0.015	0.05	0.005	0.1	0.1
Apr., 2016	Mean	0.05	0.1315	1.986	0	0	0
	Minimum	0.041	0	1.678	0	0	0
	Maximum	0.059	0.263	2.294	0	0	0
	Std. Deviation	0.012728	0.185969	0.435578	0	0	0
	Std. Error of Mean	0.009	0.1315	0.308	0	0	0
	WHO maximum permissible limit	0.5	0.01	0.05	0.003	0.05	0.07
	SON maximum permissible limit	1	0.01	3	0.003	0.05	0.02
	EPA maximum permissible limit	1.3	0.015	0.05	0.005	0.1	0.1
May, 2016	Mean	0.3125	1.943	0.202	0.055	0.32	0
	Minimum	0.293	1.166	0.153	0.05	0.1	0
	Maximum	0.332	2.72	0.251	0.06	0.54	0

	Std. Deviation	0.027577	1.098844	0.069296	0.007071	0.311127	0
	Std. Error of Mean	0.0195	0.777	0.049	0.005	0.22	0
	WHO maximum permissible limit	0.5	0.01	0.05	0.003	0.05	0.07
	SON maximum permissible limit	1	0.01	3	0.003	0.05	0.02
	EPA maximum permissible limit	1.3	0.015	0.05	0.005	0.1	0.1
May, 2016	Mean	0.3125	1.943	0.202	0.055	0.32	0
	Minimum	0.293	1.166	0.153	0.05	0.1	0
	Maximum	0.332	2.72	0.251	0.06	0.54	0
	Std. Deviation	0.027577	1.098844	0.069296	0.007071	0.311127	0
	Std. Error of Mean	0.0195	0.777	0.049	0.005	0.22	0
	WHO maximum permissible limit	0.5	0.01	0.05	0.003	0.05	0.07
	SON maximum permissible limit	1	0.01	3	0.003	0.05	0.02
	EPA maximum permissible limit	1.3	0.015	0.05	0.005	0.1	0.1
Total	Mean	0.08129	0.29021	0.48771	1.22508	0.24771	0.21033
	Minimum	0	0	0	0	0	0
	Maximum	0.332	2.72	2.294	27.246	1.303	1.932
	Std. Deviation	0.087119	0.635463	0.535367	5.556006	0.341266	0.572036
	Std. Error of Mean	0.017783	0.129713	0.109281	1.134115	0.069661	0.116766

Table 6: Pearson correlation coefficient of ions over the sampling time

	NO_3^- (mg/L)	**PO_4^{3-} (mg/L)**	**SO_4^{2-} (mg/L)**	**Cl^- (mg/L)**	**Cu (mg/L)**	**Pb (mg/L)**	**Zn (mg/L)**	**Cd (mg/L)**	**Cr (mg/L)**	**Ni (mg/L)**
NO_3^{2-} (mg/L)	1	.636**	-0.043	0.216	0.177	0.044	-0.023	-0.139	-0.071	.577**
		0.001	0.843	0.311	0.407	0.838	0.915	0.519	0.743	0.003
PO_4^{3-} (mg/L)	.636**	1	0.012	.654**	-0.195	-0.179	-0.117	-0.126	-0.129	0.34
	0.001		0.956	0.001	0.361	0.402	0.587	0.559	0.547	0.104
SO_4^{2-} (mg/L)	-0.043	0.012	1	0.326	-0.31	-0.299	.572**	0.315	-0.061	-0.332
	0.843	0.956		0.121	0.14	0.157	0.004	0.133	0.778	0.113
Cl^-	0.216	.654**	0.326	1	-0.002	-0.01	-0.166	0.057	-0.041	-0.136
(mg/L)	0.311	0.001	0.121		0.994	0.962	0.439	0.791	0.848	0.528
Cu	0.177	-0.195	-0.31	-0.002	1	.824**	-0.074	-0.211	0.158	-0.004
(mg/L)	0.407	0.361	0.14	0.994		0	0.733	0.321	0.462	0.984
Pb	0.044	-0.179	-0.299	-0.01	.824**	1	0.052	-0.102	0.234	-0.175
(mg/L)	0.838	0.402	0.157	0.962	0		0.81	0.634	0.27	0.413
Zn	-0.023	-0.117	.572**	-0.166	-0.074	0.052	1	0.019	-0.039	-0.145
(mg/L)	0.915	0.587	0.004	0.439	0.733	0.81		0.929	0.857	0.5
Cd	-0.139	-0.126	0.315	0.057	-0.211	-0.102	0.019	1	.648**	-0.085
(mg/L)	0.519	0.559	0.133	0.791	0.321	0.634	0.929		0.001	0.694
Cr	-0.071	-0.129	-0.061	-0.041	0.158	0.234	-0.039	.648**	1	0.286
(mg/L)	0.743	0.547	0.778	0.848	0.462	0.27	0.857	0.001		0.176
Ni	.577**	0.34	-0.332	-0.136	-0.004	-0.175	-0.145	-0.085	0.286	1
(mg/L)	0.003	0.104	0.113	0.528	0.984	0.413	0.5	0.694	0.176	

**. Correlation is significant at the 0.01 level (2-tailed).

Conclusion

The analysis of the water quality parameters of the upstream and downstream of the river show that pH, temperature, TDS, TSS, TS, BOD, total alkalinity and chloride values exceeded the guidelines values of WHO, SON and EPA during the dry season and within the permissible limits during the rainy season. The EC, total hardness, sulphate and nitrate were within the range of standard values while phosphate and turbidity exceeded the permissible standards throughout the sampling period. The downstream of the river had higher values for some of these parameters compared to the upstream; this revealed that the petroleum depot waste water released into the river resulted to the high value in the downstream of the river. Thus, it can be concluded that the characteristics of this water body was influenced by seasonal variations and load of effluents discharged. It is note-worthy that the levels of Pb, Cd, Zn, Ni, Cu and Cr in the river body are particularly high enough to cause public concerns.

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