2.3 Sample Test Analysis

Samples were analyzed and determined for Physiochemical Properties from the Civil Engineering Department, Rivers State Polytechnic, Water and Environmental Engineering Laboratory. All parameters were analysed according to APHA (1998), Nigerian Standard for Water Quality (NSDWQ) (NIS, 2007) and World Health Organization (WHO, 1997 and 2008).

2.3.1 pH

The pH of the streams investigated was measured using pH meter.

2.3.2 Electrical conductivity (EC)

Electrical conductivity (EC) is a measure of the ability or the numerical expression of water's ability to conduct electric current. This was measured in-situ both in the effluent channel and in the stream using a Mettler Toledo MC 226 conductivity meter.

2.3.3 Turbidity

Turbidity of samples was analyzed using the HACH 2100A turbidity meter and HACH Ratio Turbid meter APHA-214A.

2.3.4 Chemical Oxygen Demand

Chemical oxygen demand (COD) is the amount of oxygen required to completely oxidize the organic matter in waste water by use of a strong oxidant and to convert it to carbon meter (Mettler Toledo 320 model) according to APHA (1998). Potassium dichromate was used in this test because of its superior oxidizing ability. A known quantity of water sample was mixed with a known quantity of standard solution of potassium dichromate ($K_2Cr_2O_7$) and the mixture heated. The organic matter was oxidized by the potassium chromate in the presence of sulphuric acid (H_2SO_4) and the oxygen used in oxidizing the water was determined.

2.3.5 Biochemical Oxygen Demand (BOD)

The (BOD) was determined by measuring the DO of the samples contained in a BOD bottle before and after five days of incubation of 20ºC temperature. According to APHA-51210B, BOD was calculated as:

$$BOD = (S_1 - S_2) - (B_1 - B_2) \times \%\,\text{dilution} \quad (1)$$

where: S_1 = DO for the sample, S_2 = DO after incubation of sample, B_1 = DO for the first day for blank and B_2 = DO after incubation for blank.

2.3.6 Heavy metals

Copper, iron and aluminium were determined using Atomic Absorption Spectrometer (model AA6800-SHIMADZU) according to APHA (1998).

2.4 Data analysis

Data were statistically analyzed in MS Excel tool. Mean, variance and standard error were used to vary and assess the spread of the data. The mean of parameters (±SE) and one-way analysis of variance (ANOVA) were calculated to make comparison of the mean values of observations based on the seven sites. Differences in mean values obtained were considered significant if calculated P-values were < 0.05. Correlation analysis test was performed to determine the association between various parameters along sampling sites.

3. RESULTS AND DISCUSSION

The physiochemical parameters determined in samples collected from streams receiving effluents from seven industries in Trans-Amadi Industrial Layout of Port Harcourt, River State are presented in Table 2.

Table 2: Physicochemical Analysis of Waste from Receiving Water

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	WHO	NIS
pH	6.86	7.24	6.6	8.07	6.34	8.24	6.67	6.0-8.5	6.0-8.5
Temp. (ºC)	27	26	22.4	26.7	27.3	24.2	26.7	24.28	NA
EC (µs/cm)	10788	9986	10648	10552	10688	9868	10676	1000	1000
Turbidity (NTU)	26.3	27.4	29.3	31.6	36.4	30.8	27.8	5	5
BOD	1.8	1.4	5.2	4.3	2.6	3.1	1.6	4	NA

(mg/l)									
COD (mg/l)	76.7	71.3	78.3	64.8	79.3	66.3	68.3	NA	NA
DO (mg/l)	4.9	5.3	6.3	6.2	5.7	5.5	4.6	3-7	3-7
TSS (mg/l)	40.6	42.6	39.6	36.7	31.8	35.3	41.6	NA	NA
Salinity (mg/l)	1.6	2.1	1.3	0.9	1	1.3	1.4	NA	NA
Copper (mg/l)	3.47	3.09	2.56	2.44	3.36	3.41	3.10	1.0	NA
Iron (mg/l)	5.98	6.22	5.84	5.51	6.03	5.60	5.94	0.3	NA
Aluminium (mg/l)	0.82	0.64	0.55	0.73	0.59	0.52	0.67	0.2	NA

3.1 Sample pH

Though, the range of pH obtained across the sites were within the specified limits by international and local regulatory agencies (WHO, 1997 and 2008; NIS, 2007), but there are variations in pH in the respective sites, with least values recorded in site 5 (pollution from Abattoir) and the highest value in site 6 (pollution from beverages and biscuits manufacturing industry). The mean value of pH across the sites is 7.15±0.74. The low pH recorded in some of the sites was could be attributed to several sources of water such as rain water runoff that made their ways into the streams thereby, increasing the acidity of the streams. The trend in pH is shown in Figure 3.

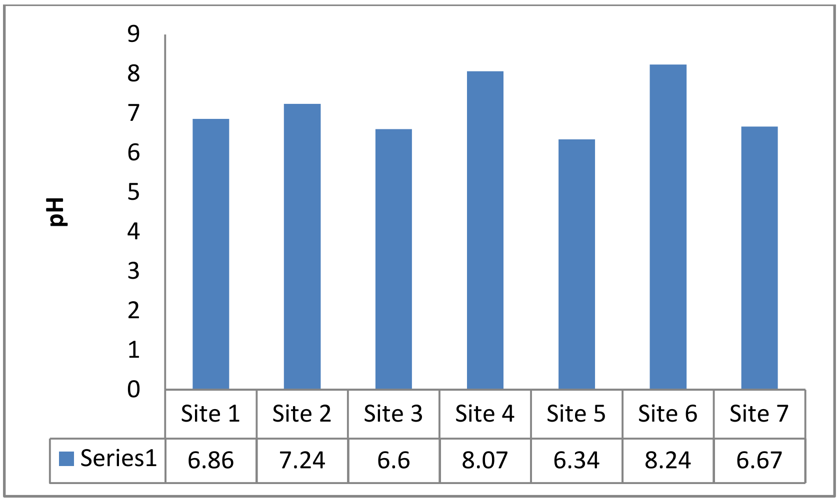

Figure 3: pH trend along the sampling sites

3.2 Temperature

Temperature across the sites are equally within the specified limits by WHO (24-28°C) except for site 3 (pollution from oil drilling fluids manufacturing industry). This implies that oil drilling fluids contain substances that increase the average temperature of the stream. The mean temperature across the sites is 25.76±1.80. The temperature trend in across the sites is shown in Figure 4.

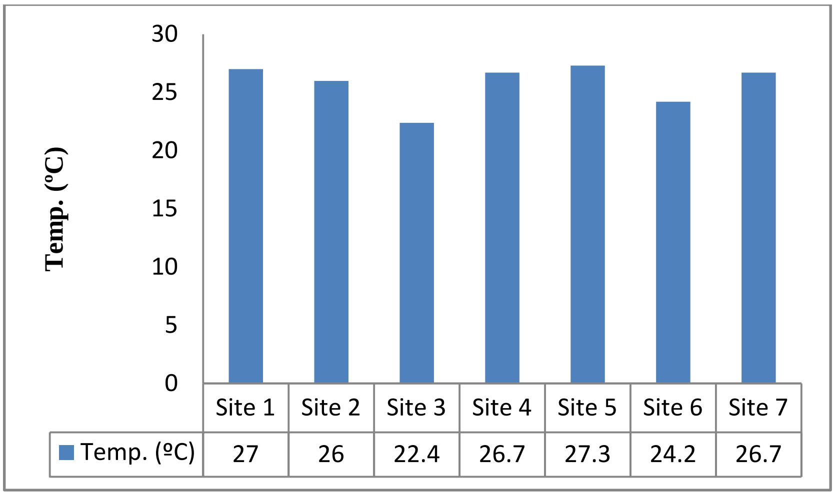

Figure 4: Temperature trend along the sampling sites

3.3 Electrical Conductivity

Electrical conductivity indicates the level of salt present in water. Thus, the higher the quantity of ions in water, the more its conductivity (Mosley et al., 2004). Figure 5 shows the level of electrical conductivity (EC) in the various sites. EC ranged from 9868 in site 6 (pollution from beverage and biscuit manufacturing industry) to 10788μS/cm in site 5 (pollution from Abattoir) with mean value of 10458.00±370.84μS/cm. The EC values across the sites are higher than the threshold limit by WHO and NIS of 1000 μs/cm. The high EC recorded in beverage and biscuit manufacturing industry implied that there are more dissolved solids than other sites, which increased the stream ions and salts. The EC trend in across the sites is shown in Figure 5.

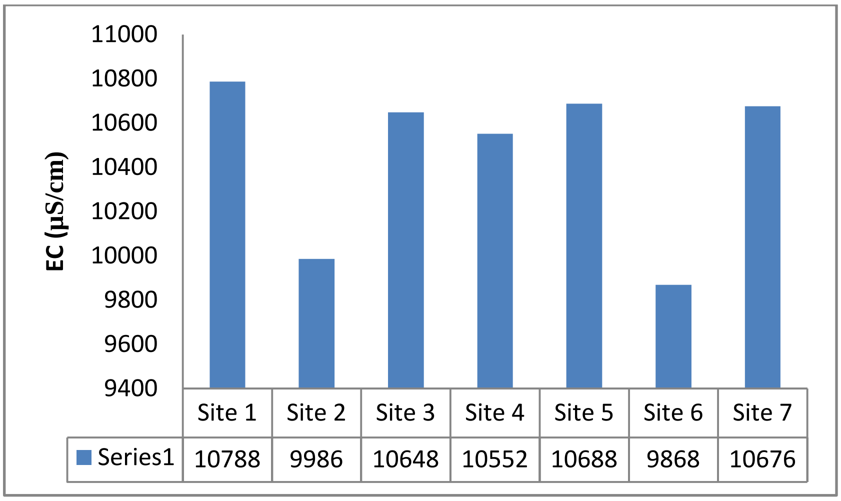

Figure 5: Electrical conductivity trend along the sampling sites

3.4 Turbidity

Figure 6 shows the level of turbidity in the sites. Thus, turbidity values across the sites are higher than the threshold limit by WHO and NIS. Site 5 recorded the highest turbidity (pollution from Abattoir) with mean value of 29.94±3.41NTU. Turbidity was above WHO standards of 5NTU for the seven (7) sites. The high turbidity could be as a result of the presence of suspended matter such as clay, silt, finely divided organic and inorganic matter, plankton, or other microscopic organisms in the effluents (Lamb, 1985). The result is also in agreement with similar investigation by Muwanga and Barifaijo (2006) in Uganda. This high turbidity will affect fish and aquatic life by interfering with sunlight penetration. If suspended particles block light, photosynthesis and production of oxygen for fish and other aquatic animals as well as sea weeds will be reduced (Smith and Davies-Colley, 2001).

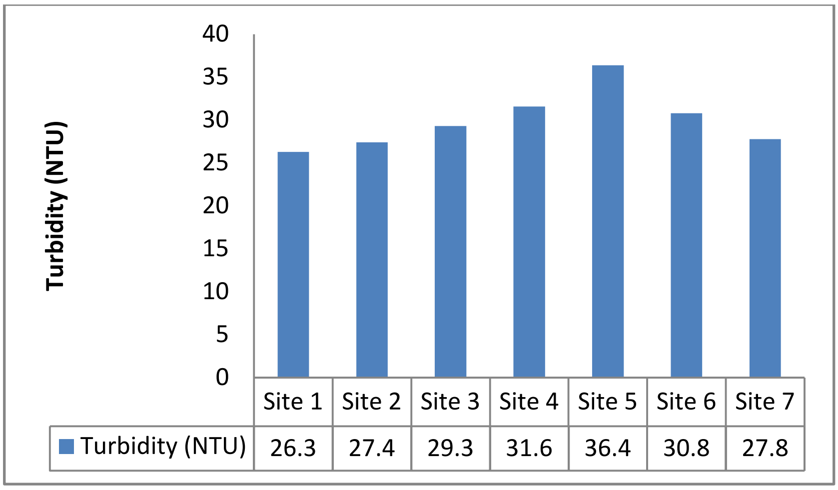

Figure 6: Turbidity and colour trends along the sampling sites

3.5 Biochemical Oxygen Demand (BOD)

Figure 7 shows the level of Biochemical Oxygen Demand (BOD) across the sampling sites. The concentration of BOD in sites 3 and 4 are higher than the maximum permissible limit by WHO (4mg/l), indicating that oil drilling fluids and wastes from servicing materials discharged into water bodies contain high content of biodegradable organic matters, which are sure to raising the amount of BOD. Thus, the continued disposal of biodegradable organic waste into the streams will lead to increased consumption of dissolved oxygen, which may in turn affect aquatic life. In recent studies, high BOD in water was attributed to effect of temperature, salinity, and putrefaction of substances or deposition of organic pollutants from industrial wastewaters and agricultural wastes (Onojake *et al*., 2017; Amic and Tadic, 2018).

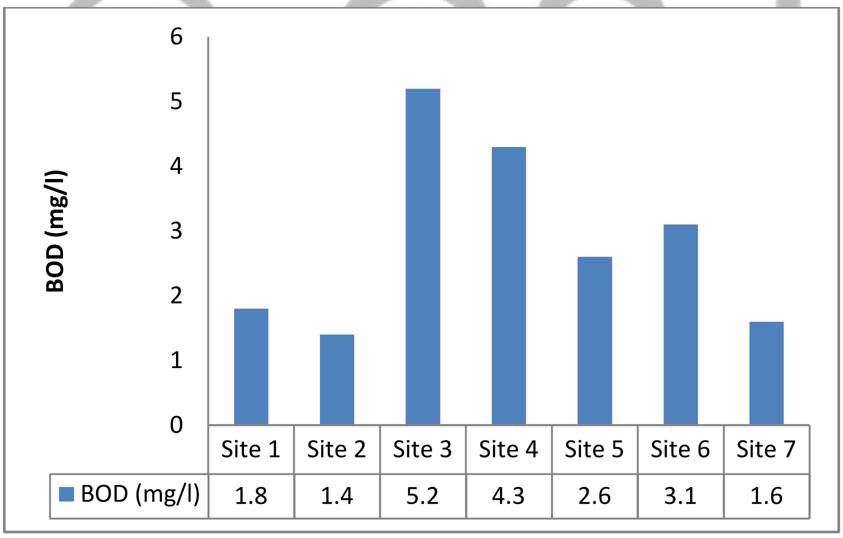

Figure 7: Trend of BOD along the sampling sites

3.6 Chemical Oxygen Demand (COD)

Similarly, the level of COD in the streams is shown in Figure 8. The COD values obtained ranged from 64.8mg/l to 79.3mg/l with mean values of 72.14±5.96mg/l. Although, there was no limit set for COD, the values recorded across the streams are above those obtained by Abu and Egenonu (2008) for New Calabar River, while values reported by Wakawa *et al*. (2008) for Challawa River in Kano State and Osibanjo *et al*. (2011) for Ona and Alaro rivers are above values recorded in this work. The high COD in water is due to high suspended organic matter (Amic and Tadic, 2018). COD values in the effluent streams are higher than their BOD counterparts. This is due to the fact that BOD only accounted for substances that oxidized biologically, while COD measures chemical and biological oxidation of substances in waste waters (Gray, 1989).

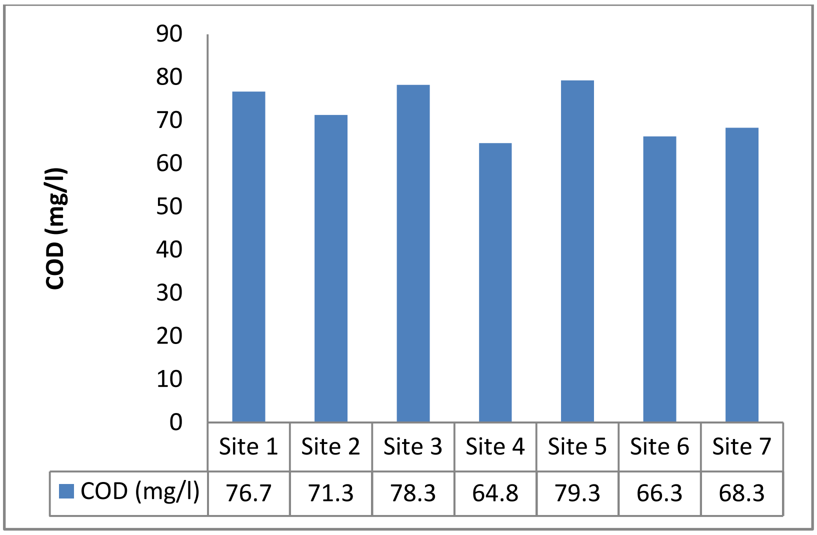

Figure 8: Trend of COD along the sampling sites

3.7 Dissolved Oxygen

Dissolved oxygen (DO) in the streams is generally within WHO and NIS standards (3-7mg/l). The DO values ranged from 4.6mg/l to 6.3mg/l with mean values of 5.50±0.63mg/l. Thus, sites 3 and 4 recorded the highest value of DO, while the least value was observed at site 7, indicating that oil fluids wastes contain substances with high potential to increasing DO in water if not properly managed. Figure 9 shows the level of DO recorded in effluents from the various sites.

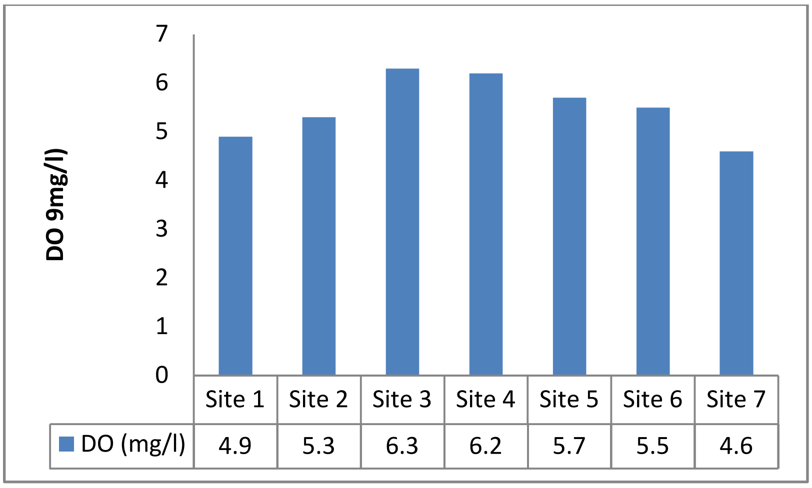

Figure 9: Trend of DO along the sampling sites

3.8 Total Suspended Solids

Total suspended solids (TSS) are present in sanitary wastewater and many types of industrial wastewater. They create uncharacteristic taste in water making it less potable (Mohamed and Hussain, 2012). The range of TSS across the sites was 31.8mg/l (site polluted by abattoir) to 42.6mg/l (site polluted by soft drinks and beverages manufacturing industry) with mean values of 38.31±3.88mg/l. Again, TSS limit are not given by WHO and NIS, but can be guided by the discomfort it creates.

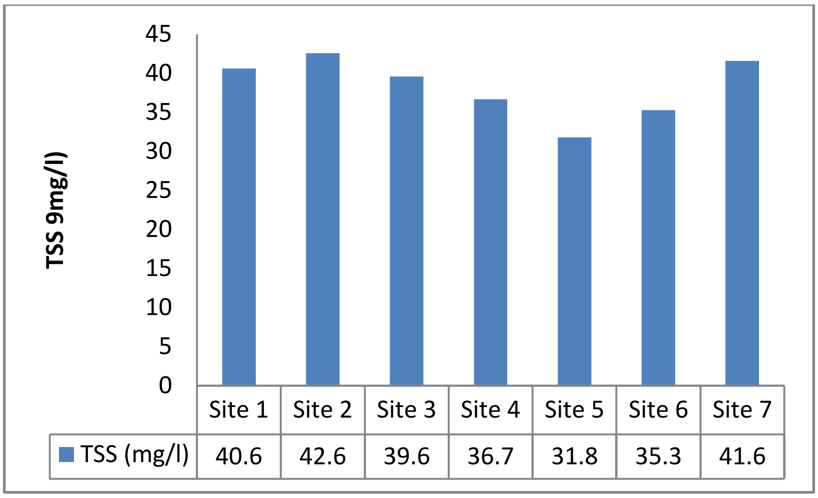

Figure 10: Trend of TSS along the sampling sites

3.9 Salinity

Salinity is a measure of the total salt concentration, comprised mostly of Na^+ and Cl^- ions. Even though there are smaller quantities of other ions in seawater (e.g., K^+, $Mg^{2+,}$ or SO_4^{2-}), sodium and chloride ions represent about 91% of all seawater ions. Like other parameters, salinity varied in the sampling sites and ranged from 0.90 mg/l (oil drilling fluids manufacturing and servicing industry) to 2.10 mg/l (site polluted by soft drinks and beverages manufacturing industry) as demonstrated in Figure 11 with mean value of 1.37±0.40mg/l across the sites.

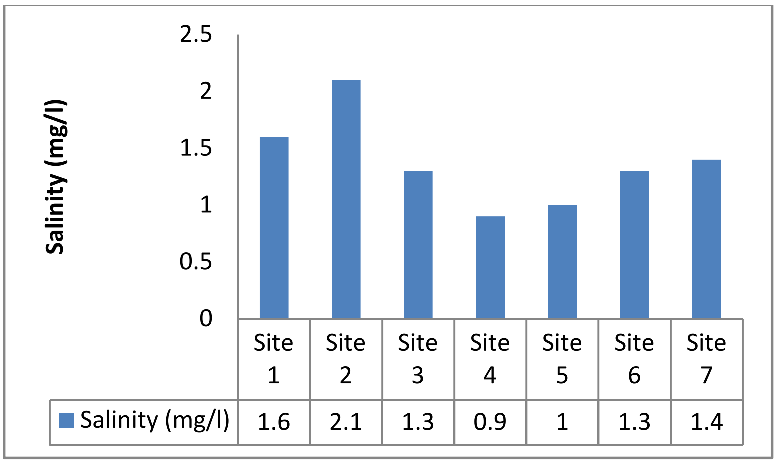

Figure 11: Trend of salinity along the sampling sites

3.10 Heavy metals

The results shown in Table 2 revealed that the contents of copper, iron and aluminium were above acceptable limits set by WHO. The lowest values for copper and iron was recorded in oil drilling fluids manufacturing and servicing industry, while for aluminium, it was recorded in beverage and biscuit manufacturing industry. However, effluent from alcoholic drinks manufacturing industry produced higher contents of copper and aluminium, while the highest amount of iron was produced from oil drilling fluids effluent. These variations could be attributed to treatments techniques applied before disposal. Figures 12 to 14 show the level of copper, iron and aluminium contents recorded in effluents from the various sites.

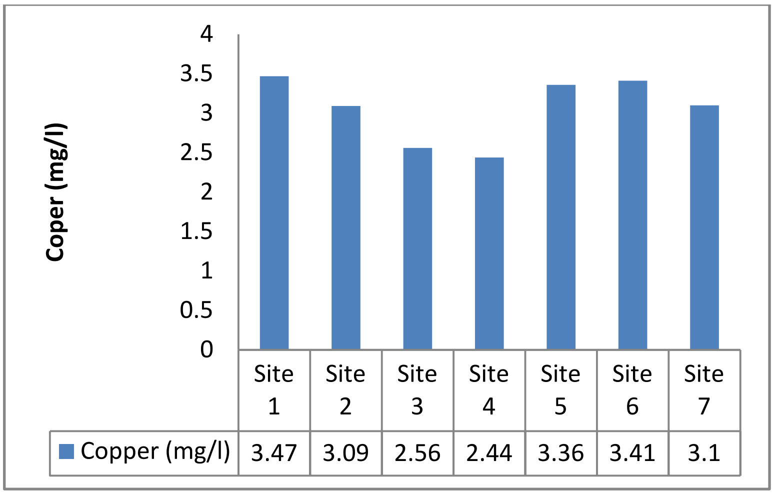

Figure 12: Copper trend along the sampling sites

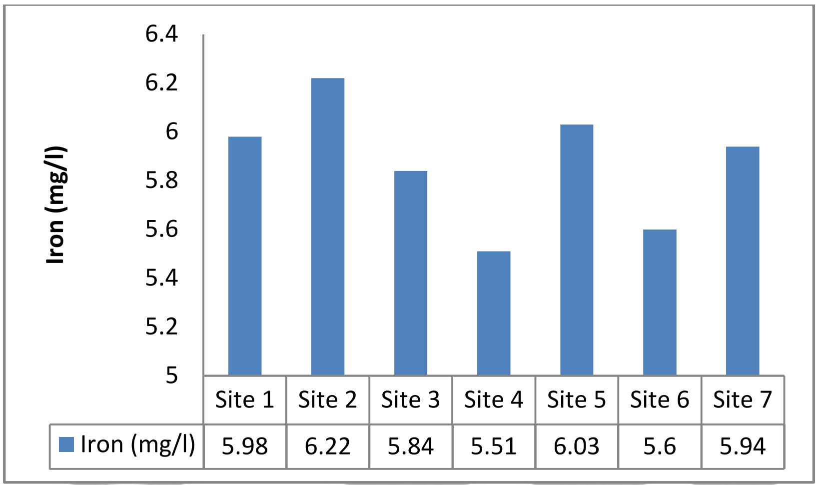

Figure 13: Iron trend along the sampling sites

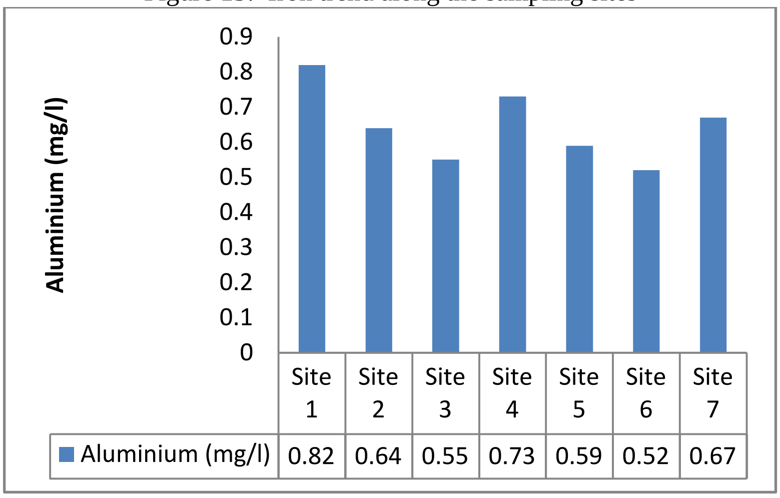

Figure 14: Aluminium trend along the sampling sites

4. CONCLUSION

Overall, the study shows that effluents from industries, especially when mot properly treated, have high impact on water quality of the receiving streams. This is depicted by the increase in concentration of the parameters analysed as opposed to the maximum permissible limits set by WHO and NIS for quality water. Although the values in some cases were lower than the maximum allowable limits by WHO (1997, 2008) and NIS (2007), the continued discharge of un-treated effluents in the stream may result in severe accumulation of contaminants. This is a situation that should alert the Nigerian Standard for Water Quality to continuously monitor industrial effluents and enforce the regulation.

In practice, industrial waste and effluents are supposed to be treated before been dispose of, but it seemed this has been compromised as the level of contaminants observed at the discharge point were not satisfactory, and their direct or indirect utilization by humans could be a potential sources of diverse of health related issues.

It is therefore recommended that careless disposal of wastes should be discouraged and there is need for each industry to install waste treatment plant that will treat wastes before being discharged into the streams. Furthermore, Federal and State environmental regulators should enact and enforce laws that will regulate, manage and protect receiving streams from contamination.

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