Research Journal of Biotechnology and Life Science
Volume 1, Issue 1, 2021 (pp. 1-17)
www.abjournals.org

IMPACT OF OIL POLLUTION ON THE WATER QUALITY OF EKEHUAN RIVER, EDO STATE, NIGERIA

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ABSTRACT: *In this study, the impact of locally refined petroleum products on the water quality of Ekehuan River was investigated between April 2013 and January 2014 to determine the water quality status, using the limits set by Nigerian standard and WHO guidelines for drinking water quality, as a guide. Water samples were collected from three stations—station I was located in the oil-impacted Ekehuan River, which is a tributary of Ovia River, while stations II and III were located along the stretch of Ovia River at Gelegele community as control stations. The water samples were analyzed for water and air temperatures, pH, conductivity, TDS, DO, BOD, COD, sodium, calcium, potassium, chloride, some selected heavy metals and total hydrocarbon concentration (THC). At the oil-impacted station I, DO and water temperature were significantly lower, while THC was significantly higher ($p < 0.05$) compared to the other stations. Statistically, the heavy metals and other parameters investigated in the water did not show any significant difference ($p > 0.05$) across the stations. However, the levels of cadmium, nickel and lead at all stations were much higher than the Nigerian standard and WHO guidelines for drinking water quality. These findings are indicative that the water quality at station I is compromised and not fit for consumption.*

KEYWORDS: Oil Pollution, Water Quality, Edo State, Nigeria

INTRODUCTION

Water is an essential natural resource required for sustaining life on earth. Water on earth can be said to be enormous in quantity, with about 72% of the earth covered by it, yet, fresh potable water free from harmful physical, biological and chemical contamination is not always available at the right time or the right place for human or ecosystem use (Imoobe and Okoye, 2011; Chinedu *et al.*, 2011). The hydrosphere is estimated to contain about 1.36 million km^3, out of which about 0.3% of the water is available as freshwater in rivers, streams and lakes for human use; about 0.32% is locked up in the form of groundwater; 2.1% is in form of polar ice and glaciers; while the remaining 97.25% is locked up in seas and oceans (Wilson, 1990).

Rivers constitute the main water sources for domestic, industrial and agricultural purposes (Yu and Shang, 2003). Thus, it is imperative to prevent and control river pollution and to have reliable information on the quality of water for effective management. Water quality is neither a static condition of a system, nor can it be defined by the measurement of only one parameter. There is a range of chemical, physical and biological components that affect water quality.

These variables provide general indication of water pollution, whereas others enable a direct tracking of pollution sources (UNEP, 2011).

Rivers are the most important freshwater resource for man. Unfortunately, river waters are being polluted by indiscriminate disposal of sewage, industrial waste and a plethora of human activities, which affect their physico-chemical characteristics and microbiological quality (Koshy and Nayar, 1999). Pollution of the aquatic environment is a serious and growing problem. Increasing numbers and amounts of industrial, agricultural and commercial chemicals discharged into the aquatic environment have led to various deleterious effects on aquatic organisms. Aquatic organisms, including fish, accumulate pollutants directly from contaminated water and indirectly via the food chain (Hammer, 2004; Mohammed, 2009).

In the Niger Delta region of Nigeria, illegal oil bunkering and artisanal refining are on the rise in various communities, worsening the environmental challenges and ecological destruction of land and surface water bodies in the region, and the social conflict caused by the oil industry. Artisanal refining begins with the procurement of stolen crude oil and subsequently refining them in the illegal or “bush’’ refineries, with the use of local resources and skills.

An estimated 150,000 barrels of crude oil are stolen every day in Nigeria. The vast majority of this is sold internationally, but approximately 25% stays in the Niger Delta for refining and consumption. Illegal oil refining in the region comes with steep environmental, economic and social costs (SDN, 2013).

On the average, typical artisanal refinery produces about forty to sixty drums of diesel a day. Severe damage is done to the environment as a result of artisanal refining. The refining process leads to a significant quantity of wastage being dumped in rivers and streams or on land; two drums of crude oil translate into one drum of product once refined (Obenade and Amangabara, 2014). According to Ogbuagu, *et al*. (2011), it has been reported that petroleum refining contributes solid, liquid and gaseous wastes in the environment. Some of these wastes could contain toxic components such as the polynuclear aromatic hydrocarbons (PAHs), which have been reported to be the real contaminants of oil and most abundant of the main hydrocarbons found in the crude oil mixture (El-Deed and Emara, 2005).

A number of studies have been carried out in Ekehuan and Gelegele Rivers to investigate the environmental impact of oil exploration on zooplankton and benthic macro invertebrates of these rivers (Ogbeibu and Omoigberale, 2005; Omoigberale and Ogbeibu, 2010). However, there has not been any study targeted at the impact of the rampant illegal oil refining activities on the water quality of Ekehuan River. This study has become imperative due to the operations of illegal refineries in the upper reaches of the river and the surrounding creeks, where illegally acquired crude oil is refined to diesel. In the process, other fractions of the crude oil are wasted and discharged into the river. The main objective of this study is to assess the impact of waste discharges from illegal refineries and accidental discharge of locally refined diesel on the water quality, as well as to compare the water quality parameters with Nigerian standard for drinking water quality (SON, 2007) and WHO guideline values (WHO, 2006) for drinking water standards, to determine if the water is potable and safe for other domestic uses.

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METHODOLOGY

Study Area

The study was conducted in Ekehuan River, a tributary of Ovia River at Gelegele. The entire study stretches between latitude 06^0 $10^'$ N and 06^0 $12^'$ N, and longitude 05^0 $20^'$E and 05^0 22' E in Ovia North East LGA of Edo State, Nigeria (Figure 1), within the tropical rainforest belt of Southern Nigeria. Rainy season in this area spans the month of March to October with a dry season covering the month of November to February. It is a freshwater with a thick tropical vegetation cover along the bank. The dominant vegetation in the area comprises rubber (*Hevea brazilensis*), Palm trees (*Elaeis guineensis*), Screw pine (*Pandanus candelabrum*), shrubs and floating aquatic macrophyte, predominantly water hyacinth (*Eicchornia crassipess*).

Sampling Stations

Station I was located at the oil-impacted Ekehuan River, that receives accidental discharge of locally refined diesel in the process of moving the products in drums onshore, from where they are transported in trucks to their eventual buyers. The diesel is refined deep inside the forest, while the final products are transported in large wooden boats through the Ekehuan River to land.

Station II was located at about 100metres from Gelegele jetty along a stretch of Ovia River at Gelelgele community at 06^0 09.331’ N, 05^0 20.646’ E. Dubril Oil Company installations—notably their barge and tugboat—are just by this station. The station is also very close to the gas flare point located within Gelegele community. Minimal human activities such as fishing, bathing and washing take place in this station. Traders and passengers board commercial boats in this station to different villages along the stretch of the River.

Station III was located in the same stretch of Ovia River at Gelegele on latitude 06^0 08.936’ N, longitude 05^0 19.939’ E. The substratum of this station is predominantly clay. Tremendous logging activities take place close to this station; pieces of wood are left floating on the surface of the river close to this station. Fishing activities thrive in this station prior to the rainy season months, when the volume of water increases.

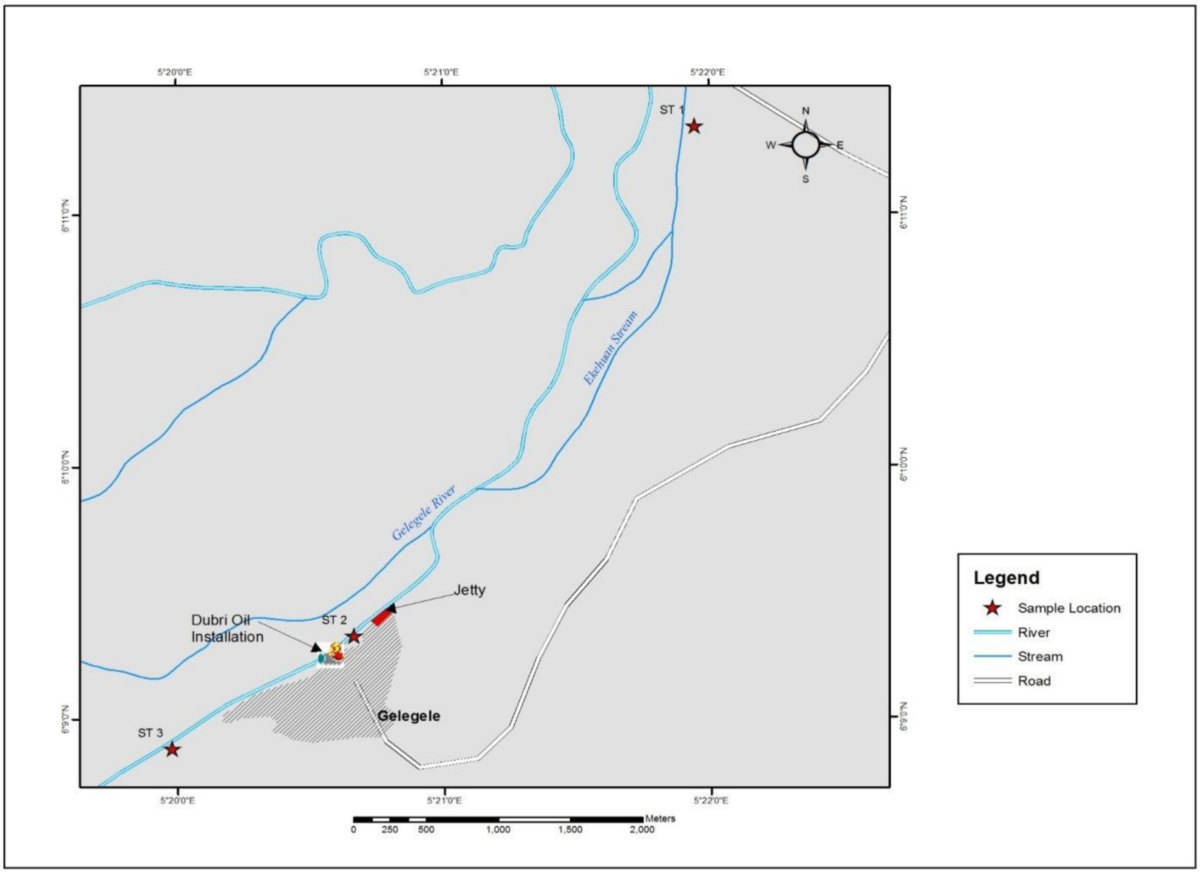


Fig. 1 Map of the study area, showing the sampling points

Collection of Water Samples

Water samples were collected monthly for ten months (April, 2013 – January, 2014), between 9am and 12 noon on each sampling day. Water samples for analysis of total hydrocarbon and physico-chemical parameters were collected in 750cl glass bottles and 2L polyethylene containers respectively, pre-rinsed with distilled water. The water samples were transported to the laboratory in a cooler containing ice block. Water samples for dissolved oxygen were collected by immersing 250ml glass stopper reagent bottles into the water body and filling them to the brim. The bottles were carefully covered tightly under water to avoid the inclusion of air bubbles; 1.5ml each of Winkler's solution A and B were added to the samples after the bottles were lifted out of water and the stoppers were carefully replaced. A thick precipitate of manganese hydroxide was formed. Water and air temperature and transparency were determined *in situ* using mercury bulb thermometer and secchi disc respectively. The analysis of the chemical parameters was done in the laboratory using standard procedures described in APHA/AWWA/WEF (1998).

Data Analysis

Data from samples were analyzed using MS Excel 2013 to test for significant difference in parameters between stations using one way ANOVA. Where the difference between investigated parameters were significantly different ($P < 0.05$ or $P < 0.01$), a post hoc test (Duncan Multiple Range Test) was used to determine the cause of the difference. Correlation analysis was conducted on the data to study the relationship between parameters in the study stations.

Water Quality Index Analysis

The water quality index (WQI) is an unambiguous tool that enables the integration of water parameters, which are deemed important to the quality of the water. In this study, the WQI was calculated using the weighted arithmetic index method (Ilaboya *et al*., 2014). It is basically a mathematical means of calculating a single value from multiple test results. The WQI result represents the level of water quality. It was used to determine the effect of the rampant illegal oil refining activities on the water quality of Ekehuan River.

The WQI is given as

$$\frac{\sum W_n . q_n}{\sum W_n}$$

where:

q_n = Quality rating (sub index) of nth water quality parameter

W_n = Unit weight of nth water quality parameter

q_n, which relates the value of the parameter in polluted water to the standard permissible value is obtained as follows:

$$q_n = \frac{100(V_n - V_{io})}{(S_n - V_{io})}$$

where:

V_n = Test result for each parameter tested

S_n = Standard value of each parameter

V_{io} = Ideal value of selected parameters tested (in pure water, Vio = 0 for all parameters tested except pH and dissolved oxygen which are 7.0 and 14.6 respectively).

The unit weight (Wn), which is inversely proportional to the values of the recommended standards is obtained as

$$W_n = \frac{K}{S_n}$$

where:

W_n = Unit weight of the parameters tested

S_n = Standard values (WHO Standard)

K = Constant of proportionality

$$K = \frac{1}{\sum_{i=1}^{s} \frac{1}{S_n}}$$

The ranges of WQI and the corresponding status of water quality are summarized in Table 1.

Table 1: Water quality index classification and the status of the water

Water Quality Index Level	**Water Quality Status**
<50	Excellent water quality
50–100	Good water quality
101–200	Poor water Quality
201–300	Very poor water quality
>300	Unsuitable for drinking

(Ramakrishniah et al., 2009).

RESULTS

The summary of the results of physico-chemical analyses are presented in Table 1. The spatio-temporal variations of the parameters across the stations are also shown in Figures 2–6.

Air temperature values ranged from 20–30.5^{0}C across the stations throughout the duration of the study, while water temperature varied from 17–25.8^{0}C for the duration of the study. Both air and water temperature across the study stations were significant ($P < 0.01$), lower in station I compared to stations II and III. pH varied from 4.66–7.25 across the study stations. While stations I and II ranged from slightly acidic to slightly alkaline, station III pH range was slightly acidic. The difference in the mean pH values across stations I, II and III was not significant ($P > 0.05$).

The conductivity values recorded in the study were within 20 to 770mgL^{-1}. Spike in conductivity was observed in May 2013. Generally, highest and lowest conductivity mean values were in stations II and 1 respectively, however, the difference across the stations was not significant ($P > 0.05$). The TDS values of the study stations ranged from 13.5 to 180mgL^{-1} for station I, 24 to 340mgL^{-1} for station II and 10 to 390mgL^{-1} for station III. Like conductivity, spike in TDS was observed in May 2013. Statistically, the mean values did not differ significantly (P > 0.05).

The mean DO was lowest in station I and highest in station II, which was significantly higher (P < 0.05) than values recorded in stations I and III. BOD ranged from 1.62–4.1mgL^{-1}, but there was no significant difference (P > 0.05) in the mean values. The COD values ranged from 4.00–164.80mgL^{-1} in all the stations. The average COD values across the stations did not differ significantly (P > 0.05).

Sodium, calcium and potassium levels were generally low and their mean concentration did not differ significantly (P > 0.05). Chloride values varied from 1.77–177.3mgL^{-1}, but there was no significant difference (P > 0.05) in the mean values.

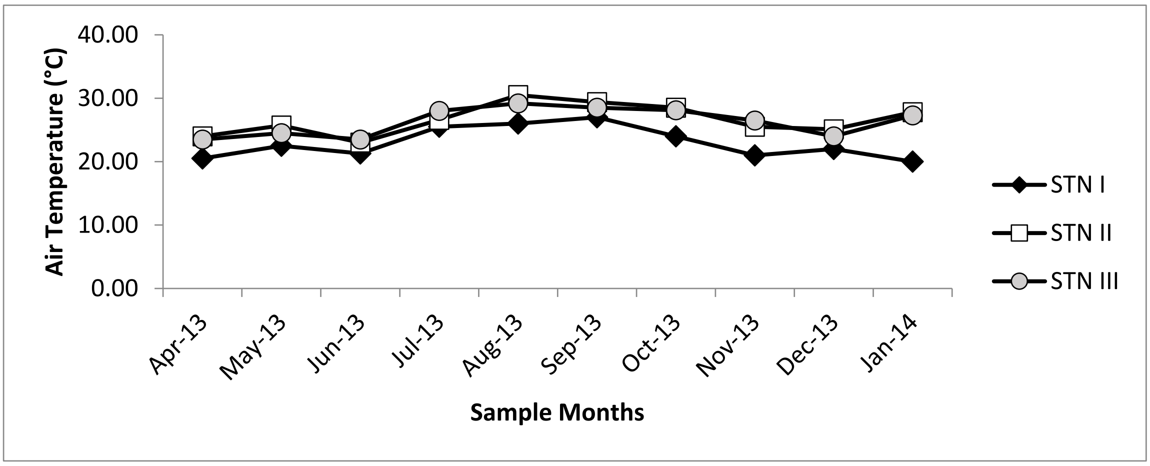
The heavy metals investigated included zinc, copper, chromium, nickel and lead. The range of their concentrations were 0.04–5.23mgL^{-1}, 0–0.89mgL^{-1}, 0–0.12mgL^{-1}, 0.02–0.48mgL^{-1} and 0–0.34mgL^{-1} respectively. There was no significant difference between their mean concentrations across the stations. The total hydrocarbon concentration (THC) ranged from 0.001–10.53mgL^{-1}. The THC concentration was highly significant (P < 0.01) across the study stations, higher in station I compared to stations II and III.

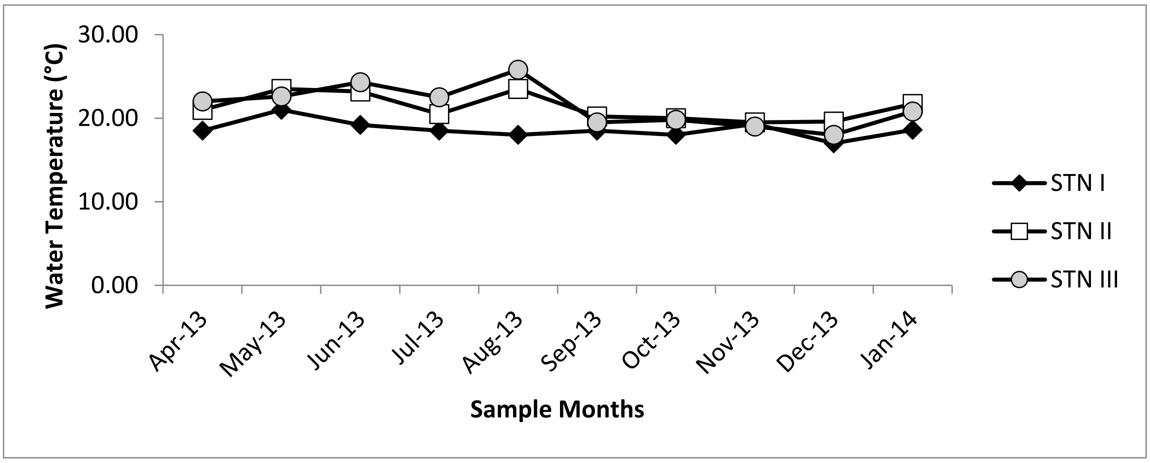
Table 2: Summary of some physico-chemical parameters

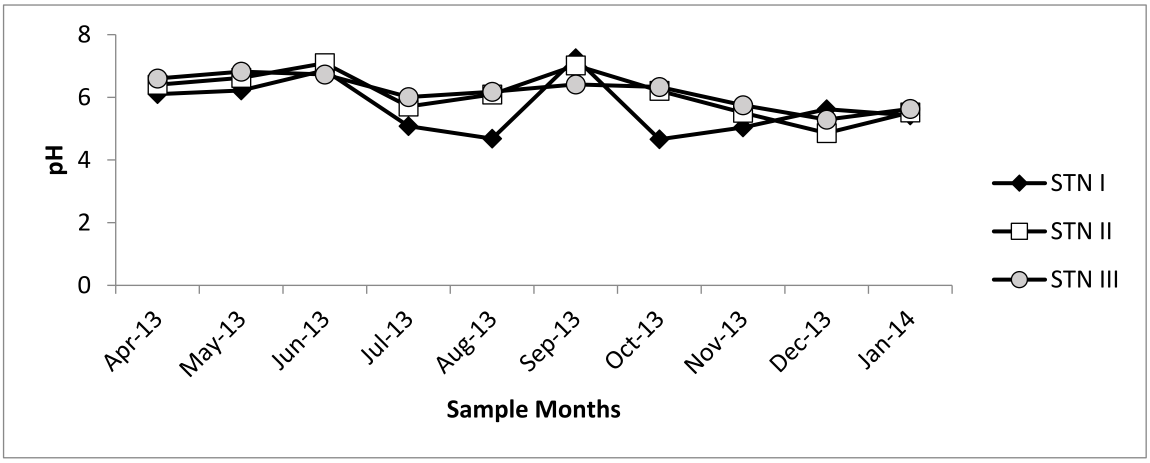
Parameters	**Station 1 Mean±SE (Min,Max)**	**Station 2 Mean±SE (Min,Max)**	**Station 3 Mean±SE (Min,Max)**	**P-Value**	**Nigerian Drinking Water Standard**	**WHO Guideline for Drinking Water Quality**
Air Temperature	22.98^{b}±0.79 (20,27)	26.61^{a}±0.76 (23,30.5)	26.31^{a}±0.7 (23.5,29.2)	****P<0.01**	-	-
Water Temperature	18.66^{b}±0.33 (17,21)	21.27^{a}±0.51 (19.5,23.5)	21.43^{a}±0.78 (18,25.8)	****P<0.01**	-	-
pH	5.69±0.28 (4.66,7.25)	6.1±0.23 (4.86,7.09)	6.18±0.16 (5.29,6.82)	P>0.05	6.5-8.5	-
Conductivity	87.75±25.21 (29,300)	134.42±59.81 (49.2,670)	126.81±72.11 (20,770)	P>0.05	-	-
TDS	46.79±15.47 (13.5,180)	67.72±30.4 (24.7,340)	64.01±36.54 (10,390)	P>0.05	500mg/l	-
DO	5.80^{b}±0.49 (3.96,8.85)	7.18^{a}±0.37 (5,9.05)	6.24^{b}±0.25 (5.1,7.36)	***P<0.05**	-	-
BOD	2.48±0.19 (1.62,3.64)	2.48±0.25 (1.68,4.1)	2.76±0.15 (1.7,3.4)	P>0.05	-	-
COD	38.98±7.6 (6.4,72.59)	31.34±8.96 (4,106.4)	29.52±15.24 (4,164.8)	P>0.05	-	-
Sodium	1.31±0.21 (0.35,2.37)	1.03±0.33 (0.41,3.9)	1.11±0.5 (0.22,5.4)	P>0.05	200mg/l	50mg/l
Calcium	3.34±0.86 (0.08,10.5)	2.54±1.57 (0.12,15.8)	2.77±1.87 (0.04,18.9)	P>0.05	-	-

Potassium	2.52±0.69 (0.11,6.22)	2.23±0.54 (0.09,4.51)	1.4±0.23 (0.1,2.42)	P>0.05	-	-
Chloride	13.36±5.56 (1.77,53.2)	34.65±7.79 (18,88.7)	45.21±18.53 (6,177.3)	P>0.05	250mg/l	-
Zinc	0.55±0.24 (0.14,2.62)	0.77±0.5 (0.15,5.23)	0.65±0.32 (0.04,3.27)	P>0.05	3mg/l	-
Cadmium	0.03±0 (0,0)	0.03±0.02 (0,0)	0.03±0.02 (0,0)	P>0.05	0.003mg/l	0.003mg/l
Nickel	0.24±0.05 (0.021,0.48)	0.23±0.05 (0.024,0.46)	0.14±0.03 (0.03,0.38)	P>0.05	0.02mg/l	0.07mg/l
Copper	0.1±0.02 (0.04,0.25)	0.13±0.03 (0.06,0.36)	0.16±0.09 (0,0.89)	P>0.05	1mg/l	2mg/l
Chromium	0.05±0.01 (0,0.12)	0.04±0.01 (0,0.08)	0.03±0.01 (0,0.06)	P>0.05	0.05mg/l	0.05mg/l
Lead	0.06±0.01 (0,0.1)	0.06±0.03 (0.01,0.34)	0.02±0.01 (0,0.09)	P>0.05	0.01mg/l	0.01mg/l
THC	3.34^{a}±1.08 (0.02,10.53)	0.02^{b}±0.01 (0.001,0.12)	0.03^{b}±0.01 (0.001,0.11)	****P<0.01**	-	-

*Key **P<0.01—Highly Significant, *P<0.05—Significant, P>0.05—Not Significant*


Air Temperature (°C)
40.00
30.00
20.00
10.00
0.00
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Sample Months
STN I
STN II
STN III


Water Temperature (°C)
30.00
20.00
10.00
0.00
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Sample Months
STN I
STN II
STN III


pH
8
6
4
2
0
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Sample Months
STN I
STN II
STN III

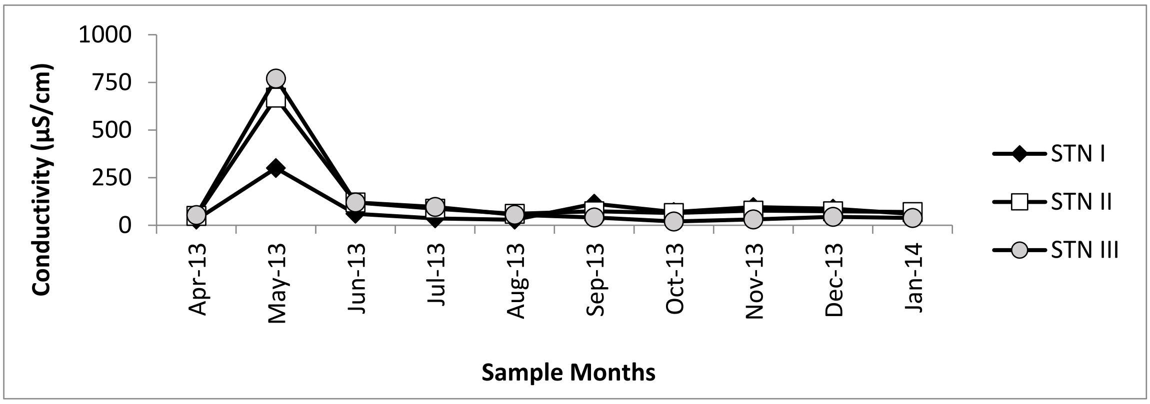
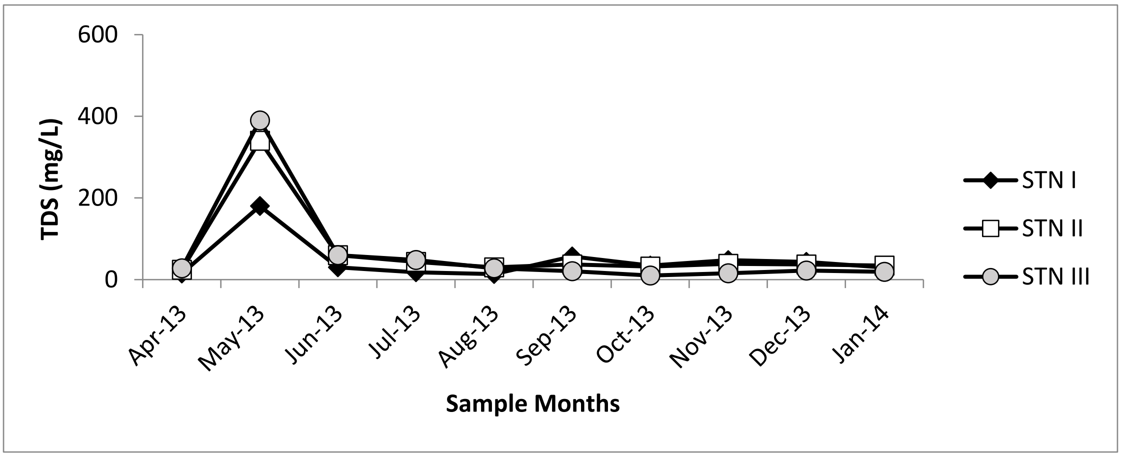
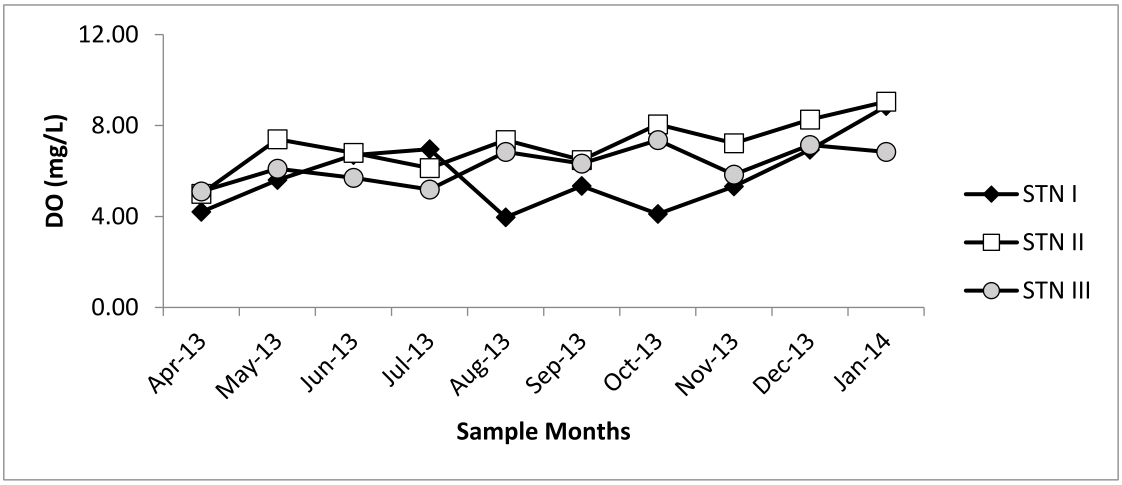
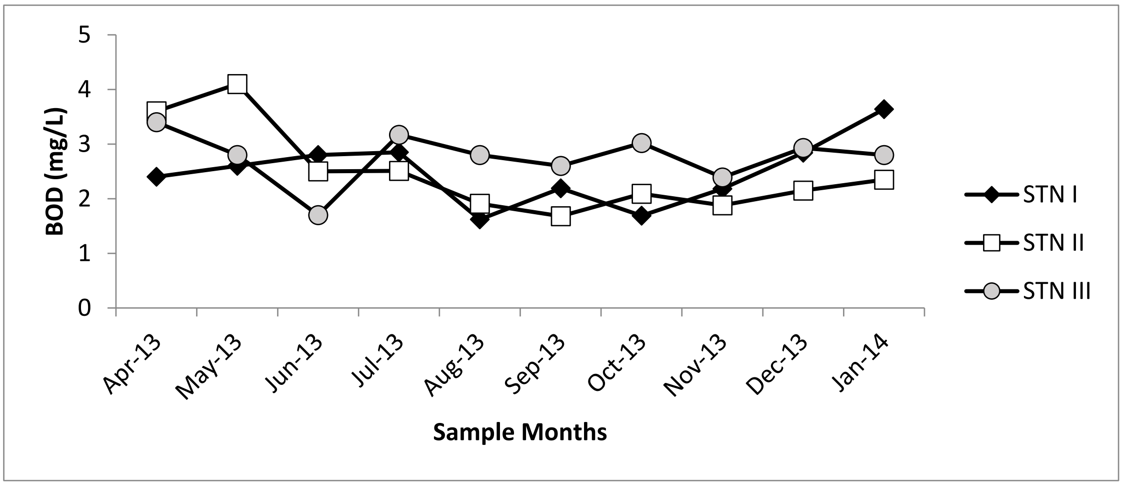


Fig 2: Spatial and temporal variation in Water temperature, Air temperature, pH and Conductivity at Ekehuan and Ovia Rivers (April, 2013 to January, 2014).







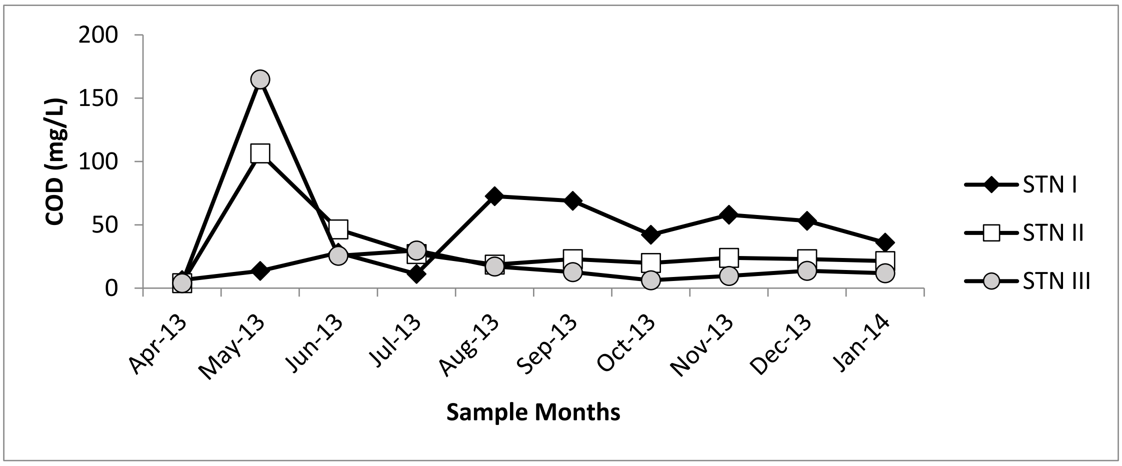
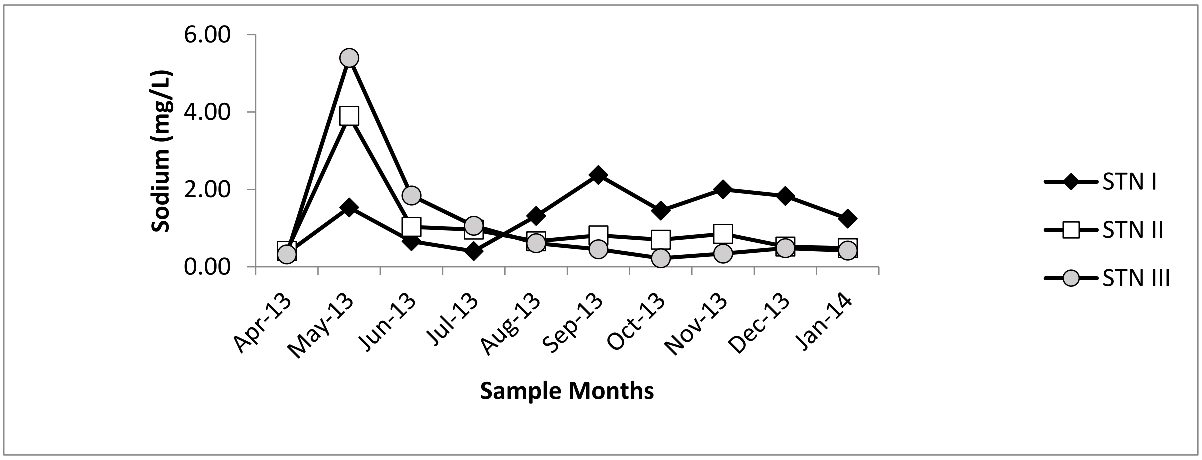
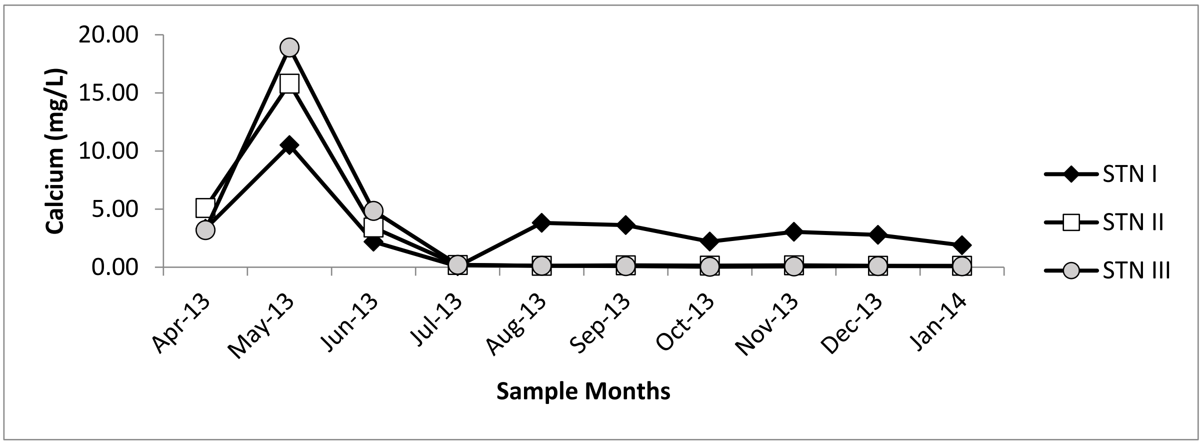
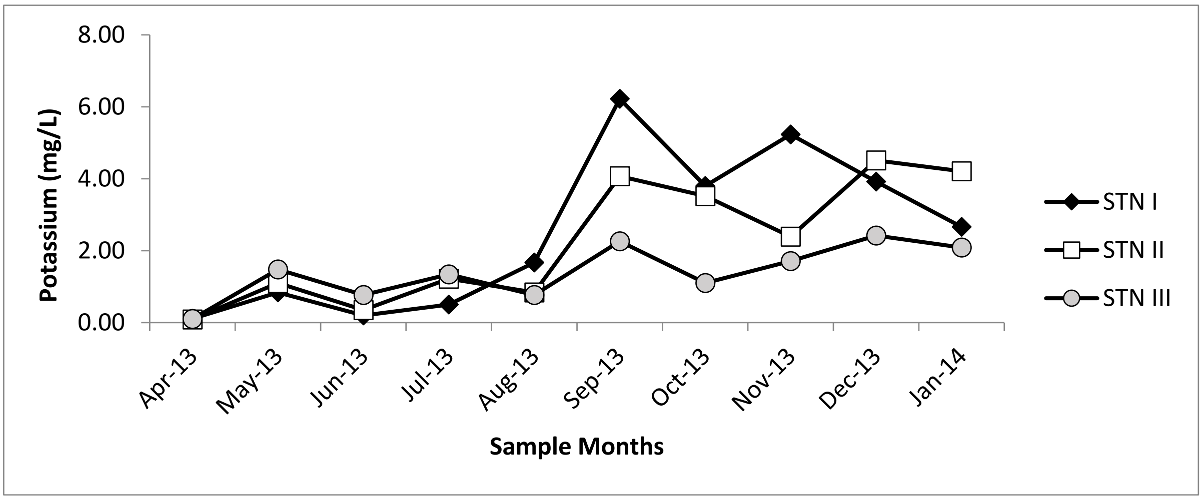


Fig 3: Spatial and temporal variation in Total Dissolved Solids, DO, BOD and COD at Ekehuan and Ovia Rivers (April 2013 to January 2014).







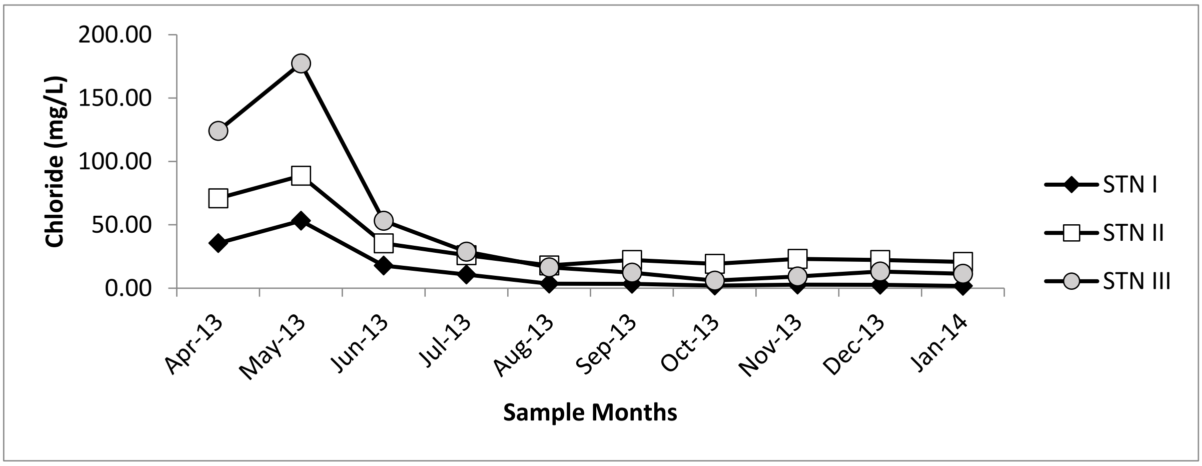
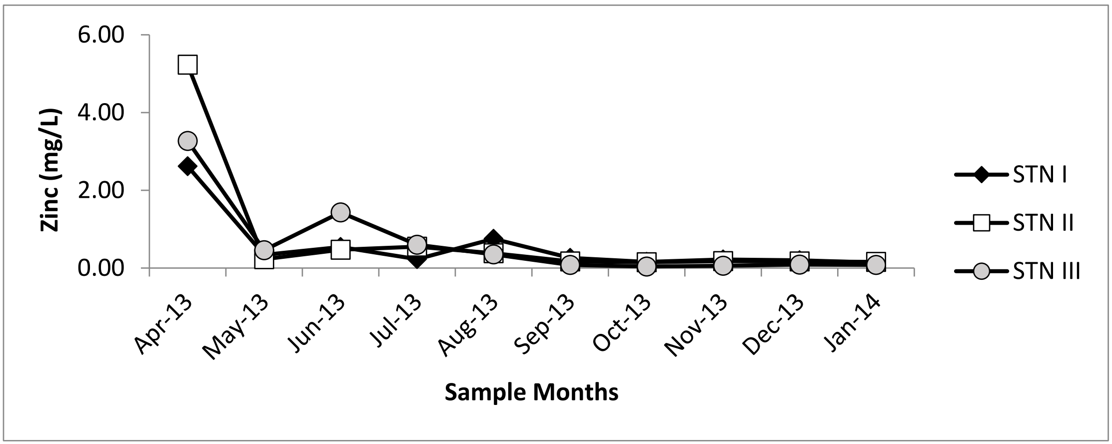
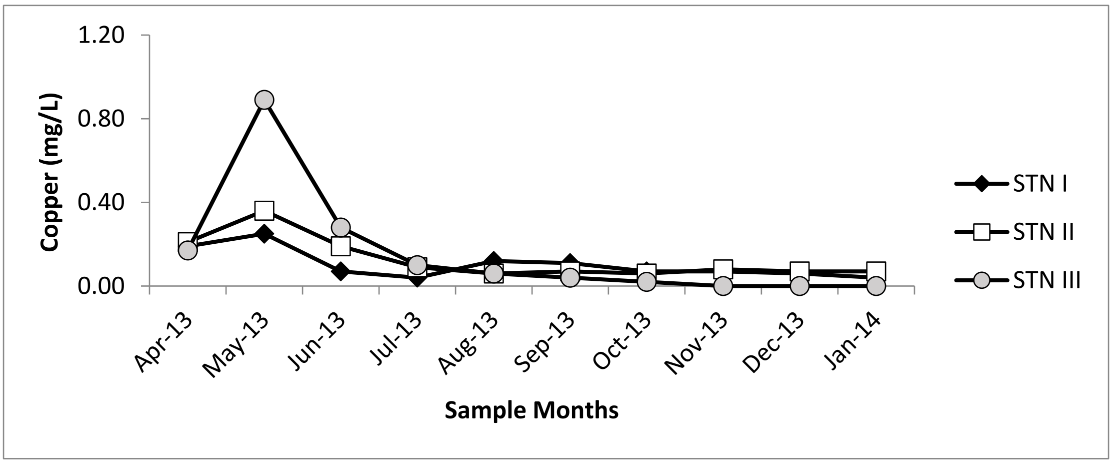
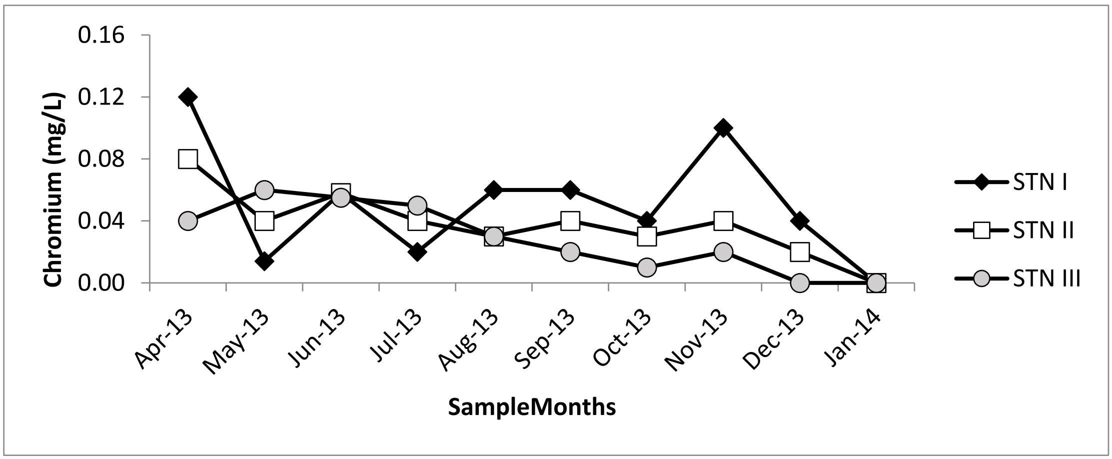


Fig 4: Spatial and temporal variation in Sodium, Calcium, Potassium and Chloride at Ekehuan and Ovia Rivers (April 2013 to January 2014).


6.00
4.00
2.00
0.00
Zinc (mg/L)
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Sample Months
STN I
STN II
STN III


1.20
0.80
0.40
0.00
Copper (mg/L)
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
Sample Months
STN I
STN II
STN III


0.16
0.12
0.08
0.04
0.00
Chromium (mg/L)
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13
Oct-13
Nov-13
Dec-13
Jan-14
SampleMonths
STN I
STN II
STN III

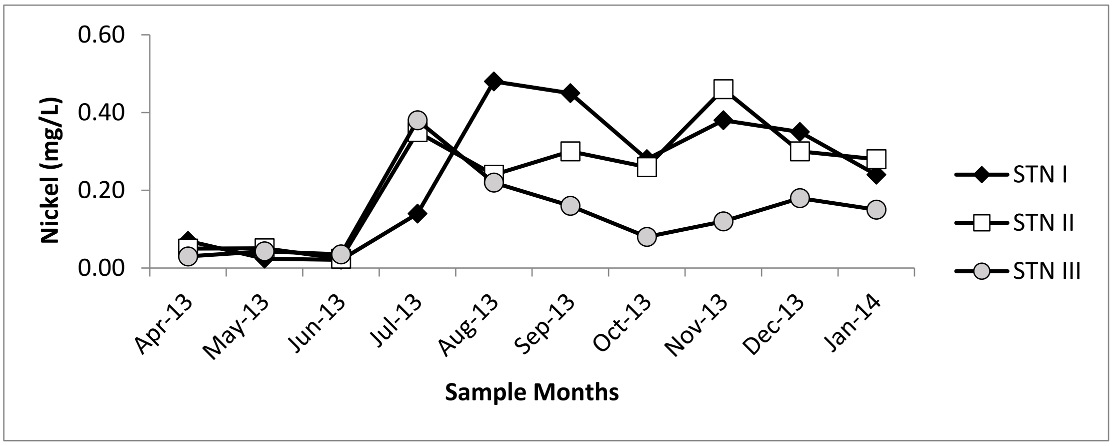
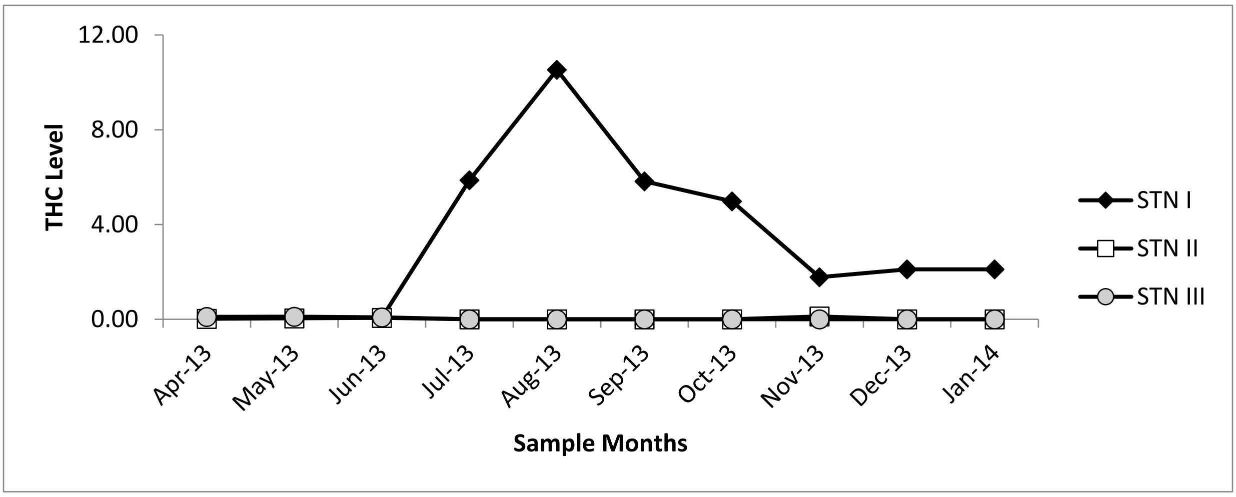


Fig 5: Spatial and temporal variation in zinc, copper, chromium and nickel at Ekehuan and Ovia Rivers (April 2013 to January 2014).



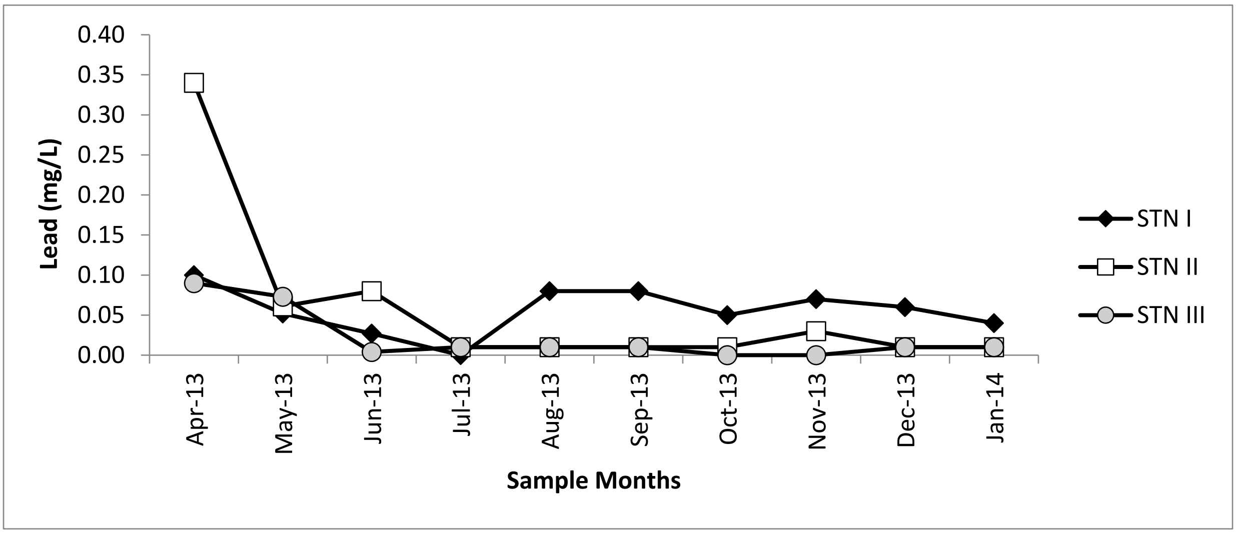


Fig 6: Spatial and temporal variation in Lead and Total Hydrocarbon at Ekehuan and Ovia Rivers (April 2013 to January 2014).

Water Quality Index

The summary of the water quality index for the individual stations in the study area is presented in table 3. The water quality status in station I indicates that the water is unfit for drinking, while the status of stations II and III are very poor water quality.

Table 3: Summary of WQI in the study area

Stations	**Station I**	**Station II**	**Station III**
WQI	692.82	98.71	99.42

DISCUSSION

The water quality parameters investigated in this study have shown significant spatial variation due to the presence of a high level of THC in the water. The Total Hydrocarbon content was highest at the Ekehuan River sampling point (Station I) because of the constant spill of diesel as a result of the mode of transportation of the locally refined product, from the point they were refined to the river bank.

The prevalent air and water temperature of the study area did not vary widely across the three Sampling stations. The values were however slightly higher in station II, due to nearness to the gas flaring site. The reported pH of the study stations were below the maximum permitted levels prescribed in the Nigerian drinking water standards (SON, 2007). However, the pH values reported in this study are consistent with values recorded in the study by Olajide *et al.*, (2009) that assessed the physico-chemical qualities of crude oil polluted rivers in the Niger Delta region of Nigeria.

Although the TDS values recorded in this study were within Nigerian drinking water standard, they suggest that the water quality is gradually deteriorating, owing to the high concentration of dissolved ions. This is supported by the high conductivity values that are indicative of the presence of ions within the water, usually due to saline water and leaching. It can also indicate direct discharge of pollutants into the water or other sources of pollution. The high concentration of dissolved solids and high conductivity values negatively impact water quality, thereby causing harm to aquatic fauna and flora as well as making the water unfit for some uses s.uch as drinking (Adefemi *et al.,* 2007).

The DO levels recorded in this study ranged from 3.96–9.05mgL^{-1}. The least DO level was recorded in Station I most likely as a result of the diesel spills that could inhibit oxygen penetration. This is in agreement with the works of Olajide *et al.*, (2009) and Uzoekwe and Achudume, (2011). Dissolved oxygen is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. A dissolved oxygen level that is too low can harm aquatic life and affect water quality. In the tropics, the dissolved oxygen concentration of aquatic ecosystems should be at least 5 mg/l in order to support diversified biota, including fish (Jha *et al.,* 2008). The BOD values of station I was significantly higher in the dry season due to the oxygen tension created by the diesel spills in the area, following the biodegradation of the pollutant. However, the reported BOD in the study was generally low, which corroborated the high DO. Biochemical oxygen demand measures the amount of oxygen consumed by microorganisms in decomposing organic matter in stream water. It is widely used to determine the pollution—due to input of organic materials into surface water—and the quality of the water.

Sodium, calcium, potassium and chloride concentrations in the water body were mostly low in the water body and below the Nigerian drinking water standard (SON, 2007). In addition, the concentrations of zinc, copper and chromium were also within the acceptable limit by the Nigerian drinking water standard (SON, 2007), while Nickel and Lead had concentrations higher than the drinking water standards. Although the mean concentrations of sodium, calcium, chromium and lead did not vary significantly, their concentrations were highest in station I. This was attributed to the pollution caused by the spill of the locally refined diesel.

The WQI for all stations where high, indicating that the water quality status was very poor in stations II and III, while station I was clearly unfit for drinking. The high value of WQI at these stations were due to the high concentration of some heavy metals in the water, namely lead, nickel and chromium. The concentration of these heavy metals were particularly high in station I, where the illegal oil refining activities took place, which resulted in the constant spill of locally refined diesel in that section of the river.

CONCLUSION AND RECOMMENDATION

This study has revealed the impact oil leaks have on the water quality of Ekehuan River. Although the concentrations of most of the chemical parameters and heavy metals were within safe limits permitted for drinking water by the Nigerian standards, the indiscriminate contamination of the river as a result of the illegal refineries is evident and should be contained. Government and all stakeholders should ensure that the process of refining and distribution of petroleum products is made more efficient. In doing this, standards should be maintained while all relevant agencies of government such as NESREA and/or DPR should be up and doing. This will guarantee minimal destruction to the environment and eliminate the economic loss that was hitherto occasioned by the theft of crude oil.

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