IMPACT OF HUMAN ACTIVITIES ON HEAVY METALS AND PHYSICOCHEMISTRY OF SURFACE AND GROUNDWATER QUALITY IN ILAJE COMMUNITY OF ONDO STATE, NIGERIA.

Nubi, O.A.*, Oyatola, O.O., Adeleke, K.G., Adekunbi, F.O.

1Department of Physical and chemical oceanography, Nigerian Institute for Oceanography and Marine Research, Lagos, Nigeria
2Department of Marine Science and Technology, Federal university of Technology Akure, Nigeria

ABSTRACT

Trace metal contamination through industrial wastes generation, geochemical structure, agricultural and mining activities is one of the most serious problems in the aquatic environments. In an attempt to know the impact of human activities on marine ecosystem and groundwater in Ilaje community, this study was carried out to reveal the levels of heavy metals in surface water and groundwater in this community. Physicochemical parameters were determined in-situ by Hanna HI 9828. Water samples were digested with aqua regia using standard digestion procedure (APHA, 1998) for heavy metals and analyzed with flame Atomic Absorption Spectrophotometer (AA320N). Temperature and pH of the study area were in compliance with National Environmental Standard and Regulations Enforcement Agency (NESREA) limit of < 40°C and 6-9 and World Health Organization (WHO) limit of 20 –32°C and 6.5-8.5. Zn and Cu values fall within the permissible limits of World Health Organization (WHO) which is 15mg/l and 1.5mg/l respectively for surface. For groundwater, Zn and Cu values were below 3 mg/l and 1mg/l Nigerian Standard for Drinking Water Quality (NSDWQ) limit and 3 mg/l and 2 mg/l WHO limit. Fe was higher than WHO (0.1 mg/l) and NSDWQ (0.3 mg/l) limits for both surface and groundwater in all the sample stations. HPI value for groundwater ranges from 17.204 to 68.243 which are below the permissible index value (100). The trace metals contamination in the surface water was also evaluated by estimating contamination factor (CF) and pollution load index (PLI). Contamination factors for Pb, Zn, Cu and Fe at all the sample stations fell within low contamination to moderate contamination. Pollution load index (PLI) ranges from 0.088 to 0.434 which showed that the surface water was not polluted.

Keywords: Trace metal, WHO, NESREA, NSDWQ, contamination factor, Heavy metal pollution index, Pollution load index, Ilaje

Introduction

Approximately one third of the world's drinking water requirements come from surface sources such as dams, rivers, canals and lakes (Jonnalagada and Mhere, 2001). However, discharges from agricultural, industrial and domestic wastes find their way to these water bodies (Das and Achary, 2003; Tukura et al., 2009). Good water quality resources depend on the physical, chemical and
biological parameters of the water (Lawson 2011: Rahillah et al., 2012) and source of any pollution load; and to assess that, monitoring of these parameters is essential (Reddi et al., 1993). The physical, chemical and biological characteristics of water may be affected by trace heavy metal pollution. Physicochemical analysis of the water is therefore useful in determining the quality and nature of water (Mohamed, 2005). Natural groundwater is generally safe from contamination compared to surface water, which is most likely to be contaminated owing to anthropogenic activities. Contempt to this advantage, groundwater quality is devolving worldwide due several factors (anthropogenic activities and continuous demand of groundwater) influencing groundwater hydrochemistry and moreover, its suitability for various usages (Akoteyon, 2013). The biological and chemical interactions between geological materials and groundwater through which water flows obtain a broad range of dissolved inorganic chemical constituents at different levels. (Todd and Mays, 2005). Mineral weathering processes contribute immensely to the hydrochemistry of groundwater and surface resources worldwide (Yidana et al., 2012). Heavy metals have been discovered to be extremely toxic, particularly when their natural levels are exceeded. At normal concentration, they promote the functions of the enzymes but could lead to a lot of adverse metabolic reaction when their concentrations exceed the maximum contaminant levels. Such heavy metals as Hg, Cd, Pb and Cu are very harmful to the body; they form complexes with metabolic enzymes.

Ilaje is one of the coastal communities in Ondo state, Nigeria which empties into the Atlantic Ocean and due to domestic wastes, industrialization, urbanization, agricultural growth and oil exploration in this area both the surface water and groundwater have been affected by a number of organic and inorganic pollutants. This study was aimed at knowing the impact of human activities on heavy metals and physicochemistry of surface and groundwater quality in Ilaje community of Ondo state, Nigeria and the factors responsible for this quality.

Materials and Methods

Study Area

The coastal area of Ondo State lies on Latitude 5°50’N – 6°09’N and Longitude 4°45’E – 5°05’E (Figure 1). The study area is located along the coastal communities of Ilaje, It has an area of 1318km² and It is bounded in the West by Ogun State, in the East by Irele Local Government Area and Edo State, in the North by Okitipupa Local Government Area and in the South by Bight of Benin and Atlantic Ocean (Olasola and Festus, 2015), which means that its pollution may have national and global health and ecological effects.

Figure 1: Map of Ondo state showing the study area

Sample Collection

Ten water samples each were collected from surface water and underground water from Ilaje local government area (Fig.1). Water samples were collected in plastic water sampler. Sample bottles were rinsed with the sample water before
taking the samples. The samples were then acidified with 2ml of nitric acid (HNO₃) in pre-cleaned 1 litre plastic containers at the sampling point so as to ensure that the respective ions remain in solution pending analysis. The physicochemical parameters (total dissolved solids, dissolved oxygen, salinity, conductivity, temperature and pH) of the surface water samples were determined in situ by a multiparameter water quality meter (Hanna HI 9828). The samples were then digested with Nitric/Hydrochloric acid (1:3), aqua regia using standard digestion procedure (APHA, 1998). All Chemicals used were analytical grade reagents. Instrumental method was adopted using flame Atomic Absorption Spectrophotometer (AA320N) with air/acetylene flame. Standard solutions of the studied metals were prepared from their salts and used for calibration curve for Pb, Zn, Cu and Fe. The determinations were carried out according to the standard methods for water quality (APHA, 1998).

**Heavy metal pollution index (HPI) for groundwater**

The HPI, represent the total quality of groundwater with respect to heavy metals. The proposed HPI was developed by assigning a rating or weightage (Wi) for each selected parameter. The ranking is between zero and one, demonstrating the comparative significance of individual quality factors and is inversely proportional to the recommended standard (Si) for each parameter (Prasad and Mondal, 2008; Mohammed and Ibrahim, 2014). For this study, the concentration limits [i.e. highest permissive value for drinking water (Si) and maximum desirable value (Ii) for each parameter] were taken from the Indian drinking water specifications (Indian Standard, 1991, 10500). The highest permissive value for drinking water (Si) relates to the maximum permissible limit in drinking water in the lack of any alternative source of water. The desirable maximum value (Ii) set the normal boundaries for the same parameters in drinking water. The HPI is calculated with the following equation,

\[
\text{HPI} = \frac{\sum_{i=1}^{n} (Q_i \times W_i)}{\sum_{i=1}^{n} W_i}
\]

Where Qᵢ is the sub-index of the ith parameter, Wᵢ is the unit weightage of ith parameter, where Mᵢ is the monitored value of heavy metal of ith parameter, Iᵢ is the ideal value of ith parameter, and Sᵢ is the standard value of the ith parameter.

**Correlation Matrix for surface water**

Correlation Matrix was employed for the data set to discover similarities in geochemical source and basic relationship among the trace metals (Davis, 1986). Correlation of different elements in the surface water samples were calculated by the non-parametric Pearson rank method. Correlation coefficient measures the strength of a linear relationship between two variables on a scale of -1 (perfect inverse relationship) through 0 (no relation) to +1 (perfect sympathetic relation). The correlation coefficients developed for heavy metals in the study area was based on 10 samples.

**Contamination Ratios for surface water**

Contamination factor and pollution load index were estimated and used to assess the contamination status of the Ilaje community surface water (Figure 3 & 4). According to Nishida et al (1982) and Hakanson, (1980), the contamination factor was used in this research to assess the degree of heavy metal contamination in surface water samples. The permissible levels of the element concentration in the surface water considered safe for marine organisms (Lee et al., 1998; WHO, 1993) were used as background...
level for the contamination factor and the pollution index ratio.

**Contamination factor**

\[ \text{Cf} = \frac{C}{C_n} \]  

where, \( \text{Cf} \) = contamination factor; \( C \) = mean concentration of each metal in water sample. \( C_n \) = background value of metal in water.

**The Pollution load index (PLI)**

It is an outcome of the impact of many heavy metals and it is defined as the root of the ratio of contamination factor to the number of heavy metal.

\[ \text{PLI} = \sqrt[n]{\text{Cf}_1 \times \text{Cf}_2 \times \text{Cf}_3 \times \text{Cf}_4 \times \ldots \text{Cf}_n} \]  

Values of \( \text{PLI} = 1 \) indicate heavy metal loads close to background, and values above 1 indicate progressive pollution (Tomlinson *et al.*, 1980 and Wilson, 1980).

**Results**

The spatial variation of physicochemical parameters of Ilaje surface water is shown in figure 2. Water temperature ranged from 28.51°C to 29.67°C during the research period with an average temperature of 29.07°C. The lowest and highest water temperature observed was the sites 28.51°C (SW4) and 29.67°C (SW1) respectively (fig. 2). Water temperature did not exhibit significant difference (\( P > 0.05 \)) between the sample stations. The values for pH throughout the sample stations showed the stations were near-neutral. Figure 2(b) Show that pH values of the water samples varied from 6.90 to 7.64 with a mean of 7.25. The maximum pH value (7.64) was recorded at sample station 5 and sample station 8 has the minimum pH value (6.90). pH did not show significant difference (\( P > 0.05 \)) between the sample stations. Electrical conductivity (EC) of the study area varied from 599 to 13010 µS/cm with a mean value of 6272.8 µS/cm. The highest (13010 µS/cm) and lowest values (599 µS/cm) were observed at sample station 1 and 8 respectively. EC recorded significant difference (\( P < 0.05 \)) between the sample stations. The measured TDS showed a wide variation between 299 and 6497mg/l with a mean of 3145.38 mg/L. TDS recorded significant difference (\( P < 0.05 \)) between the sample stations. Dissolve oxygen value in the present study ranged from 2.86 – 4.14 mg/L with an average of 3.52 mg/L. Dissolve oxygen did not record significant difference (\( P > 0.05 \)) between the sample stations. Sample station SW1 and SW8 has the highest and lowest value of salinity of 7.41 and 0.29 ppt respectively. Salinity did not record significant difference (\( P > 0.05 \)) between the sample stations.

The results obtained for the concentrations of metals ions (Pb, Zn, Cu, Fe) in the water samples collected from different groundwater and surface water sample stations are shown in figure 3 and 4 respectively. Lead concentration in the surface water and groundwater varied between 0.0116 to 0.2709 mg/L and between 0.0173 to 1.0141 mg/L with an average concentration of 0.08978 mg/L and 0.2896 mg/L respectively. For groundwater, sample station GW1 has the highest value (1.0141 mg/L) of lead and the lowest value (0.0173 mg/L) at sample station GW5 while for surface water, sample station SR10 has the highest concentration (0.2709mg/L) of Pb and lowest concentration at sample station GW1 and GW5 while for surface water, sample station GW10 has the highest concentration (0.2709mg/L) of Pb and lowest concentration at sample station GW5. The concentration of Zn in the surface water ranged from 0.0804 to 0.2486 mg/L and between 0.0594 to 0.3507 mg/L in groundwater with concentration mean of 0.1656 mg/L and 0.1346 mg/L respectively. For groundwater, station GW8 has the highest value of concentration (0.3507mg/L) of Zn and the lowest concentration (0.0116mg/L) at station GW7 for groundwater. The concentration of Cu in the study area for...
groundwater varied between 0.0132 and 0.096 mg/L with average concentration of 0.0559 mg/L and between 0.0128 and 0.1963 mg/L in surface water with average concentration of 0.0791 mg/L. Location GW3 and SR10 has the highest value of concentration, 0.096 mg/L and 0.1963 mg/L for groundwater and surface water respectively. The minimum and maximum concentrations of iron obtained from the groundwater at the sample stations in Ilaje community ranged from 0.5866 to 1.9525 mg/L and from 0.5481 to 2.7533 mg/L for the surface water. Stations SR10 and SR7 have the highest and the lowest concentration respectively.

Heavy metal Pollution Index (HPI) for groundwater

Table 2 shows the heavy metal pollution index for each groundwater station. HPI value varied from 17.204 to 68.243 with a mean value 61.1595. Sample station GW1 having the maximum value (68.243) and sample station GW3 having the least value (17.204).

Contamination Factor (CF) and Pollution Load Index (PLI)

The CF for Pb in the study area varied from 0.116 to 2.709 with average value 0.8978. Sample station 6 and 8 has the least CF value while sample station 10 has the highest value. For Zinc the value varied from 0.016 to 0.047 with an average value 0.0333. Sample station 9 has the least value (0.016) and sample station has the maximum value (0.047). CF value for Cu varied from 0.006 to 0.098 with an average value 0.0395. Sample station 2 and 10 has the minimum and maximum CF value. Pb contamination factor has the highest value (4.589) and the least value (0.914) at sample station 10 and 7 respectively. PLI of the trace metals varied from 0.088 to 0.434 (fig. 5) with mean value 0.186. Sample station 7 has the minimum value (0.008) and sample station 10 has the maximum value (0.0434).

Figure 2: Physicochemical parameters of surface water
Figure 2: Concentration of heavy metals in groundwater

Figure 3: Concentration of heavy metals in the surface water
Table 1: Heavy metal pollution index for groundwater.

<table>
<thead>
<tr>
<th>STATIONS</th>
<th>GW 1</th>
<th>GW 2</th>
<th>GW 3</th>
<th>GW 4</th>
<th>GW 5</th>
<th>GW 6</th>
<th>GW 7</th>
<th>GW 8</th>
<th>GW 9</th>
<th>GW 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPI</td>
<td>68.243</td>
<td>67.243</td>
<td>17.204</td>
<td>66.290</td>
<td>60.982</td>
<td>66.146</td>
<td>66.188</td>
<td>66.316</td>
<td>66.509</td>
<td>66.474</td>
</tr>
</tbody>
</table>

GW- Sample stations  
HPI- Heavy metal pollution index

Table 2: HPI calculations for ground water based on Indian drinking water standards (Indian Standard 1991, 10500)

<table>
<thead>
<tr>
<th>Metal</th>
<th>Highest permitted value for drinking water (Si)</th>
<th>Desirable maximum value (I.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>Cu</td>
<td>1000</td>
<td>50</td>
</tr>
<tr>
<td>Zn</td>
<td>15000</td>
<td>5000</td>
</tr>
<tr>
<td>Fe</td>
<td>1000</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 3: Correlation coefficient matrix of analyze d heavy metals.

<table>
<thead>
<tr>
<th></th>
<th>Temp</th>
<th>EC</th>
<th>pH</th>
<th>Salinity</th>
<th>DO</th>
<th>TDS</th>
<th>Pb</th>
<th>Zn</th>
<th>Cu</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC</td>
<td>0.744*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>-0.121</td>
<td>0.241</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salinity</td>
<td>0.755*</td>
<td>1.000**</td>
<td>0.225</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td>-0.733*</td>
<td>-0.794*</td>
<td>0.166</td>
<td>-0.800*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDS</td>
<td>0.746*</td>
<td>1.000**</td>
<td>0.241</td>
<td>1.000**</td>
<td>-0.793*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>0.237</td>
<td>0.163</td>
<td>-0.263</td>
<td>0.163</td>
<td>0.039</td>
<td>0.159</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td>0.325</td>
<td>0.357</td>
<td>0.07</td>
<td>0.362</td>
<td>-0.216</td>
<td>0.361</td>
<td>-0.277</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>-0.085</td>
<td>0.067</td>
<td>0.201</td>
<td>0.056</td>
<td>0.228</td>
<td>0.061</td>
<td>0.645*</td>
<td>-0.006</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Fe</td>
<td>0.164</td>
<td>-0.006</td>
<td>-0.076</td>
<td>0.002</td>
<td>-0.153</td>
<td>-0.001</td>
<td>0.439</td>
<td>-0.273</td>
<td>0.451</td>
<td>1</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).
Figure 4: The contamination factor of heavy metals in the surface water

Figure 5: Pollution load index of heavy metals in the surface water

Table 6: Standard ratio of contamination factor, Hakanson (1980)

<table>
<thead>
<tr>
<th>Contamination Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
</tr>
<tr>
<td>Indication</td>
</tr>
<tr>
<td>Cf&lt;1</td>
</tr>
<tr>
<td>Low contamination</td>
</tr>
<tr>
<td>1&lt;Cf&lt;3</td>
</tr>
<tr>
<td>Moderate contamination</td>
</tr>
<tr>
<td>3&lt;Cf&lt;6</td>
</tr>
<tr>
<td>Considerable contamination</td>
</tr>
<tr>
<td>6&lt;Cf</td>
</tr>
<tr>
<td>Very high contamination</td>
</tr>
</tbody>
</table>

Cf-contamination factor
Discussion

Temperature is an important biologically significant factor, which plays an important role in the metabolic activities of the organism. It controls the solubility of gases in water, affects the rate of chemical reactions, the metabolic rates of organisms, as well as the distribution of aquatic organisms throughout aquatic system. The temperature also determines the solubility of dissolved oxygen (DO) in water (Hasan et al., 2016). The temperature values from all the sampling stations are within the WHO which is within 20 – 32°C and Nigerian Environmental Standards and Regulations Enforcement Agency (NESREA) limit which is < 40°C. pH is a term used universally to express the intensity of the acid or alkaline condition of a solution which ranges from 0 – 14 (Ramalingam et al., 2011). According to WHO and NESREA standards pH of drinkable water ranges from 6.5 to 8.5 and 6 to 9 respectively. Waters with pH values of 6.5 to 9.0 are considered best for fish production, while the acid and alkaline death points are 4.0 and 11 respectively (Arazu et al., 2015, Muhammad et al., 2015). Most of the water samples were slightly alkaline due to presence of carbonates and bicarbonates and were found within the limit prescribed by WHO and NESREA. The least value of pH at sample station 8 could be to the increase in the rate of organic matter decomposition by the microbial respiration, which may be increase CO₂ level leading to lowering the pH values (Ahmed and Khalid, 2015). The alkalinity of pH during the study period may be due to the influx and decay of debris in the area as well as imbalance level of hydrogen ions input from surface run-offs during the rains.

(EC) is a measure of water capacity to convey electric current. It signifies the amount of total dissolved salts. Though it does not provide detailed information about the ionic composition in water, this can be used to determine the suitability of water for drinking and irrigation use. EC has a strong positive correlation with temperature (r = 0.744 at P < 0.05), salinity (r = 1.000 at P < 0.01), TDS (r = 1.000 at P < 0.01). Low level of conductivity recorded at some of these sample stations could be attributed to the low levels of conducting chemical particles such as chloride, phosphate and some heavy metals present in the stations.

Total dissolved solids (TDS) indicate the salinity behavior of marine ecosystem. The degree of TDS can be classified as fresh, if it is less than 1,000 mg/l; brackish, (1,000 to 10,000 mg/l); saline (10,000 to 1,000,000 mg/l); and brine more than 1,000,000 mg/l (Muhyminul Islam et al., 2016). Based on this classification, location SW6, SW7 and SW8 are fresh water. Sample station SW1, SW2, SW3, SW4 and SW5 are brackish water. This could be as a result of these sample stations closeness to the sea. Dissolved oxygen shows the physical, biological and metabolic balance process in the water body. DO values act as a pollution indicator of water body. The amount of waste (High organic content from human faeces and decayed plant materials), turbulence of the stream and the temperature of the water may be responsible for low dissolved oxygen in the study locations (table 3). The observed DO values obtained in this study were in agreement with Emmanuel and Onyema (2007) whose research work was on the plankton and Fishes of a tropical creek in South-Western Nigeria showed their DO values are ≤ 4mg/l across the study area. Salinity is a strong contributor to Conductivity. It is a major driving factor that affects the density and growth of aquatic organism’s population in the mangrove swamp (Powell et al., 2001; Wuenschel et al., 2001). The high salinity obtained at SW1 was due to the fact that it shares a boundary with the sea. Fresh water intrusion from the surrounding rivers could be responsible for low salinity at sample station 8. Salinity has strong positive
correlation with EC ($r = 1.000$ at $P < 0.01$), TDS ($r = 1.000$ at $P < 0.01$).

The concentration of lead in the groundwater collected from the sample stations were above the permissible limit set by WHO and NSDWQ which is 0.01 mg/L. This could be attributed to the pipe used to channel the water to the surface, household sewages, agricultural run-off containing phosphatic fertilizers, animal and human excreta (Abdul Jameel et al., 2012). The values of Pb at sample stations for surface water were found to be within the WHO standard which is 0.1 mg/L. Vehicular emission, domestic activities, the discharge of domestic waste water such as detergent and also paint from boat in the study area has less impact on the marine environment.

All the zinc values for both groundwater and surface water fall under the permissible limit of WHO/NSDWQ and WHO/USEPA respectively. This suggests that there is no intense anthropogenic influence due to industrialization and urbanization within the study area.

Copper is an essential nutrient but at elevated doses anemia, stomach and intestinal distress, liver and kidney damaged haven been reported (USEPA, 2003). Copper is one of the most common contaminants associated with urban runoff. Important anthropogenic inputs of copper in estuarine and coastal waters include sewage sludge dumpsites, municipal waste discharge, and anti-fouling paints (Kennish, 1996). Copper concentrations in the surface water were found to be lower than the WHO quoted maximum tolerance limit 1.5 mg/L. For groundwater, all concentration of copper were found to be lower than the WHO/NSDWQ quoted maximum tolerance limit 1.5/1.0 mg/L respectively for drinking water. Chronic consumption of water with iron overload results in gene mutation leading to hemochromatosis whose symptoms include fatigue, weight loss, joint pain and ultimately heart disease, liver problem and diabetes (US-CDC, 2011). Considering permissible level of WHO/NSDWQ for domestic water, the results of the analysis from Ilaje community shows that the Fe concentration for surface and groundwater of the study area is greater than the maximum tolerance limit values quoted by these international standards. Higher concentration of iron in the surface water of the study area could be attributed to the discharge of domestic waste into the water and also paint of boat could also contribute to level of iron at this station. Higher concentration of iron at SR10 could be attributed to the rust metal used for the construction of jetty. On the mean scale, the general observed trends for the metals at all sampling locations for groundwater in decreasing order, were Fe(1.3038mg/L) > Pb(0.18606mg/L) > Zn(0.1346mg/L) > Cu(0.0559mg/L) and for surface water were Fe(1.142mg/L) > Zn(0.1656mg/L) > Pb(0.0898mg/L) > Cu(0.0792mg/L).

**Heavy metal Pollution Index (HPI) for groundwater**

HPI value of groundwater at the sample stations were below the permissible index value (100). The value of the Index indicates that the water to be safe for drinking purpose and free from heavy metal pollution.

**Contamination Factor and Pollution Load Index**

The values of contamination factor for Zinc (Zn) and Copper (Cu) in all the sample stations were less than one (< 1) hence they exhibit low contamination factor (fig. 5). Lead (Pb) also was of low contamination factor in all the sample stations except for stations SR7 (1.44), SR9 (2.19) and SR10 (2.709) which were of moderate contamination. This could be characterized by discharge of domestic water waste such as detergent and also paint from boat into this area. The values of contamination factor for Iron (Fe) were within moderately contaminated in all the
sample stations except for station SR7 (0.914) that was of low contamination (figure 5 & table 6), these might be attributed to the pigments and paints, fuel from the boats and oil exploration in the environment. The metals at all the sample stations for surface water were however of low degree contamination (figure 5 & table 6). PLI of the surface water from sample locations indicated heavy metal loads close to the background level, which imply that the ecosystem may not be critically affected by anthropogenic contamination.

Conclusion

It is apparent from the outcomes acquired from HPI, CF and PLI that the concentration of heavy metals present in the sample stations as a result of impact of human activities around the study area are not in concentrations that could be dangerous to humans and marine lives. The research obviously indicated the presence of heavy metals (Pb, Zn, Cu and Fe) in the sample stations even though the results are not risky at present thus there is a need for continuous monitoring of these heavy metals. Moreover, the values of the physicochemical parameters (EC, salinity, TDS, temperature and pH) are within the permissible limit for aquatic ecosystems, however the low values of the DO can be related to anthropogenic effluents arising from human impact into the aquatic ecosystems.

Conflict of interest: Authors have declared that no conflicts of interests exist.

References


Rafiullah, M., Khan, Milind, J. and Jadhav, I. R. (2012). Physicochemical Analysis Of Triveni Lake Water Of Amravati District In (Ms) India Bioscience Discovery, 3(1): 64-66


and Forestry of South Africa, Pretoria; 185pp.


