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Sediment Geochemistry of River Okura: Implications to Weathering and Transport

Gideon Y. B* and Fatoye F. B

Abstract
Rocks, soils and bed sediments of River Okura catchment area in Anambra basin have been analysed for major oxides using minipal 4 ED version of XRF machine. A total number of five (5) rocks and twenty (20) samples of soil, river bed sediments for each were collected from the study area. These results have been used to characterize and deduce the effect of weathering and transport in the study area. Chemical composition and field studies assessment of the rock(s) in the study area indicated lithic arenite type of sandstone. Results of soils analyses shows a compositional enrichment of Fe$_2$O$_3$ (12.54%) and depletion of Al$_2$O$_3$ (13.74%) when compared to the average crustal compositions of the earth by Clarke and Washington, which have 6.70% Fe$_2$O$_3$ and 15.65% Al$_2$O$_3$. A trend of concentration of major oxides in soils in which: SiO$_2$ > Al$_2$O$_3$ > Fe$_2$O$_3$ and CaO > K$_2$O > Na$_2$O > MgO is the same in all the locations, which strongly suggest that, the soils in the study area are of the same origin and probably a weathered product of the sandstone member of the Ajali Formation derived from the immediate vicinity. Compositionally, the soils in the study area and river bed sediments of Okura River shows similar trend in concentration with the rocks (sandstone) within the catchment area except that, they are enriched in SiO$_2$ and Al$_2$O$_3$, and depleted in Fe$_2$O$_3$. These are obviously due to the complex processes of weathering, ferrugenization, transport (flow) system, purification, accumulation and dilution in the presence of precipitation within the study area.

Keywords: Bed Sediment, Okura River, Rock, Soil, Weathering and Transport.

Introduction
Sediments originate from the weathering of near the surface of exposed rocks of igneous, sedimentary and metamorphic origin as well as the decomposition of plants and animals. Wind, water and ice serves as agent of transportation of the broken-down particles to rivers, lakes and streams. Natural and environmental factors control the chemical composition of surface waters. The interaction among water bodies, soils and rocks lead to type of suspended sediments carried by the surface waters and the mineralogical as well as the geochemical properties of the bed sediment. Rainfall, surface runoff, infiltration, climate, erosion and weathering of rocks contribute to this situation (Gibbs, 1970 and Gaillardet et al., 1997). As sediments accumulate, the stratum serves as an important habitat for the benthic macro invertebrates whose metabolic activities contribute to aquatic production. Organic matter decomposition is largely carried out by bacteria in sediment (Abowei and Sikoki, 2005). The soil fraction of the sediment is composed of inherited minerals. A whole range of minerals can be found in sediments both at near the surface and at shallow depth. The heavy minerals cannot be easily transported owing to it high specific gravity and they tend to sink as the river flows. Other sources of heavy metals in rivers sediments apart from geologic weathering includes industrial processing of ore and metals, use of metal and metal compounds, leaching of metals from garbage/ solid waste dumps among others (Forster and Wittman, 1983).

Many researchers have worked on water bodies (stream, lake and river) and its bed sediments with different and diver aims. For instance, Yarun et al., (2004), studied the geochemistry of bed sediments of Yamuna River in the Himalaya and characterized its chemical weathering and
transport, and assessed relative mobility of elements during weathering Awosika et al. (1982), researched on the heavy minerals in Nigeria Rivers sediments and concluded that, the textural properties of Terrigenous sediments are almost entirely controlled by transportation and depositional environment while mineralogical composition is a function of provenance. Azubuike and Anthony (2011), assessed the trace element chemistry in stream sediments of river around the vicinity of a recently established aluminum smelting complex in Ikot Abasi, south-eastern Nigeria and reported that, the river sediments exhibits geochemical characteristics consistent with sediments from other parts of the Niger Delta. This research is to investigate the geochemistry of River Okura bed sediments as a weathered and transported product of rocks within the catchment area of Okura River.

**Location**

The study area is located between latitudes 7°21’N and 7°38’N and longitudes 7°07’E and 7°34’E. Okura River originates from Oji-Aji in Omala local government area of Kogi State. It covers part of Omala and Dekina Local Government Areas of Kogi State, Nigeria (Fig. 1). The sample locations are Oji-Aji, Igodo, Ogodu, Okura town and Ofe-jiji. All the sample locations are accessible by either foot paths or minor roads. The Ofe-Jiji and Okura Township locations are off the Anyigba – Ankpa paved road, while the locations at Ogodu, Igodo and Oji-Aji are accessible through the Anyigba–Egume –Ofogu paved road. Other villages around the study area includes: Ochaja, Elubi, Acharu and Ogbogodo. Accessibility can be described as moderate and the pattern of settlement as linear.

**Topography and Drainage**

The study area is situated on an undulating terrain. Okura River flows along gentle slopes, meandering through the valleys and lowlands of the area. The elevation above sea level of the River ranges from about 367m at its source in Oji-Aji to about 203m in Ofe-Jiji. The stretch of River Okura covered in this study is about 33.6 km. The river is perennial and parallel in pattern of flow when compared to Ofu and Imabolo rivers which are close to the study area. Okura River joined Imabolo River in Egabada (Kogi State) and further flow southwards before joining the Ofu River and the ‘three-in-one’ river empties into the famous Anambra River (Anambra State).

**Climate and Vegetation**

The study area falls within the humid tropical rain forest of Nigeria that is characterized by a mean annual rainfall over 200mm and two main seasons; the wet and the dry. The wet season usually covers from May to October and is associated with flooding, soil leaching, ground water migration and percolation. The dry period spans from November to April and is characterized by hamattan (December – February), low visibility, dusty atmosphere and high wind blows. The annual average temperature of the region is 30.8°C and the highest temperature was recorded during the dry season (Ogbonna et al, 2006). The relative humidity is lowest during the dry season and highest during the wet season of the years. The area falls within the guinea savannah vegetation belt which consists essentially of short to tall trees. The trees are of different sizes and height with shrubs of different species which reflects daily degradation by human activities including bush burning, cutting and cultivation.

**Geology**

The study area falls within the Anambra sedimentary basin which is Cretaceous in age. According to Reyment (1965), Anambra Basin was a plat form that is only thinly covered by older sediment during the Albian-Santonian epoch of the Cretaceous. The Post Maastrichtian folding movement affected all the sediments, which were less intensified than the Santonian episode. The later sediment in Anambra Basin were sourced from the Abakaliki uplift, Cameroon basement granite and Oban massif to the South-East. Anambra Basin is a nearly triangular-shaped embayment, covering an area of about 30,000 square kilometers. It stretches from the area just south of the confluence of the Rivers Niger and Benue across localities like Ankpa, Anyigba, Idah, Nsukka, Onitsha and Awka (Obaje, 2009). The geological map of the study area (Fig. 2) shows the Ajali, Mamu and Nkporo Formations of the Anambra sedimentary basin.
Materials and Methods
Relevant abstracts, maps and materials which are similar to this research were studied from sources. Geologic mapping of the study area was carried out using topographic map at a scale of 1:50,000, global positioning system (GPS), compass clinometers, sample bags, plastic hand trowel, plastic hand auger, masking tape, indelible marker and field record book. Five (5) sampling locations were strategically marked at Oji-Aji, Igodo, Ogodu, Okura town and Ofe-Jiji in a way that soil and riverbed sediments representatives’
samples for analyses can be accessed. Five (5) rock (sandstone) samples were obtained within the catchment area of the river. Twenty (20) soil samples were collected using plastic hand auger from the catchment area of Okura River: Two (2) samples of about 500g each were taken from both eastern and western sides of the river at an approximate distance interval of 50 meters and 100 meters from the river bank at each of the five (5) sampling location. Also, a total of twenty (20) river bed sediments samples were collected from the five (5) locations: Four (4) from each sample location within the stretch of about 33.6km of Okura River starting from its source. The depth of sampling was 0 cm to 10 cm. The samples were directly collected by cello-bags, labeled and taken to the laboratory for preparation and analyses.

All the samples were separately air-dried and broken down into aggregates. Each preliminary ground sample was subdivided by using quartering. Then, each sample was sieved through sieve 60 micron size and the oversize was ground again until no grain larger than 60 micron was left. Sieves made of nylon were used to avoid contamination by metals. The prepared samples were sent to the Central Research Laboratory, Federal University of Technology, Akure, Nigeria where major elements were analysed using Minipal 4 ED-version X-ray Fluorescence machine.

**Results and Interpretation**

**Rock Analysis**

Chemical composition of the rock samples from the study area consists on the average, 59.80% SiO2, 2.71% Al2O3, 28.32% Fe2O3, 0.24% MgO, 0.42% CaO, 0.05% MnO, 0.04% K2O, 0.14% Na2O, 0.04% K2O and 5.79% LOI (Table 1). These values imply low silica (SiO2) but high Fe content rock. Field studies assessment and results of the rock analysis strongly suggests lithic arenite type of sandstone. Also, result of rock samples shows a trend in concentration of major oxides in which: SiO2 > Fe2O3 > Al2O3 (Fig. 3a) and CaO > MgO > Na2O > K2O (Fig. 3b).

### Table 1: Major Element Concentration of Rock in Okura River Catchment Area.

<table>
<thead>
<tr>
<th>Location</th>
<th>SiO2</th>
<th>Al2O3</th>
<th>Fe2O3</th>
<th>MgO</th>
<th>CaO</th>
<th>MnO</th>
<th>Na2O</th>
<th>K2O</th>
<th>TiO2</th>
<th>LOI</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST1</td>
<td>59.1</td>
<td>2.67</td>
<td>28.98</td>
<td>0.22</td>
<td>0.5</td>
<td>0.06</td>
<td>0.14</td>
<td>0.05</td>
<td>1.85</td>
<td>6.0</td>
<td>0.38</td>
<td>100.00</td>
</tr>
<tr>
<td>ST2</td>
<td>60.1</td>
<td>2.54</td>
<td>27.79</td>
<td>0.32</td>
<td>0.4</td>
<td>0.04</td>
<td>0.15</td>
<td>0.04</td>
<td>1.97</td>
<td>5.9</td>
<td>0.68</td>
<td>100.00</td>
</tr>
<tr>
<td>ST3</td>
<td>59.9</td>
<td>2.68</td>
<td>28.10</td>
<td>0.29</td>
<td>0.3</td>
<td>0.03</td>
<td>0.09</td>
<td>0.04</td>
<td>1.99</td>
<td>6.0</td>
<td>0.43</td>
<td>100.00</td>
</tr>
<tr>
<td>ST4</td>
<td>60.2</td>
<td>2.91</td>
<td>27.75</td>
<td>0.03</td>
<td>0.4</td>
<td>0.06</td>
<td>0.10</td>
<td>0.03</td>
<td>2.02</td>
<td>5.7</td>
<td>0.71</td>
<td>100.00</td>
</tr>
<tr>
<td>ST5</td>
<td>59.5</td>
<td>2.75</td>
<td>28.99</td>
<td>0.33</td>
<td>0.3</td>
<td>0.06</td>
<td>0.21</td>
<td>0.03</td>
<td>1.95</td>
<td>5.2</td>
<td>0.49</td>
<td>100.00</td>
</tr>
<tr>
<td>Average</td>
<td>59.8</td>
<td>2.71</td>
<td>28.32</td>
<td>0.24</td>
<td>0.4</td>
<td>0.05</td>
<td>0.14</td>
<td>0.04</td>
<td>1.96</td>
<td>5.7</td>
<td>0.54</td>
<td>100.00</td>
</tr>
</tbody>
</table>

*ST1 – ST5 are rock(s) sample locations, each value represents an average of 3 samples.*

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Soil Analysis

Compositionally, soils samples from the catchment area of Okura River on the average indicates 60.45% SiO$_2$, 13.74% Al$_2$O$_3$, 12.54% Fe$_2$O$_3$, 1.92%MgO, 3.68%CaO, 0.08% MnO, 2.22% Na$_2$O, 2.39% K$_2$O, and 1.86% LOI (Table 2) which shows an enrichment in Al$_2$O$_3$ (13.74%) and depletion in Fe$_2$O$_3$ (12.54%) when compared to the average composition of the rock in the study area, which have 2.71% Al$_2$O$_3$ and 28.32% Fe$_2$O$_3$. Intense chemical weathering could be responsible for these. Also, the soil composition shows a trend of concentration of major oxides in which: SiO$_2$ > Al$_2$O$_3$ > Fe$_2$O$_3$ (Fig. 4a) while the concentration of alkalis shows the same trend of CaO > K$_2$O > Na$_2$O > MgO in all the locations (Fig. 4b).

Table 2: Major Element Concentration of Soil in Okura River Catchment Area.

<table>
<thead>
<tr>
<th>Major Oxides</th>
<th>SiO$_2$</th>
<th>Al$_2$O$_3$</th>
<th>Fe$_2$O$_3$</th>
<th>MgO</th>
<th>CaO</th>
<th>MnO</th>
<th>Na$_2$O</th>
<th>K$_2$O</th>
<th>TiO$_2$</th>
<th>LOI</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oji-Aji</td>
<td>61.01</td>
<td>14.04</td>
<td>12.09</td>
<td>1.92</td>
<td>3.64</td>
<td>0.06</td>
<td>2.48</td>
<td>2.55</td>
<td>1.08</td>
<td>1.03</td>
<td>0.10</td>
<td>100.0</td>
</tr>
<tr>
<td>Igodo</td>
<td>61.02</td>
<td>14.02</td>
<td>12.33</td>
<td>1.92</td>
<td>3.6</td>
<td>0</td>
<td>2.45</td>
<td>2.52</td>
<td>1.03</td>
<td>1.05</td>
<td>0.06</td>
<td>100.0</td>
</tr>
<tr>
<td>Ogodu</td>
<td>60.13</td>
<td>13.83</td>
<td>12.94</td>
<td>1.94</td>
<td>3.48</td>
<td>0.09</td>
<td>2.08</td>
<td>2.44</td>
<td>0.96</td>
<td>2.03</td>
<td>0.08</td>
<td>100.0</td>
</tr>
<tr>
<td>Okura</td>
<td>60.11</td>
<td>13.5</td>
<td>12.81</td>
<td>1.94</td>
<td>3.7</td>
<td>0.08</td>
<td>2.04</td>
<td>2.34</td>
<td>1.06</td>
<td>2.33</td>
<td>0.09</td>
<td>100.0</td>
</tr>
<tr>
<td>Ofe-Jiji</td>
<td>59.96</td>
<td>13.3</td>
<td>12.53</td>
<td>1.90</td>
<td>3.99</td>
<td>0.08</td>
<td>2.04</td>
<td>2.11</td>
<td>1.06</td>
<td>2.88</td>
<td>0.15</td>
<td>100.0</td>
</tr>
<tr>
<td>Average</td>
<td>60.45</td>
<td>13.74</td>
<td>12.54</td>
<td>1.92</td>
<td>3.68</td>
<td>0.08</td>
<td>2.22</td>
<td>2.39</td>
<td>1.04</td>
<td>1.86</td>
<td>0.08</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*Each value represents an average of 4 samples.*
Sediment Analysis
Analysis for Major oxides in Okura River bed sediments within the study area show concentration ranges of 70.72% SiO$_2$, 6.54% Al$_2$O$_3$, 7.57% Fe$_2$O$_3$, 0.65% MgO, 2.97% CaO, 0.01% MnO, 0.58% Na$_2$O, 0.45% K$_2$O, 0.28% TiO$_2$ and 9.60% LOI on the average (Table 3). The concentration trend of SiO$_2$ > Fe$_2$O$_3$ > Al$_2$O$_3$ as well as CaO > MgO > Na$_2$O > K$_2$O are noticed. The concentration of the alkali and alkali earth metals in the Okura river bed sediments is higher but similar in trend when compared with those of rocks within the study area (Fig. 5).
Table 3: Major Element Concentration of Okura River Bed Sediments.

<table>
<thead>
<tr>
<th>Location</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>MgO</th>
<th>CaO</th>
<th>Mn</th>
<th>Na₂O</th>
<th>K₂O</th>
<th>TiO</th>
<th>LOI</th>
<th>Other Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oji-Aji</td>
<td>70.4</td>
<td>6.46</td>
<td>7.22</td>
<td>0.63</td>
<td>2.54</td>
<td>BDL</td>
<td>0.32</td>
<td>0.4</td>
<td>0.23</td>
<td>11.0</td>
<td>0.61</td>
</tr>
<tr>
<td>Igodo</td>
<td>70.6</td>
<td>6.43</td>
<td>7.31</td>
<td>0.65</td>
<td>2.28</td>
<td>BDL</td>
<td>0.35</td>
<td>0.4</td>
<td>0.27</td>
<td>9.98</td>
<td>1.61</td>
</tr>
<tr>
<td>Ogodu</td>
<td>71.1</td>
<td>6.39</td>
<td>7.78</td>
<td>0.37</td>
<td>2.63</td>
<td>0.02</td>
<td>0.26</td>
<td>0.4</td>
<td>0.26</td>
<td>10.1</td>
<td>0.63</td>
</tr>
<tr>
<td>Okura town</td>
<td>70.4</td>
<td>6.75</td>
<td>7.50</td>
<td>0.80</td>
<td>3.76</td>
<td>0.02</td>
<td>0.97</td>
<td>0.3</td>
<td>0.33</td>
<td>9.01</td>
<td>0.06</td>
</tr>
<tr>
<td>Ofe-Jiji</td>
<td>70.9</td>
<td>6.68</td>
<td>8.07</td>
<td>0.81</td>
<td>3.66</td>
<td>0.03</td>
<td>1.01</td>
<td>0.5</td>
<td>0.35</td>
<td>7.84</td>
<td>0.06</td>
</tr>
<tr>
<td>Average</td>
<td>70.7</td>
<td>6.54</td>
<td>7.57</td>
<td>0.65</td>
<td>2.97</td>
<td>0.01</td>
<td>0.58</td>
<td>0.4</td>
<td>0.28</td>
<td>9.60</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Each value represents an average of four (3) samples. BDL...Below detection limit.

Fig. 5: Average Concentration and Trend of Alkali and Alkali Earth Metals in River Bed Sediments of Okura River and Rocks within Its Catchment Area.

Fig. 6: Average Concentration of Major Oxides in Rocks, Soils and River bed Sediments of the Study Area.

**Discussion**

The concentrations of major elements in weight % of the rock, soils and bed sediments from the catchment area of Okura River are presented in Tables 1, 2 & 3, respectively. Results of geochemical analysis of rocks within the study area shows that, SiO₂, Fe₂O₃ and Al₂O₃ are the dominant major oxides having averages of 59.80%, 28.32% and 2.71%, respectively, (Table 1) in which SiO₂ > Fe₂O₃ > Al₂O₃. The alkalis shows a trend of CaO > MgO > Na₂O > K₂O. The chemical composition and field studies assessment of the rocks strongly suggests lithic arenite type of sandstone which are usually characterized as sub-mature to immature mineralogy owing to their low silica content and abundant unstable.
minerals. The iron content of the rock samples is relatively high. The rock is comparable to those of Lokoja formation which have been similarly described as fluvial in origin (Omali et al, 2010).

The result of soils analyses (Table 2) from the study area show a compositional enrichment of Fe$_2$O$_3$ (12.54%) and depletion of Al$_2$O$_3$ (13.74%) when compared to the average crustal compositions of the earth by Clarke and Washington (1924), which have 6.70% Fe$_2$O$_3$ and 15.65% Al$_2$O$_3$. The Ferrugenization and laterization which could have lead to Fe$_2$O$_3$ enrichment in the soil may have resulted from precipitation of Fe$^{2+}$ and Fe$^{3+}$ within the soils particles. The depletion in Al$_2$O$_3$ concentration may also be an indication that, the mobility of aluminum in the environment, particularly in the soil is high. A trend of concentration of major oxides in which: SiO$_2$ > Al$_2$O$_3$ > Fe$_2$O$_3$ and CaO > K$_2$O > Na$_2$O > MgO (Fig. 4a and 4b) is the same in all the locations, which strongly suggest that, the soils in the study area are of the same origin and probably a weathered product of the sandstone rock.

The composition of Okura River bed sediments indicates on the average 70.72% SiO$_2$, 7.57% Fe$_2$O$_3$, 6.54% Al$_2$O$_3$ and 2.97% CaO as the dominant major oxides and SiO$_2$ > Fe$_2$O$_3$ > Al$_2$O$_3$ (Table 3). The concentration of the alkali and alkali earth metals in the Okura river bed sediments is higher but similar in trend (CaO > MgO > Na$_2$O > K$_2$O) when compared with those of rocks within the study area (Fig. 5). The similar compositional trends strongly suggest that, Okura River bed sediments in the study area are weathered product of the rocks (sandstone) within its catchment area and the higher concentration is obviously due to the refining and accumulative influence and processes of weathering (chemical), solubility and precipitation of Okura River transport (flow) system. Okura river bed sediments show enrichments of SiO$_2$ (70.72%) and depletion of Fe$_2$O$_3$ (7.57%) in concentration when compared to the composition of the rocks in its catchment area, which have 59.80% and 28.32% of SiO$_2$ and Fe$_2$O$_3$, respectively (Fig. 3). Purification of the iron-stained quartz content, dilution, transport and mineral sorting by the river action could be responsible for the concurrent enrichment of SiO$_2$ and depletion of Fe$_2$O$_3$. Also, the enrichment of alumina (Al$_2$O$_3$) in the river bed sediments to 6.54% from 2.71% in the rocks (Fig. 4) buttress the strong suggestion that, chemical weathering and transport processes are of high intensity in the study area. According to McLennan (1995), intense weathering in river sediments basin yields high clay content and aluminum (Al) concentration.

Conclusion

The chemical composition and field studies assessment of the rocks in the study area indicated lithic arenite type of sandstone which is usually characterized as sub-mature to immature mineralogy owing to their low silica content and abundant unstable minerals. The result of soils analyses shows a compositional enrichment of Fe$_2$O$_3$ (12.54%) and depletion of Al$_2$O$_3$ (13.74%) when compared to the average crustal compositions of the earth by Clarke and Washington (1924), which have 6.70% Fe$_2$O$_3$ and 15.65% Al$_2$O$_3$. The Ferrugenization and laterization which could have lead to Fe$_2$O$_3$ enrichment in the soil may have resulted from precipitation of Fe$^{2+}$ and Fe$^{3+}$ within the soils particles. The depletion in Al$_2$O$_3$ concentration may also be an indication that, the mobility of aluminum in the environment, particularly in the soil is high. A trend of concentration of major oxides in which: SiO$_2$ > Al$_2$O$_3$ > Fe$_2$O$_3$ and CaO > K$_2$O > Na$_2$O > MgO (Fig. 4a and 4b) is the same in all the locations, which strongly suggest that, the soils in the study area are of the same origin and probably a weathered product of the sandstone rock. Compositonally, the soils in the study area and river bed sediments of Okura River shows similar trend in concentration with the rocks (sandstone) within the catchment area except that, they are enriched in SiO$_2$ and Al$_2$O$_3$, and depleted in Fe$_2$O$_3$ (Fig 6). These are obviously due to the complex processes of weathering, ferrugnenization, transport (flow) system, purification, accumulation and dilution in the presence of precipitation.

References


