Grain Size Analysis of Sediments From Okpoama – Brass Beach in the Niger Delta

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Abstract
Granulometric analysis was carried out on sixty – three sediment samples collected from the Okpoama – Brass Beach, in the Niger Delta, to determine the particle size distribution, the nature of the sediments and transport mode of the sediments. The sediment population is predominantly unimodal, with the 0.25 – 0.125 mm (fine sand) as the modal class, though, a significant population are polymodal. Sorting ranges from 0.1 (very well sorted for the unimodal samples) to 1.01 (poorly sorted for the polymodal samples). The average sorting value for the entire sampled population is 0.89 (Moderately sorted). The skewness of the population range from symmetrical to negatively skewed. The average values for the kurtosis is 1.2 (Leptokurtic). The average value for the Median (φ) is 1.92 which represents the medium sand size grade, while the average Mean value is 1.95 φ. The predominant mode of transport is by saltation for the modal class, and suspension and traction for the finer and coarser sediments respectively. The sediment load from Okpoama – Brass beach are dominantly fine sands, indicative of distant source rock and a gentle depositional slope.

Keywords: Beach. Grain size analysis, Unimodal, Mean value, Cumulative curve, Saltation.

1. Introduction
Okpoama – Brass beach is located in Bayelsa State, which is a lowland state with a lot of tidal flats, coastal beaches, beach ridge barriers and flood plains. Features such as cliffs and lagoons are the dominant features of the state. Okpoama – Brass beach is one of the active beaches that sit at the edge of the Atlantic Ocean. It is a long narrow accumulation of sand parallel to the shore line. Figure 1 shows the map of Bayelsa State and the study area in Brass.

A typical beach is divided into several units which are: sand dune, backshore, foreshore and shoreline. The backshore represents the upper part of the beach which is normally dry except there is unusual high water condition when it can be flooded or acted upon by waves and rip current (Reineck and Singh, 1980). The Okpoama - Brass beach is an erosive beach with the prevalence of high waves and currents (Figure 2).

The climate is tropical in Okpoama, the temperature varies so little throughout the year. The wet season is warm and overcast; the dry season is hot and mostly cloudy. Sixty –three samples were collected from the beach and grain size analysis was carried out to determine the particle size distribution, the nature of the sediments and transport mode of the sediments.

2. Stratigraphy
The Okpoama – Brass beach is located in the lower section of the Niger Delta. The Niger Delta complex comprises the sediment load of Mid Eocene to Recent age. It is bordered by the Atlantic Ocean in the South and to the North by an acuate line which runs roughly through Benin, Onitsha, Umuahia, and slightly SSW of Calabar. It extends from about longitudes 3° to 9° E and Latitudes 4° 30ʺ to 5° 20ʺ N (Whiteman, 1982). The subsurface geology of the Niger Delta is made up of three lithostratigraphic units. They are: The Akata Formation, Agbada Formation and the Benin Formation. The Benin Formation is overlain with the Quaternary sediments (Table 1, Allen, 1965)
Table 1: Stratigraphic Column of the Niger Delta (after Allen, 1965)

| Geologic Unit            | Lithology                                         | Age       |
|--------------------------|---------------------------------------------------|-----------|
| Alluvium (General)       | Gravel, sand, clay, silt                         | Quaternary|
| Freshwater Backswamp,    | Sand, clay, some silt gravel                      |           |
| Meander Belt             |                                                   |           |
| Mangrove and Salt        | Medium fine sands, clay and some silt             |           |
| Water/Backswamps         |                                                   |           |
| Active /Abandoned Beach Ridges | Sand, clay, and some silt                  |           |
| Sombreiro – Warri Deltaic Plain | Sand, clay, and some silt            |           |
| Benin Formation          | Coarse to medium sand with subordinate silt and clay lenses | Miocene  |
| Coastal Plain Sand       |                                                   |           |
| Agbada Formation         | Mixture of sand, clay and silt                   | Eocene    |
| Akata Formation          | Clay                                              | Paleocene |

3. Methodology

Sampling of the beach was done in transects. Each transect included the sampling of the sand dunes, backshore and beach face deposits where possible, otherwise only two samples were collected from sections of the beach that was reachable in that transect. A total of sixty – three (63) samples were collected into sample bags and properly labeled. They were taken to the laboratory for granulometric analysis. Mechanical sieving by Folks and Ward (1957) was employed. Samples were oven dried to remove moisture content before pouring the loose samples through a stack of wide sieves (set of sieves) with different apertures of known sizes with a minimum time of fifteen minutes used to shake the samples contained in the sieves. This is done to separate the grains into their various sizes. The results got after sieving were used to calculate grain size parameters and to plot frequency and cumulative curves graphs. The calculated parameters include median, mean, mode, sorting (standard deviation), skewness and kurtosis of the grain population.

**Median Diameter (Md):**

This is the average size of the sample grain which corresponds to the second quartile associated with the 50% percentileMd=φ50.

**Mean (GM):**

This is the best measure of average grain size, which is best computed from size of particles spread through a range of percentile values. It is calculated from

\[ \text{M} = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3} \]  

Equation (1)  

\[ \text{Phi} = \phi \]
Mode (Mo):
This is the size class in which the greatest percentage of grains is represented. The mode class means the commonest grain size which is got from a size frequency histogram.

Sorting Co-efficient (So) Standard Deviation (GSD):
This is a measure of spread in the size distribution. It is defined statistically as the extent to which grain spread on either side of the average diameter.

\[
D = \frac{\phi_{84} - \phi_{16} + \phi_{95} - \phi_{5}}{6.6}
\]

Skewness (GSK):
It is the measure of the symmetry of the grain size distribution on a cumulative curve. It is a positively or negatively sign dimensionless number. It has neither metric nor phi value and lies between the range -1 to +1.

\[
GSK = \frac{\phi_{84} + \phi_{16} - 2(\phi_{50}) + \phi_{95} + \phi_{5} - 2(\phi_{50})}{2(\phi_{84} - \phi_{16})}
\]

Kurtosis (K):
It is a measure of the peakedness of the grain distribution. It is the ratio of the spread of the falls and centre of the distribution.

\[
K = \frac{\phi_{95} - \phi_{5}}{2.44(\phi_{75} - \phi_{25})}
\]

4. Presentation And Discussion Of Results.
4.1 Presentation of Samples and Description
The sample points, brief textural description, elevations and their associated geo-references are presented in Table 2. A total of 30 transects were taken along the Okpoama – Brass beach.

Table 2: Sample Locations and Descriptions.

| SAMPLE NO. | NORTHINGS | EASTERLIES | ELEVATION (m) | TEXTURE | REMARKS |
|------------|-----------|------------|---------------|---------|---------|
| OBO01      | N 04° 17’ 848" | E 006° 19’ 343" | 3 m | Light brown, fine grain sand | Transect 1 Vegetation |
| OBO02      | N 04° 17’ 832" | E 006° 19’ 342" | 5 m | Light brown, fine grain sand |
| OBO03      | N 04° 17’ 825" | E 006° 19’ 341" | 7 m | Light brown, very fine grain sand |
| OBO04      | N 04° 17’ 828" | E 006° 19’ 207" | 9 m | Light brown, fine grain sand | Transect 2 |
| OBO05      | N 04° 17’ 822" | E 006° 19’ 210" | 6 m | Light brown, fine grain sand | Small debris found around |
| OBO06      | N 04° 17’ 811" | E 006° 19’ 212" | 6 m | Light brown, very fine grain sand |
| OBO07      | N 04° 17’ 817" | E 006° 19’ 077" | 10 m | Light brown, fine grain sand | Transect 3 Massive vegetation |
| OBO08      | N 04° 17’ 809" | E 006° 19’ 007" | 10 m | Light brown, fine grain sand |
| OBO09      | N 04° 17’ 800" | E 006° 19’ 007" | 9 m | Light brown, very fine grain sand |
| OBO10      | N 04° 17’ 799" | E 006° 18’ 942" | 8 m | Light brown, fine grain sand | Transect 4 |
| OBO11      | N 04° 17’ 783" | E 006° 18’ 944" | 4 m | Dark brown, fine grain sand |
| OBO12      | N 04° 17’ 782" | E 006° 18’ 810" | 8 m | Light brown, fine grain sand | Transect 5 |
| OBO13      | N 04° 17’ 766" | E 006° 18’ 811" | 11 m | Dark brown, very fine grain sand |
| OBO14      | N 04° 17’ 760" | E 006° 18’ 680" | 8 m | Light brown, fine grain sand | Transect 6 Vegetation and debris |
| OBO15      | N 04° 17’ 741" | E 006° 18’ 683" | 5 m | Dark brown, fine grain sand |
| OBO16      | N 04° 17’ 740" | E 006° 18’ 548" | 7 m | Light brown, fine grain sand | Transect 7 Vegetation and debris |
| OBO17      | N 04° 17’ 718" | E 006° 18’ 552" | 4 m | Dark brown, very fine grain sand |
| OBO18      | N 04° 17’ 719" | E 006° 18’ 416" | 7 m | Light brown fine grain sand | Transect 8 Vegetation and debris |
| OBO19      | N 04° 17’ 696" | E 006° 18’ 421" | 8 m | Dark brown, very fine grain sand |
| OBO20      | N 04° 17’ 696" | E 006° 18’ 285" | 6 m | Light brown, fine grain sand | Transect 9 Vegetation and debris |
| OBO21      | N 04° 17’ 673" | E 006° 18’ 289" | 7 m | Dark brown, very fine grain sand |
| OBO22      | N 04° 17’ 679" | E 006° 18’ 156" | 7 m | Light brown, fine grain sand | Transect 10 Debris observed |
| OBO23      | N 04° 17’ 655" | E 006° 18’ 159" | 7 m | Dark brown, very fine grain sand |
| OBO24      | N 04° 17’ 662" | E 006° 18’ 027" | 8 m | Light brown, fine grain sand | Transect 11 Root of trees and vegetation |
| OBO25      | N 04° 17’ 640" | E 006° 18’ 029" | 6 m | Dark brown, very fine grain sand |
4.2 Presentation of Grain Size Parameters and Discussions.
Table 3 shows the various statistical parameters for the individual sample calculated from the grain size analysis carried out. Frequency curves and cumulative curves of some of the samples, showing the distribution of the sample population are also plotted for graphical presentation in Figures 3 - 54.
### Table 3: Table of calculated statistical parameters of sediments

|   | Mean (φ) | GSD   | GSK   | K     | Median (φ) |
|---|----------|-------|-------|-------|------------|
| OBO1 | 1.93     | 0.56  | -0.10 | 2.25  | 1.9        |
| OBO2 | 1.80     | 0.39  | 0.50  | 1.91  | 1.9        |
| OBO3 | 2.20     | 0.64  | 0.15  | 1.64  | 2.3        |
| OBO4 | 2.20     | 0.50  | -0.25 | 0.61  | 2.2        |
| OBO5 | 2.00     | 0.32  | -0.05 | 1.13  | 2.0        |
| OBO6 | 2.00     | 0.22  | 0.00  | 1.09  | 2.0        |
| OBO7 | 2.10     | 0.36  | 0.10  | 1.23  | 2.1        |
| OBO8 | 1.90     | 0.45  | 0.80  | 1.23  | 1.8        |
| OBO9 | 2.30     | 0.67  | -0.20 | 0.96  | 2.4        |
| OBO10 | 2.03    | 0.53  | 0.08  | 0.87  | 2.0        |
| OBO11 | 2.70    | 0.10  | 0.25  | 1.05  | 2.2        |
| OBO12 | 2.37    | 0.76  | -0.03 | 0.90  | 2.4        |
| OBO13 | 2.50    | 1.01  | -0.23 | 1.10  | 2.6        |
| OBO14 | 2.40    | 0.75  | -0.02 | 0.77  | 2.4        |
| OBO15 | 2.50    | 0.80  | 0.07  | 0.85  | 2.4        |
| OBO16 | 2.23    | 0.69  | -0.28 | 0.83  | 2.4        |
| OBO17 | 2.03    | 0.65  | -0.32 | 1.57  | 2.1        |
| OBO18 | 1.96    | 0.65  | 0.27  | 2.20  | 2.0        |
| OBO19 | 2.27    | 0.29  | 0.22  | 1.84  | 2.2        |
| OBO20 | 1.96    | 0.55  | 0.28  | 0.23  | 2.0        |
| OBO21 | 2.10    | 0.53  | 0.17  | 0.77  | 2.0        |
| OBO22 | 2.10    | 0.55  | -0.44 | 1.06  | 2.2        |
| OBO23 | 1.80    | 0.61  | -0.04 | 0.27  | 1.8        |
| OBO24 | 2.07    | 0.71  | -0.12 | 1.06  | 2.1        |
| OBO25 | 1.83    | 0.53  | -0.09 | 0.51  | 1.8        |
| OBO26 | 2.07    | 0.35  | -0.33 | 3.13  | 2.1        |
| OBO27 | 1.83    | 0.34  | 0.12  | 0.75  | 1.8        |
| OBO28 | 1.90    | 0.37  | 0.03  | 1.54  | 1.9        |
| OBO29 | 1.83    | 0.39  | 0.07  | 1.43  | 1.8        |
| OBO30 | 1.87    | 0.44  | 0.02  | 1.15  | 1.9        |
| OBO31 | 1.86    | 0.35  | 0.05  | 0.88  | 1.8        |
| OBO32 | 1.93    | 0.44  | -0.02 | 0.82  | 1.9        |
| OBO33 | 1.83    | 0.37  | 0.11  | 1.07  | 1.8        |
| OBO34 | 1.83    | 0.34  | 0.21  | 0.90  | 1.8        |
| OBO35 | 1.87    | 0.42  | 0.09  | 0.89  | 1.9        |
| OBO36 | 1.90    | 0.37  | -0.05 | 0.90  | 1.9        |
| OBO37 | 2.03    | 0.39  | 0.14  | 1.15  | 2.0        |
| OBO38 | 2.00    | 0.47  | 0.29  | 1.09  | 1.9        |
| OBO39 | 1.90    | 0.38  | 0.83  | 0.98  | 1.9        |
| OBO40 | 2.10    | 0.39  | -0.44 | 1.13  | 2.2        |
| OBO41 | 1.80    | 0.30  | 0.00  | 1.02  | 1.8        |
| OBO42 | 1.87    | 0.34  | -0.12 | 0.90  | 1.9        |
| OBO43 | 1.80    | 0.30  | 0.00  | 1.02  | 1.8        |
| OBO44 | 1.83    | 0.26  | 0.16  | 1.23  | 1.8        |
| OBO45 | 1.83    | 0.54  | -0.11 | 1.43  | 1.8        |
| OBO46 | 1.77    | 0.45  | -0.29 | 1.48  | 1.8        |
| OBO47 | 1.73    | 0.43  | -0.08 | 1.39  | 1.7        |
| OBO48 | 1.80    | 0.30  | 0.00  | 0.82  | 1.8        |
| OBO49 | 1.70    | 0.39  | -0.19 | 1.64  | 1.7        |
| OBO50 | 1.80    | 0.45  | -0.44 | 1.48  | 1.9        |
| OBO51 | 1.70    | 0.41  | -0.15 | 1.39  | 1.7        |
| OBO52 | 1.70    | 0.42  | -0.22 | 1.84  | 1.7        |
| OBO53 | 1.77    | 0.42  | -0.26 | 1.31  | 1.8        |
| OBO54 | 1.87    | 0.36  | -0.07 | 1.23  | 1.9        |
|        | Mean (φ) | GSD   | GSK   | K    | Median (φ) |
|--------|----------|-------|-------|------|------------|
| OBO55  | 1.83     | 0.34  | 0.12  | 0.90 | 1.8        |
| OBO56  | 1.80     | 0.32  | 0.05  | 1.13 | 1.8        |
| OBO57  | 1.73     | 0.45  | -0.10 | 1.48 | 1.7        |
| OBO58  | 1.80     | 0.30  | 0.00  | 1.02 | 1.8        |
| OBO59  | 1.83     | 0.34  | 0.12  | 1.13 | 1.8        |
| OBO60  | 1.80     | 0.41  | -0.26 | 1.74 | 1.8        |
| OBO61  | 1.73     | 0.43  | -0.08 | 1.39 | 1.7        |
| OBO62  | 1.60     | 0.43  | 0.13  | 1.39 | 1.5        |
| OBO63  | 1.73     | 0.46  | -0.06 | 1.56 | 1.7        |
| **AVERAGE** | **1.95** | **0.89** | **-0.0016** | **1.2** | **1.94** |

The grain size population of the sampled sediments shows variations in the modal presentation. Most of the samples are unimodal as can be seen from the frequency histograms, with the 0.25 – 0.125 mm as the modal class (fine sand grade), but a significant number are polymodal (Figures 3-8, 15-22, 31-54). The unimodal samples show very good sorting while the polymodal sediments exhibit poor sorting. Sorting ranges from 0.1 (very well sorted) to 1.01 (poorly sorted). The average sorting value for the entire sampled population is 0.89 (Moderately sorted).

The average value for kurtosis is 1.2, which indicates the sediments are leptokurtic. The kurtosis values range from 0.51 (very platykurtic) for the polymodal sediments to 2.25 for the unimodal sediments which are very leptokurtic.

The skewness of the population range from symmetrical to negatively skewed. The average value for the Median (φ) is 1.92 which represents the medium sand size grade. This does not tie exactly with the modal class, which is the 2 – 3 φ, (fine sand grade). The average Mean value is 1.95 φ.

The size distribution consists of sizes from coarse sands to silt size class. According to Visher (1969), coarse grains larger than 0.5 φ are transported by traction method, bedload between 0.5φ and 3 φ are by saltation method, whereas, those finer than 3 φ are carried by suspension. All the three modes of transportation are inferred from the cumulative curves of the sediments (Figures 9-14, 23-30).

Waves and currents are responsible for sediment transport and reworking within the beach. In a prograding coast like the Niger Delta, rivers carry sediment load from the in-land into the ocean. These sediment loads are reworked by waves and current and deposited in the beaches. Coastal sediments are usually made up of sands, and are gravelly where source rock is nearby (Reineck and Singh, 1980). The sediment load from Okpoama – Brass beach are dominantly fine sands, indicative of distant source rock.

Weigel (1964) observed that a systematic relationship exist between grain size, beach slope and exposure to wave action. For a given grain size, a beach slope will increase with decreasing wave action. Alternatively, under similar wave conditions, coarser sand will always form a steeper slope than finer sand (Reineck and Singh, 1980). Conclusively, Okpoama – Brass beach is a low lying beach composed mainly of fine sand grade.

5. Conclusion

The Okpoama – Brass beach is an active beach that sits at the edge of the Atlantic Ocean parallel to the shore line. The beach is low lying and is composed of sand, predominantly the fine sand grade. Most of the samples are unimodal with a significant number polymodal. The modal class is the 0.25 – 0.125 mm class (fine sand grade). The average value for the median (φ) is 1.92. Sorting ranges from 0.1 (very well sorted) to 1.01 (poorly sorted), the average value is 0.89 (moderately sorted). The sediments are symmetrical to negatively skew. The average value for kurtosis is 1.2, which indicates the sediments are leptokurtic.

The modal class of the sediment is transported by saltation, while, the finer and coarser sediments which occur in lower quantities are transported by suspension and traction respectively.

![Figure 3: Histogram for sample OBO1](image1.png)

![Figure 6: Histogram for sample OBO7](image2.png)
Figure 11: Cumulative curves for samples OBO12, and OBO13

Figure 14: Cumulative curves for samples OBO20, and OBO21

Figure 15: Histogram for sample OBO12

Figure 19: Histogram for sample OBO18

Figure 16: Histogram for sample OBO13

Figure 20: Histogram for sample OBO19

Figure 17: Histogram for sample OBO14

Figure 21: Histogram for sample OBO20
Figure 18: Histogram for sample OBO15

Figure 22: Histogram for sample OBO21

Figure 23: Cumulative curves for samples OBO28, and OBO29

Figure 27: Cumulative curves for samples OBO44, OBO45, OBO46 and OBO47

Figure 24: Cumulative curves for samples OBO32, and OBO33

Figure 28: Cumulative curves for samples OBO48, OBO49, OBO50 and OBO51

Figure 25: Cumulative curves for samples OBO36, and OBO37

Figure 29: Cumulative curves for samples OBO56, OBO57, OBO58 and OBO59
Figure 26: Cumulative curves for samples OBO40, and OBO41

Figure 30: Cumulative curves for samples OBO60, OBO61, OBO62 and OBO63

Figure 31: Histogram for sample OBO28

Figure 35: Histogram for sample OBO36

Figure 32: Histogram for sample OBO29

Figure 36: Histogram for sample OBO37

Figure 33: Histogram for sample OBO32

Figure 37: Histogram for sample OBO40
Figure 34: Histogram for sample OBO33  
Figure 38: Histogram for sample OBO41  
Figure 39: Histogram for sample OBO44  
Figure 43: Histogram for sample OBO48  
Figure 40: Histogram for sample OBO45  
Figure 44: Histogram for sample OBO49  
Figure 41: Histogram for sample OBO46  
Figure 45: Histogram for sample OBO50
Figure 42: Histogram for sample OBO47

Figure 46: Histogram for sample OBO51

Figure 47: Histogram for sample OBO56

Figure 51: Histogram for sample OBO60

Figure 48: Histogram for sample OBO57

Figure 52: Histogram for sample OBO61

Figure 49: Histogram for sample OBO58

Figure 53: Histogram for sample OBO62
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References
Allen, J. R. L. (1965). Late Quaternary Niger Delta and adjacent areas: Sedimentary environments and lithofacies. American Association of Petroleum Geologists Bulletin, Vol. 49, No. 5, pp. 549 – 600.
Folk, R. L., Ward, W. (1957). Brazos river bar: a study of the significance of grain size parameters. Journal Sedimentary Petrology 27, pp. 3-26.
Reineck, H. E., Singh, I. B. (1980). Depositional sedimentary environments, with reference to terrigeneous clastics. Springer – Verlag, Berlin Heidelberg, New York.
Visher, G. S. (1969). Grain size distribution and depositional process. Journal of Sedimentary Petrology, 39(3): pp, 1074 - 1106
Wiegel, R. L. (1964). Oceanography engineering. Prentice Hall, New York.
Whiteman, A. J. (1982). Nigeria: Its petroleum geology, resources and potential. Vol 1 & 2.