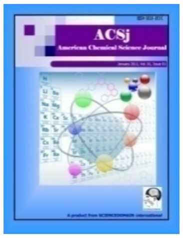

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Studies on the Quality of Brine from Selected Sites in Lafia-Obi Local Government Area of Nasarawa State, North-Central Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author ADA designed the study, author AAN performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author AAD paid for the analyses of the study. Author AT paid for fieldwork. All authors read and approved the final manuscript and are paying jointly for the publication fee.

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ABSTRACT

A comparative geochemical assessment of brine from selected sites in Lafia-Obi, Nassarawa State, North-central Nigeria was carried out in the present study. The study is aimed at determining the quantity, quality and sustainability of the brine for salt production. The Piper diagram, Stiff and Scatter plots revealed that the water type in the area is NaCl type. The result of the geochemical analysis indicates that the brine from the study area is good for domestic and industrial purposes as it is free from heavy metal and microbial contamination. The present investigation shows that brine from the area can be marketed locally and internationally due to its high quality. It is recommended that the Nasarawa State Government should establish a brine processing factory in Lafia-Obi Local Government in order to harness the huge brine deposit in the area. This will bring about socio-economic development of the area in particular and the state in general.

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1. INTRODUCTION

The evolution of Nigeria Benue trough has been described by several authors among them are [1,2,3,4]. Benue trough is among the sedimentary basins and based on Geology stratigraphy and Paleontology, Benue trough was subdivided into the lower Benue trough where we have the anticlinorium in Abakaliki and Afikpo syncline [5,6]. The middle Benue trough (where there is Keana sand stone and Giza syncline and the upper Benue (where we have Dadylarium syncline and Lariorude anticline). The trough however contains more than 500mm of cretaceous sediment with concentrations of mafic to felsic dykes, sills and extrusive and of important lead, zinc, barite and fluorite in the gently folded Albian exposed on the axis [7]. The Benue trough of Nigeria is a rift basin in central West Africa (Figs. 1 & 2) that extends NNE-SSW for about 800km in length and 150km in width, the southern limit is the Northern Boundary of the Niger Delta while the Northern Limit is the Sothern boundary of the Chad basin [8]. The trough contains up to 6,000m of cretaceous-tertiary sediment of which those predating the mid-santonia have been compressionally folded, faulted and uplifted in several places [9]. Compressional folding during the Mid-Santonia tectonic episode affected the whole of the Benue trough and was quite intense, producing over 100 anticlines and synclines [10,11].

The numerous isolated brine occurrences in the Benue Trough of Nigeria share some geomorphic, geological and tectonic features in common [12]. Evaluation of these features as well as the hydrochemical properties of the brines is important in speculating the origin of the brines [13]. Field observations suggest that the brines are not confined to any bedrock type but are hosted in diverse lithologies: sandstones, shales, mudstones and limestones. Despite the varied bedrock types, the hydrochemical data are generally similar. The data, in conjunction with the hydro-isotopes and the general tectonics of the Benue Trough, suggest the existence of connate waters pressed out during tectonic compaction and stored in the resulting fractures [14,15].

Reports of the actual salinity at individual sites have however been made but these differ from author to author, most probably due to seasonal variations resulting from very low up to nearly six percent sodium chloride, and in at least two cases, up to seven and a half percent total dissolved solids (TDS) where the concentration of sodium and chloride ions are relatively high, calcium, magnesium and potassium, sulphate and carbonate (bicarbonate are present in very much smaller quantities. The springs are frequently associated with fractures, and it is probable that in many other cases such fractures are masked by superficial cover. There is also a material association between salt water and mineral veins containing, variously based metal and iron sulphides, siderite, quartz, and barites, but there are many cases where salt springs do not have any nearby indication of epigenetic mineralization at least on the surfaces. The salt water springs may also appear as seepages along bedding planes, particularly in inter bedded sandstones and shale. The waters are freely flowing at the surface in most cases, even on relatively elevated topography, often giving rise to pools of salty water (brine) which form important local sources of salt (Plate 1).

Every large village has a thriving salt industry, the qualities of salt issuing in solution from the more active salt water sources are such that they could supply all of Nigeria’s present domestic and industrial requirement provided an economic energy source is available to evaporate the huge quantities of water involved. The study areas were Keana which is about 64km, Ribi is about 95 km, Azara about 106 km and lastly Akiri is 164 km. All the selected areas are located at Lafia the state capital of Nasarawa State (Fig. 1) which has been approximately tagged as Nigeria's home of Solid Minerals, the state is situated in the North-central part of Nigeria and their common language is Hausa. The local methods of processing brine by villagers in the study area are illustrated in plates 2 to 5.

The entire study areas are domiciled in Nasarawa State (Fig. 2) which is characterized by tropical sub humid climate with distinct seasons. The wet seasons last from about the beginning of May and ends in October. The dry season is experienced between November and April. Annual rainfall ranges from 1100mm to about 2000mm. Nasarawa state falls within the Southern Guinea Savannah Zone, However, clearance of vegetation for farming, fuel wood extraction for domestic and coltage industrial uses and saw-milling has led to the development of re-growth vegetation at various levels of serial development. As a result of Dense forests being few and far apart, Agriculture became the main industry of the profile of Nassarawa State, crops produced include groundnut, cotton, millet, cassava, guinea corn, beans, tomatoes, rice, maize, yam, wheat, orange, banana, bean seed, melon, bambara nuts, sorghum, cowpea, also animal rearing. In addition to farming the state is also rich with solid minerals which include barites, salt mines, gypsum, marble, galena, tin gemstones, mica, kaolin, columbite, clay, zircon, feldspars cassiterite and limestone.

Fig. 1. Map of Nigeria showing the Nasarawa State

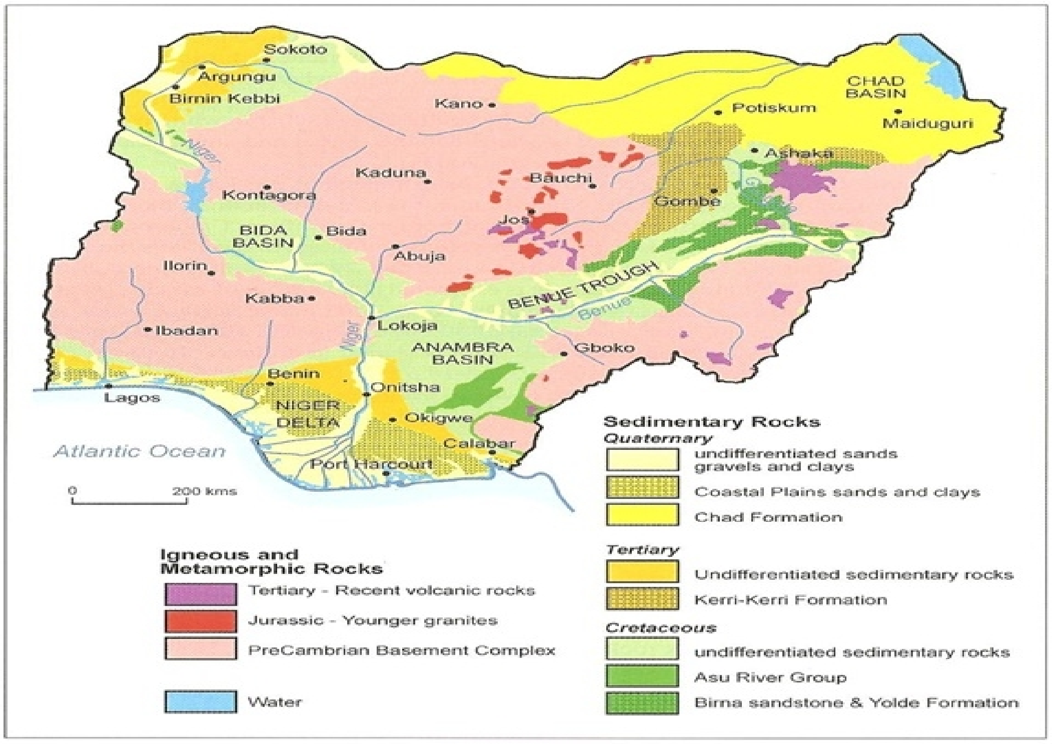


Fig. 2. Geological map of Nigeria showing the study area

Plate 1: An overview of brine pond in the Keana Salt Village, Nasarawa State

Plate 2: Local processing of brine in Ribi Salt Village, Nasarawa State

Plate 3: Brine production by filtering and drying techniques in Azara Salt Village

Plate 4: Primitive brine mining technique in Akiri Salt Village, Nasarawa State

Plate 5: Brine processing in progress at Ribi Salt Village, Nasarawa State

2. MATERIALS AND METHODS

Water samples from the salty-ponds/salty-streams were collected using water sampler in the months of January and February, 2011 and stored in a tight capped high quality polyethylene bottles under low temperature conditions in ice-boxes before been transported to the laboratory for analysis. Samples for heavy metal analysis were collected separately and acidified at the site (pH<2) with concentrated nitric acid. The pH, temperature, conductivity and turbidity were measured on site using pH meter (Model 744, Metrohm, Switzerland), mercury thermometer and conductivity meter (Model 162 A, ThermOrio., USA) respectively. All other parameters were determined in the laboratory following standard protocols outlined by [16] and (Polintest Photometer 5000) for examination of water and wastewater. The cation and anion were determined using Flame Photometer (Model CL-360, Elico, India) and AAS (Model Analyst 300, Perkins-Elmer, USA). The results of the pH indicate an acidic condition (<5.0) as against the normal pH value of (6.5–8.5) recommended by [17,18]. Studies have revealed that low pH enhances the precipitation and mobility of heavy metals in the environment [19].

3. RESULTS AND DISCUSSION

The results of the analyses of brine are summarized in Table 1 and Figs. 3 to 5. Detailed evaluation of chemical quality of brine from nine community rivers/ponds was undertaken in the present study. The communities includes: Akiri, Keana, Ribi, Awe, Akwana, Abuni, Kanje, Azara and Arufu. The brine was analyzed for physico-chemical parameters such as the pond temperature and pH as well as heavy metals which include: lead, arsenic, cadmium, nickel, copper and zinc (Table 1). The quality of brine is determined by its potability and is a function of the physical and chemical properties of the salt-water/brine and its intended use [20]. The results of the analysis are illustrated using Piper diagram, Stiff plots and Scatter plots and discussed below. The temperature ranged between 26^{o}C to 27^{o}C and the values are within the [17] acceptable limit. The high chloride is expected as it is the main constituent in brine analysis and characterization. The value of sodium is also high but less than that of chloride in all the ponds. The results of the heavy metals (Table 1) were below maximum standard for a good brine postulated by the [17, 18]. High concentration of heavy metals causes cancer and other health disorders [21, 19, 22]. According to [20], the quantity of brine mapped in Akiri, Keana, Ribi, Awe, Akwana, Abuni, Kanje, Azara and Arufu areas of Nasarawa State can sustain the entire country for years if probably harnessed and well managed.

3.1 Piper Diagram

This method was devised by [23], to outline certain fundamental principles in a graphic procedure which appears to be an effective tool in separating analytical data for critical study with respect to sources of the dissolved constituents in water. The concentration of 8 major ions (Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, Cl^{-}, CO_3^{2-}, HCO_3^{-} and SO_4^{2-}) are represented on a trilinear diagrams (Fig.3) by grouping the (K^{+} with Na^{+}) and the (CO_3^{2-} with HCO_3^{-}), thus reducing the number of parameters for plotting to 6. On the piper diagram, the relative percentages of the cations and anions are plotted in the lower triangles, and the resulting two points are extended into the central field to represent the total ion concentration. The Piper diagram was used to classify the hydrochemical facies of the water samples according to their dominant ions. This plot reveals useful properties and relationships for large water sample groups showing clustering of data points which implies that the water samples have similar compositions. It should be noted that all the plotted points are concentrated at the (Na^{+} + K^{+}) and Cl^{-} region.

Table 1. Results of the Physico-chemical parameters from 3 selected salt ponds in the area

Location	Cu mg/l	Temp ^oC	pH	Cl mg/l	TOC mg/l	Na mg/l	Ni mg/l	Zn mg/l	As mg/l	Cd mg/l	Pb mg/l	BC
Keana-1	<0.005	27	4.8	216	1.02	28	<0.005	<0.005	<0.001	<0.001	<0.005	45
Keana-2	<0.005	27	4.9	248	0.64	25	<0.005	<0.005	<0.001	<0.001	<0.005	34
Ribi-1	<0.005	27	4.9	242	0.80	31	<0.005	<0.005	<0.001	<0.001	<0.005	12
Ribi-2	<0.005	26	4.5	222	0.92	27	<0.005	<0.005	<0.001	<0.001	<0.005	30
Azara-1	<0.005	27	4.9	234	1.04	29	<0.005	<0.005	<0.001	<0.001	<0.005	09
Azara-2	<0.005	27	4.7	246	0.78	23	<0.005	<0.005	<0.001	<0.001	<0.005	26

BC: bacteria count (cfu/100ml)

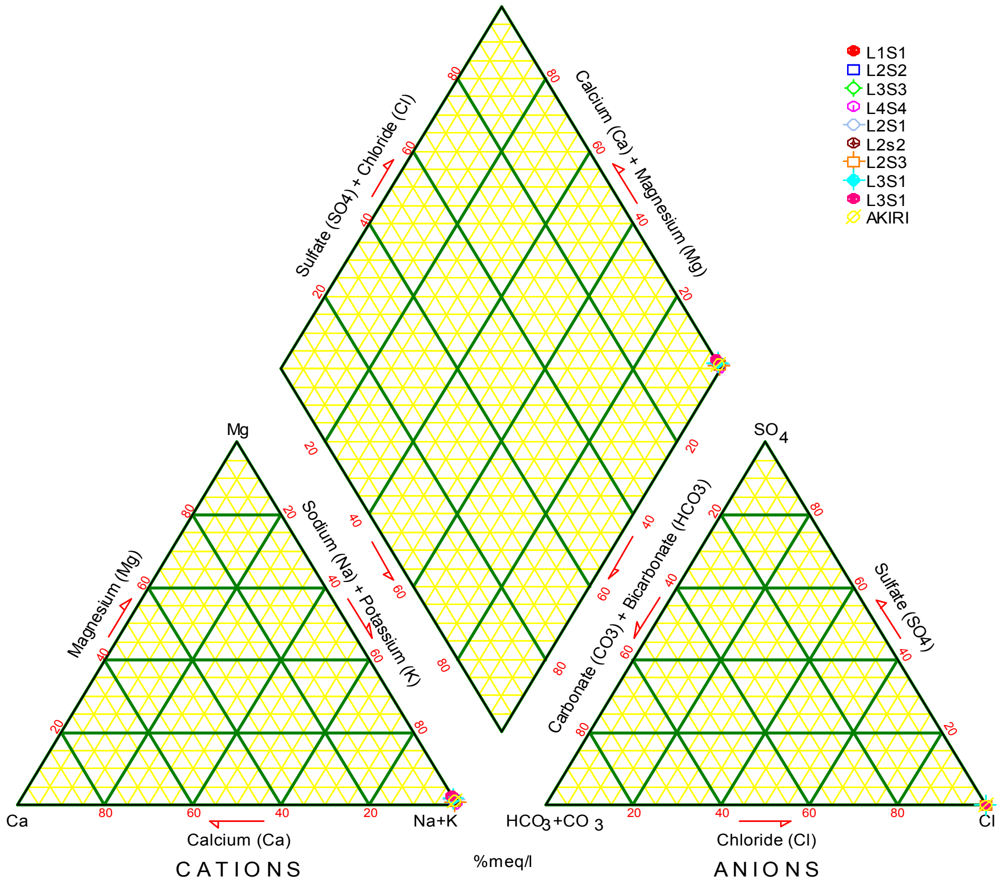


Fig. 3. Piper Diagram of the water samples from the area

3.2 Stiff-plots

Stiff diagrams are plotted for individual samples as a method of graphically comparing the concentration of selected anions and cations for several individual samples (Figs. 4a & 4b). The shape formed by the Stiff diagrams will quickly identify samples that have similar compositions and are particularly useful when used as map symbols to show the geographic location of different water facies. The Stiff plots (Figs. 4a & 4b) show two main hydrochemical facies which are NaCl water type and Na + K + Cl facies.

3.3 Scatter Plots, Sieve Analysis, Skewness and Sorting Plots

The concentration of pH, TDS, Na and Cl were subjected to correlation analysis via scatter plot in order to determine their relationships and illustrated in Figs. (5a-5d). No clear positive correlation was established in the various plots [24], which implies that the parameters (pH, TDS, Na and Cl) have different sources of pollution and therefore cannot be linked together (Figs. 5a-5d). The results of the grain size analysis are shown in Figs. (6a and 6b) while the sorting and skewness plot is illustrated in Fig.7.

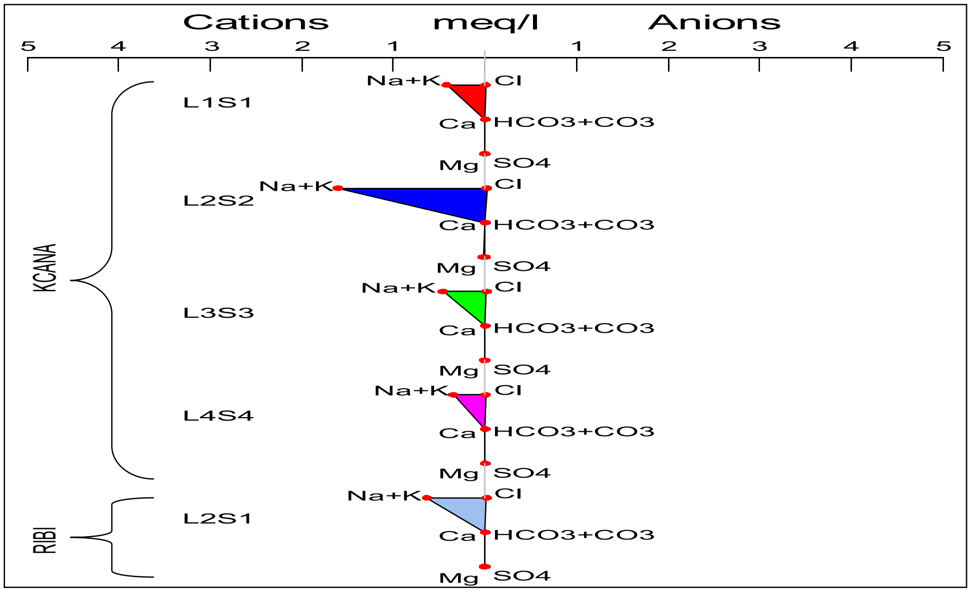


Fig. 4a. Stiff Diagram

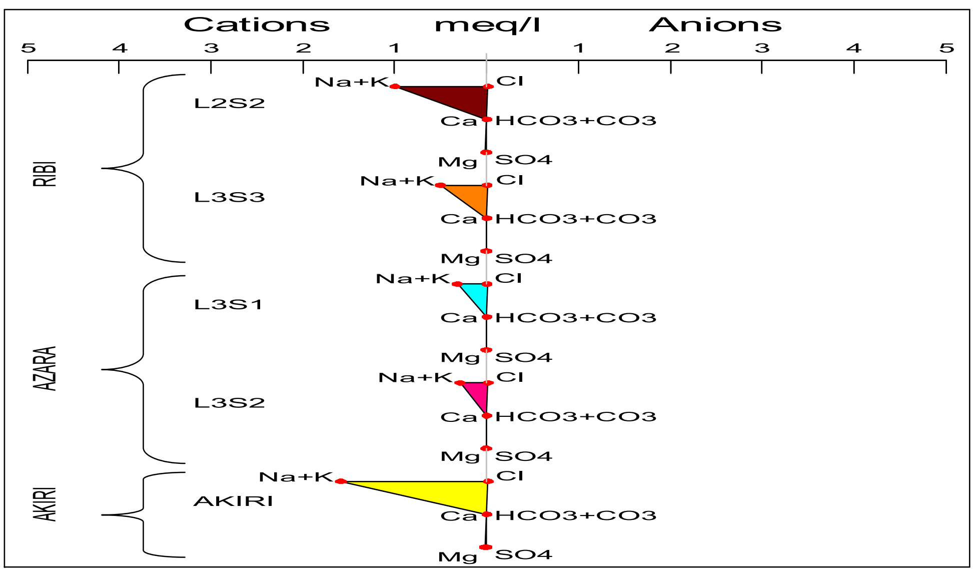


Fig. 4b. Stiff Diagram

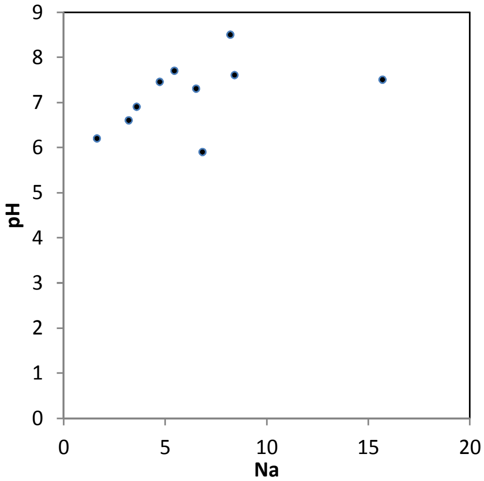


Fig. 5a. Plot of pH versus Na

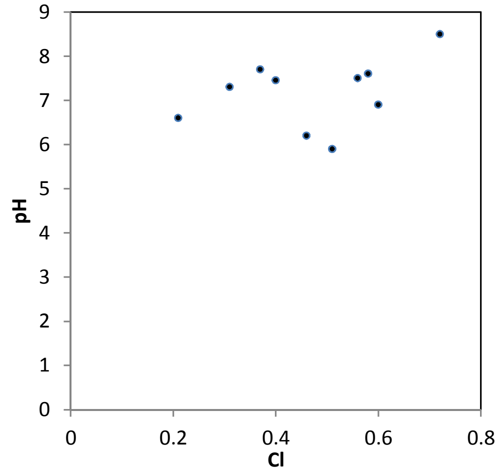


Fig. 5b. Plot of pH versus Cl

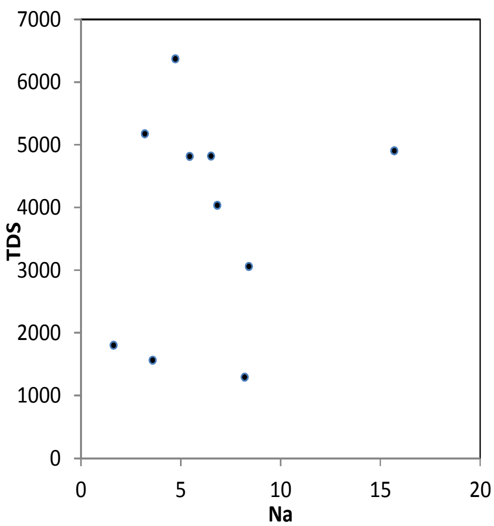


Fig. 5c. Plot of TDS versus Na

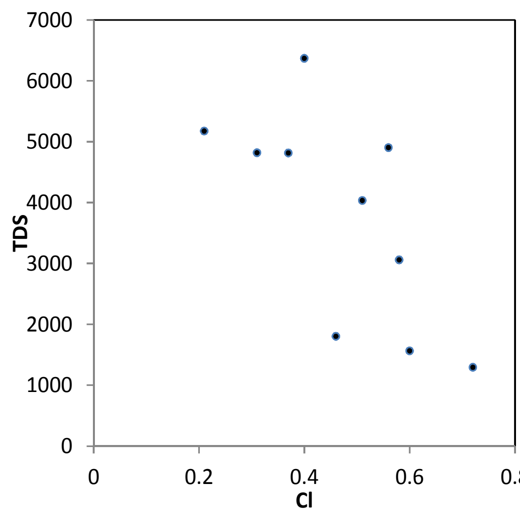
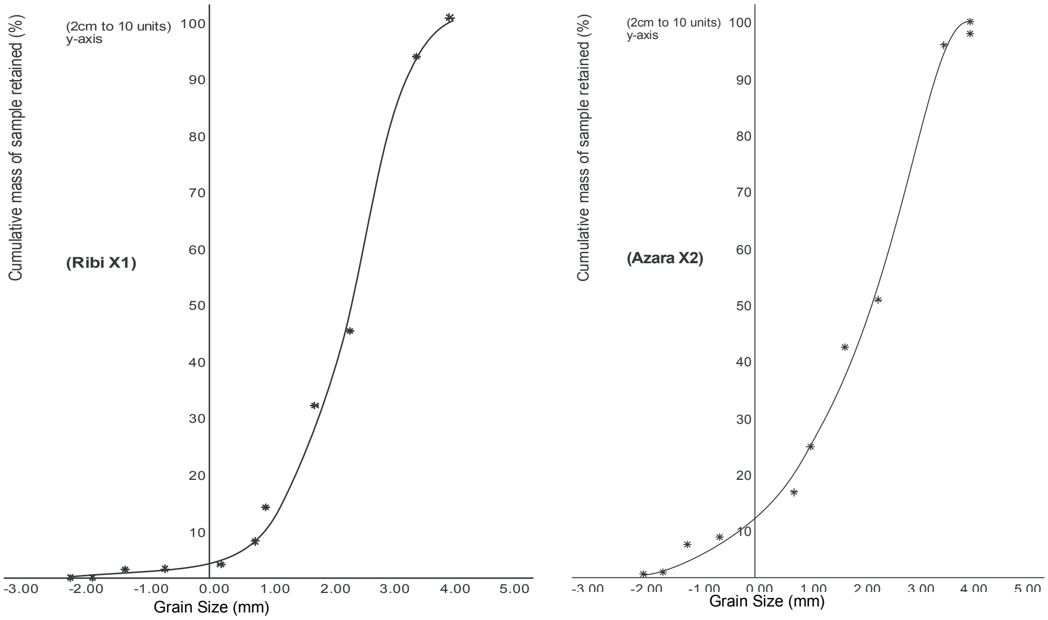


Fig. 5d. Plot of TDS versus Cl



Figs. (6a & 6b). Grain-size distribution curves for Keana and Azara area of Nasarawa state

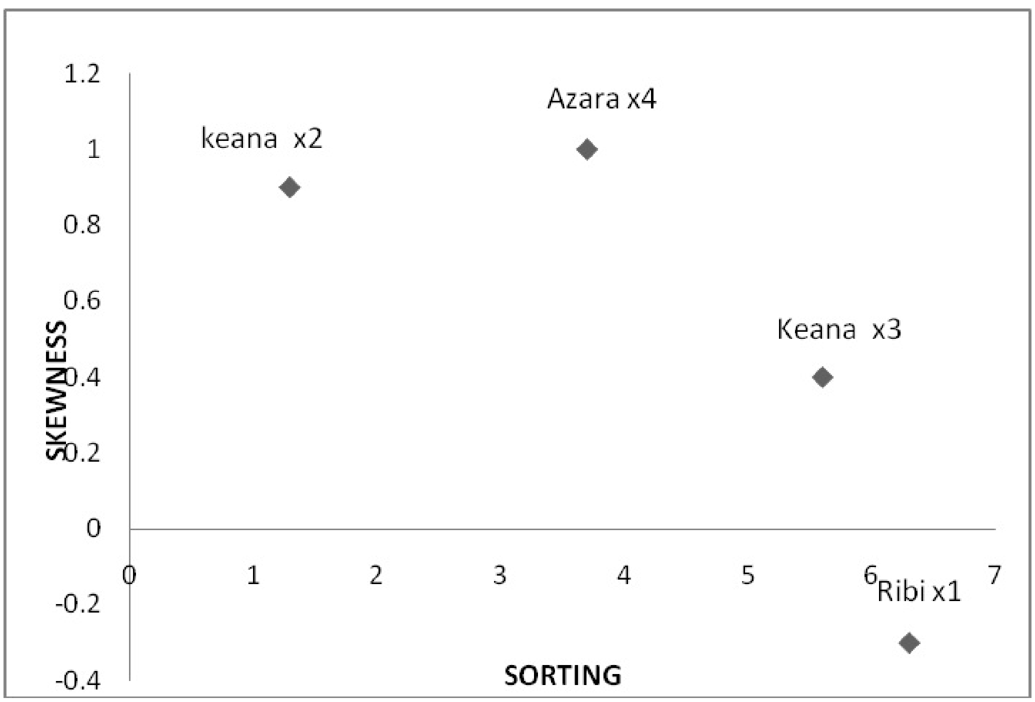


Fig. 7. Scatter plot of Skewness against Standard Deviation of the Ribi, Keana and Azara area

4. CONCLUSION

The present study involves a comparative chemical analysis on brine from selected sites in Lafia-Obi, Nassarawa State, North-central Nigeria with the view of assessing the quantity, quality and sustainability of the brine for salt production for human and industrial purposes. The result of the Piper diagram, Stiff and Scholler plots revealed that the water type in the area is predominantly NaCl type which is the major raw material for brine production. The result of the analysis also indicates that the brine from the study area is free from heavy metal and microbial contamination hence it is good for both domestic and industrial purposes. The production of brine from Lafia-Obi area of Nasarawa State should be encouraged by local, state and federal governments of Nigeria as it has the potential of providing employment for the youths in the area as well as generating income for the people and government of Nasarawa State.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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