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COMPARATIVE STUDY OF TOTAL DISSOLVED SOLIDS EVALUATED FROM RESISTIVITY SOUNDING, WATER ANALYSIS AND LOG DATA.

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ABSTRACT

Combined methods of evaluating Total Dissolved Solids (TDS) from electrical resistivity sounding, water analysis and single point resistance logs were used in this study. Twelve (12) resistivity soundings, (8) eight water samples were collected and (1) one well was logged near sounding locations. The results showed that TDS in groundwater (depth > 30m) from resistivity sounding, water analysis and single - point resistance log varied from 21.2 to 183.4 ppm, 11.6 to 108.4 ppm and 8.6 to 81 ppm respectively. The result indicates that the three methods give nearly similar TDS values. Comparison of TDS levels evaluated by resistivity sounding and water analysis showed that there was a significant positive relationship (R^2 = 0.91). Thus from this study in the absence of water analysis, estimates of TDS values in groundwater can be made from resistivity sounding data.

INTRODUCTION

Water being a chemically active liquid becomes easily contaminated when certain harmful soluble materials along the pathway of groundwater that is always on the move in accordance to the law of hydrodynamics are caught up by water and become dissolved solids. Total dissolved solids measure organic and inorganic substances in groundwater; they are mostly chemicals which include mineral salts, cations and anions.

As groundwater slowly moves through an aquifer, the chemistry of the water constantly changes usually by addition of dissolved constituents (Freeze and Cherry, 1979). Total dissolved solids are not generally considered as primary pollutant because most of its constituents have little or no short-term effect. It is however used as an indication of aesthetic characteristic of potable water. The presence of dissolved solids in water may affect its taste (Bruvold and Pangborn, 1966). However, toxic ions of arsenic, lead, cadmium etc. may also be dissolved in groundwater. As a result, high level of TDS in groundwater is an indication that high concentration of major constituent will also be present in that sample; hence, high level of TDS is usually an indicator of potential concerns and would require further investigation.

Most groundwater schemes in the Niger Delta are developed without prior water quality assessment. TDS in groundwater, a secondary means of assessing groundwater quality, is measured by two primary methods: gravimetric (from conductance) and conductivity methods. The most accurate is the gravimetric method but it is time consuming and as a result the conductivity method provides an approximate means of determining TDS. In-situ temperature of groundwater is a requirement for determining conductance. However, this temperature cannot be easily determined because temperatures of collected water samples are readily altered between the period of collection and testing (Hagemeyer, 1988). Resistivity sounding can measure resistivity of groundwater at aquifers in-situ temperature and also because formation resistivities are strongly influenced by the chemistry of groundwater in the formation and its lithology (Hagemeyer, 1988). In older boreholes or new boreholes where water analysis was not performed an indirect method must be employed to determine groundwater quality. Electrical resistivity method used in this study provides a means by which groundwater quality can be obtained indirectly from existing geoelectrical data.

In this study a comparison of the most commonly used method of determining TDS from water samples using conductivity meter is presented with discussion of TDS from resistivity sounding and single – point resistance log.

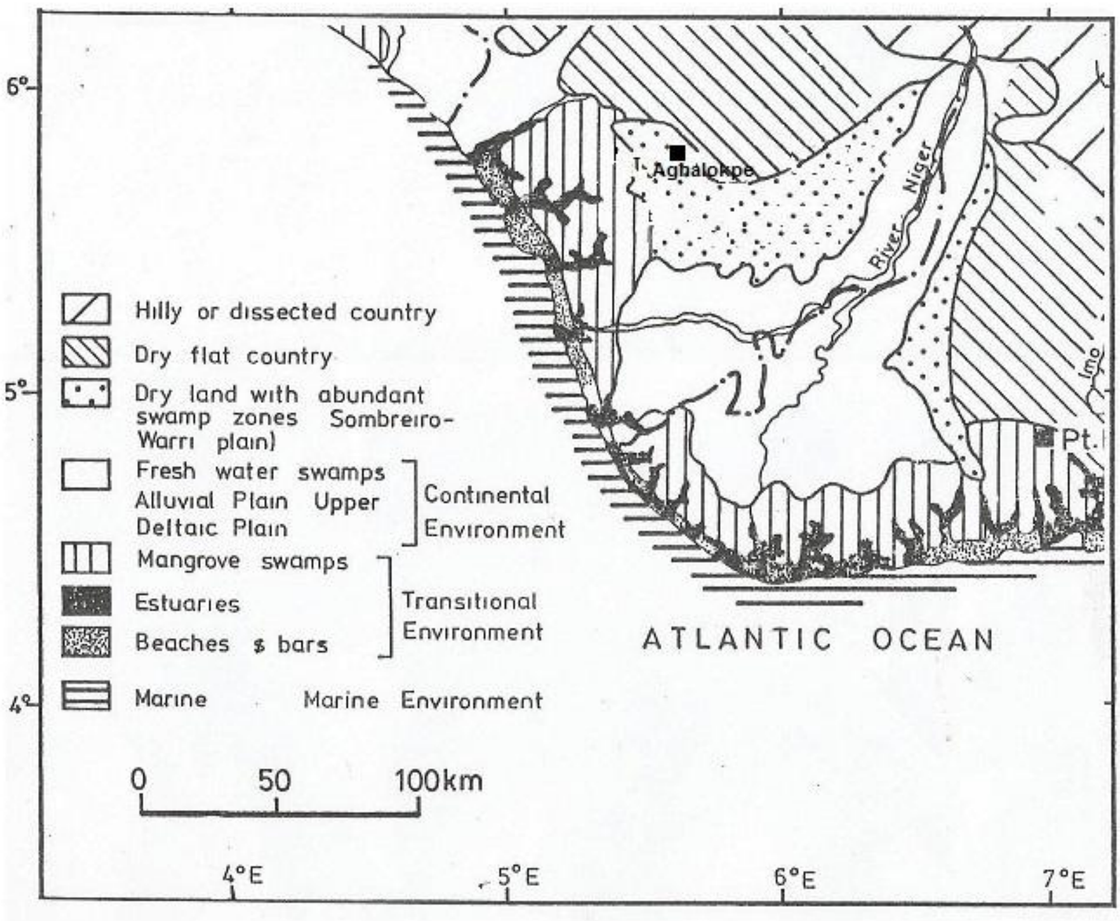

Figure. 1: Geologic Map of Study Area

Location and Geology

Aghalokpe is bordered by longitudes 5º 50ˈ E, 5º 51ˈ E and latitudes 5º 45ˈ N, 5º 47ˈ N and lies within the Tertiary Niger Delta (Figure 1). The lithostratigraphic units consist of the Benin Formation, Agbada Formation and Akata Formation (Reyment, 1965; Short and Stauble, 1967). The area is

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underlain by the Quaternary (Recent) sediments known as the Sombreiro – Warri Deltaic Plain sand which overlies and mask the Benin Formation. This sand deposit is between 40 – 150 m thick and consists of an admixture of sand, silts and intercalation of clay bands (Etu-Efeotor and Akpokodje, 1990).

MATERIALS AND METHODS

In this report, a total of twelve (12) previous vertical electrical soundings carried out in 2013 using Schlumberger configuration because of its sensitivity to surface inhomogeneities (Sharma, 1997). The measured apparent resistivities were plotted against half current electrode spacing to generate the corresponding sounding curves. These curves were interpreted by partial curve matching and computer iteration techniques (Zhandov and Keller, 1994; Vander, 1988; 2004) and converted to layer resistivity and thickness; the resistivities of the layers constituting the aquifer were used to evaluate TDS values of groundwater.

Total dissolved solids were measured from groundwater samples collected from boreholes at eight (8) locations near sounding points using HACN conductivity/TDS meter. Total dissolved solids was also evaluated from single - point resistance (SPR) log which measures the resistance in ohm-meter between an electrode on the surface and another inside the well (Keys, 1990) using ABEM SAS 4000 Terrameter. One (1) well was logged from a depth of between 8 and 36 m.

Evaluation of TDS from resistivity sounding and SPR log data

Archie (1942) showed that within an aquifer, the resistivity of the formation water (ρ_w) and bulk resistivity (ρ_b) are related by

$$\rho_b = C\,\rho_w \phi^{-m} S^{-n} \quad \text{........ (1)}$$

where ϕ is porosity; S is degree of saturation, C, m and n are constants with typical values of $0.5 \le C \le 2.5$, $1.3 \le m \le 2.5$ and n-2 .

From equation 1

$$\frac{\rho_b}{\rho_w} = C\phi^{-m} S^{-n} \quad \text{.............. (2)}$$

Also,

$$F = = C\phi^{-m} S^{-n} \quad \text{.............. (3)}$$

where F is the formation factor and relates to porosity in the following empirical equation (Winsauer, *et al*., 1952).

$$F = \frac{a}{\phi^m} \quad \text{........................ (4)}$$

where a is a constant = 0.62 for soft deposits (Repsold, 1989) ϕ = 0.34 and F = 5.4 (Aweto, 2013).

Combining equation (1) and (3) and dividing both sides of the equation by ρ_w we have:

$$F = \frac{\rho_b}{\rho_w} \quad \text{...................... (5)}$$

The resistivity of the formation water can be determined from equation (4) and used for evaluation of TDS in ppm using the expression.

TDS = Kc × EC ……….. (6) (Lloyd and Heathcote, 1985)

Kc is a correlation factor which is dependent on the type of dissolved solids in groundwater varies between 0.55 and 0.80 and EC is electrical conductivity in μS/cm. Most conductivity measurements option use a common approximated correlation factor of 0.64 (USCOP, 2004). Measurements involving mixed or saline water with greater conductivity; the correlation would be higher around 0.735 and 0.8 respectively (Atekwana *et al*., 2014) and hence, equation 6 can be written as:

$$TDS = 0.64 \times \frac{10{,}000}{\rho_w}$$

RESULTS AND DISCUSSION

In other to interprete the groundwater TDS level from resistivities and conductivities, we would rely on the comparison water chemistry and resistivity measurements by Aweto (2013). TDS values in groundwater measured using resistivity sounding method varied from 21.2 to 183.4 mg/l and 11.6 to 108.44 m/l for conductivity/TDS meter. The results from the SPR log (Table 1) showed that TDS values ranged from 259.7 to 8449.5 mg/l between depths of 8 and 30 m. At depths greater than 32 m TDS values reduced considerable to between 14 and 30.8 mg/l (average TDS level at these depths is 21.9 mg/l). Comparison with results of TDS measurements by (Aweto, 2013) showed that TDS values varied between 137 and 5524 mg/l at depths between 8 and 30 m while at depths greater than 32 m TDS values varied between 8.6 and 81 mg/l (average TDS being 30.4 mg/l).

The results of TDS evaluated from resistivity soundings, water analysis and SPR log are presented in Table 2. A cursory look at Table 2 show that values of TDS obtained by the three methods (resistivity sounding, water analysis and SPR log) at the same location (location 4) is 27.7 mg/l, 22.4 mg/l and 30.4 mg/l respectively while at location 10 values of TDS measured is 22.7 mg/l, 15.4 mg/l and 21.9mg/l by resistivity sounding, water analysis and SPR log.

Table 1: TSD Estimates from Single – Resistance log Data.

Depth (meter)	Bulk Resistivity (ohm-meter)	Formation water Resistivity (ohm-meter)	TDS (mg/l)
8	20.8897	3.8685	1654.40
10	34.4316	6.3762	1003.73
12	13.5063	2.5012	2558.80
14	32.4051	6.0009	1066.50
16	9.0266	1.6716	3828.60
18	8.2945	1.5360	4166.60
20	10.2675	1.9014	3365.95
22	4.0902	0.7574	8449.50
24	9.9724	1.8467	3465.58
26	57.1353	10.5806	604.88
28	31.4039	5.8155	1100.50
30	133.0766	24.6438	259.70
32	1,121.7137	207.7248	30.81
34	1,661.5385	307.6923	20.80
36	2,465.0499	456.4907	14.02

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Table 2: Evaluated TDS concentration in mg/l at depth greater than 30 meter.

Location	Resistivity of layer (ohm-meter)	Resistivity Sounding	Water Analysis	SPR log
1	*1210.0	28.6		
2	*188.6	183.4	108.4	
3	*937.5	36.9	41.5	
4	*1246.1	27.7	22.4	*30.4
5	*1570.0	22.0	17.0	
6	*1370.8	25.0	21.9	
7	*958.5	36.1	34.7	
8	*1214.0	28.5		
9	*1341.6	25.8		
10	*1524.8	22.7	15.4	21.9
11	*1632.0	21.2	11.6	
12	*1352.0	25.6		

*Data obtained from Aweto (2013).

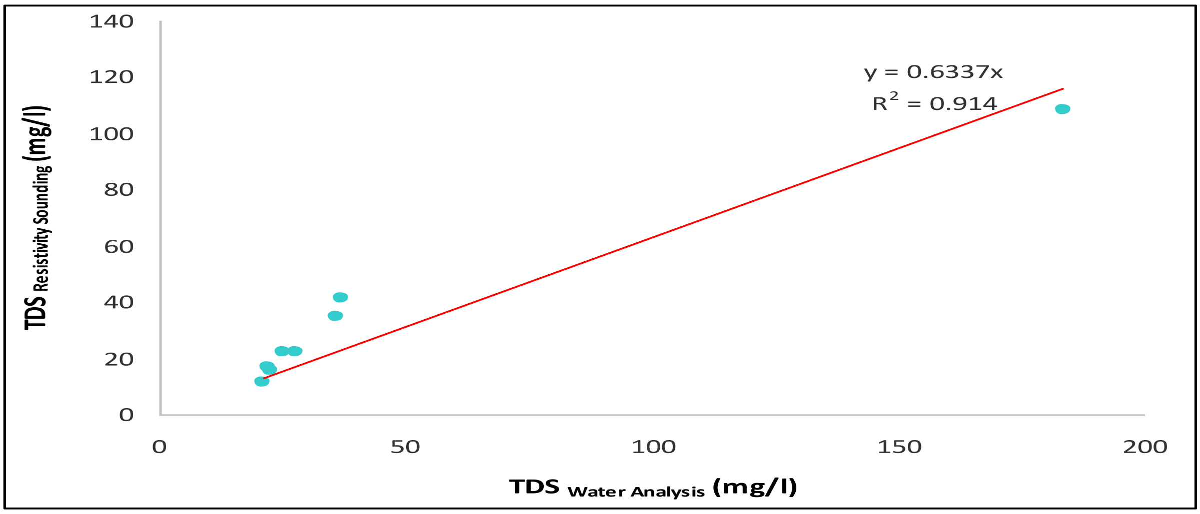

Figure 2: Comparison of TDS values estimated from resistivity sounding and water analysis.

Correlation of TDS determined by resistivity sounding and water analysis (Fig. 2) indicates that TDS determined by the two methods are positively correlated (R^2 = 0.91) suggesting that the TDS evaluated by the two methods give nearly similar values. Thus the results, shown above, confirm that the two methods give similar results.

The results of this study showed that average TDS in groundwater at depths greater than 30m from resistivity sounding, water analysis and logging techniques is 27.7 mg/l, 24.4 mg/l and 21.9 mg/l respectively. Comparison of TDS values evaluated by resistivity sounding and water analysis shows a significant positive correlation. The results of the three methods indicates that TDS level in the aquifer is below the maximum contamination level of 500 mg/l.

This study has shown that in the absence of water analysis, simply because the groundwater was not sampled when the wells were originally drilled and completed; surficial resistivity sounding can serve as a useful tool in evaluating TDS values in groundwater. It is however recommended that further studies of this nature be carried out to ascertain the precision of these methods.

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