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Electrical Resistivity Imaging (ERI) and Physicochemical Assessment of Buried Septic Tank Contamination of Groundwater in Uduaka Community, Oghara, Delta State, South-South, Nigeria

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Abstract— *Electrical Resistivity Imaging (ERI) in 2D and 3D format and physiochemical investigations were carried out in Uduaka, Delta State, South-South Nigeria with a view to assess the extent of the supposed groundwater contamination by breached subsurface municipal septic tank in the study area. Twelve traverses were occupied and 2D ERI data using Wenner array were acquired in grid format. Five water samples from two boreholes and three hand-dug wells were collected from the study area. The 2D ERI data were inverted with DIPRO to generate the 2D resistivity sections. These were collated in RES3D to generate the 3D depth slice while the subsurface 3D resistivity block distribution was generated in EarthImager. The water samples were tested for important anions and cations and other parameters based on WHO standards. The 2D ERI revealed three (3) to four (4) resistivity structures across each of the twelve traverses which are all symptomatic of sand. Resistivity generally varies from 238 – 2563 Ωm in the study area, across a lateral distance of 100 m and a maximum depth of 25 m on each traverse. The resistivity of the four sandy resistivity structures varies from 238 - 388 Ωm, 471 – 672 Ωm, 816 – 1891 Ωm and 1988 – 2563 Ωm respectively. The 3D resistivity depth slice revealed a five-layer depth slice of 0 – 2.5 m, 2.5 – 5.38 m, 5.38 – 8.68 m, 8.68 – 12.5 m and 12 .5 – 16.9 m with corresponding resistivity values of 118 – 5819 Ωm, 118 – 11135 Ωm, 118 – 3040 Ωm, 118 – 3040 and 118 – 3040 respectively. These denote clayey sand and sand in the study area. The 3D block resistivity distribution reveals a resistivity distribution of 239 – 2564 Ωm across a depth of 19.8 m. These results show that there is no indication of contamination of the subsurface in the area. The physicochemical results reveal that all water samples tested fall below the permissible WHO limits. These results reinforce those obtained from the 2D and 3D resistivity imaging except in BH1 and BH2 that showed elevated cases of Total Dissolved Solids and Total Solids above the allowable limit and this may not be unconnected with the dissolution of minerals in the BHs source at deep depth. In Uduaka therefore, the groundwater is not contaminated by the supposedly breached subsurface septic tank in the area as earlier speculated as there are no indications to that effect from the investigations. However, an integrated continuous monitoring of the aquifer to detect an onset of contamination is recommended.*

Keywords— *Septic tank, Wenner, ERI, Physicochemical, Groundwater.*

I. INTRODUCTION

Septic tank systems have been widely used in both developed and developing countries for the treatment of domestic wastewater in rural areas for over 100 years. In recent decades, they have become increasingly popular in suburban areas not serviced by public sewer systems. The widespread use of the septic tank system has continued in the face of a consistent history of failure, with attendant severe localized groundwater pollution and almost unanimous disapproval by researchers in the field (Hubert, 1990).

The feasibility of using septic tank systems as a method of treating domestic wastewater was questioned as early as 1956 when Kiker suggested that “at best a septic tank is a poor substitute for centralized sewage collection and should be avoided whenever possible”. As a essential treatment framework, septic tanks don't altogether decrease the contaminating potential of the wastewater. The bulk of the treatment takes put within the soil through different physical, chemical and organic intuitive between the emanating and soil colloids. Later thinks about have appeared that septic tank frameworks are a major source of groundwater contamination. Water wells become contaminated with fecal bacteria contained in the effluent from the septic tank. The microorganisms present in excreta directly pass through the septic tank into the soil and enter the groundwater system.

Emphasis on cost-effective geophysical surveys to pinpoint plumes, estimate quantities, and delineate plumes of conductive contaminants in groundwater and confirmation of groundwater contamination through monitoring well networks designed on the basis of plumes and subsurface stratigraphy defined by the geophysical surveys are required (Noel *et al*. 1982). Customarily, location examination for contaminants has depended upon; penetrating to get data on the normal setting, screen wells for gathering water tests, and research facility investigation of soil and water tests. This approach has advanced over numerous a long time, and is frequently respected as the standard explanatory approach. In any case, there are various pitfalls related with this coordinate inspecting approach, which can result in an inadequate or indeed incorrect understanding of location conditions, thus the integration of geophysical evaluation of the subsurface.

Geophysical methods have been used by a number of authors for detecting, characterizing and monitoring contaminants derived from domestic and industrial waste storage and disposal facilities. Electrical and electromagnetic methods often prove useful for detection of ionic contaminants that increase pore fluid conductivity, thereby reducing the bulk resistivity. Applications of these procedures for identifying and observing contaminant crest and for foreseeing future contaminant pathways have been portrayed by many authors (e.g. Aristodemou and Thomas-Betts 2000; Buselli and Lu 2001; Martinho and Almeida 2006; Santos *et al*. 2006; Lee *et al.* 2006; Perozzi and Holliger 2008, Casado *et al*. 2015). A number of authors have moreover illustrated sensible relationships between clear electrical resistivity and conductivity (ECa) and concentrations of different chemicals in groundwater, counting those which will contain microbiological contaminants. For example, ECa has been correlated with concentrations of K+, Na+, Cl-, SO42-, NH4+ and NO3- in soils affected by animal manure wastes (Eigenberg *et al*. 1998; Martínez-Pagán *et al*. 2009; Ranjan and Karthigesu, 1995; Stevens *et al*., 1995). By differentiate, more restricted research has been published on the use of geophysics for assessing contaminants resulting from wastewater treatment systems (Lee *et al*. 2006; Donohue *et al*. 2010).

The study area, Uduaka, in recent times has been faced with the problem of poor groundwater quality. This has been attributed to the breached buried municipal septic tank in the locality. Integration of geophysical and hydrochemical assessment has been proposed to investigate the problem and its extent in the area with a view to designing a remediation system. In this study therefore, integration of 2D and 3D electrical resistivity imaging of the subsurface and physicochemical investigations of the groundwater were carried out to assess the buried septic tank contamination of groundwater in Uduaka, Delta State, South-South Nigeria.

II. MATERIALS AND METHODS

2.1. Geology and Location of the Study Area

Uduaka in Oghara, Ethiope West Local Government Area of Delta State, Nigeria falls within the Niger Delta Basin. The basin is an extensive continental margin basin situated in the Gulf of Guinea built out into the Central South Atlantic Ocean at the mouths of the Niger-Benue and Cross River systems during the Eocene (Fig. 1). It is a wave dominated and tidally influenced delta with sand bodies whose thickness may be influenced by growth faulting (Avbovbo and Ayoola, 1981).

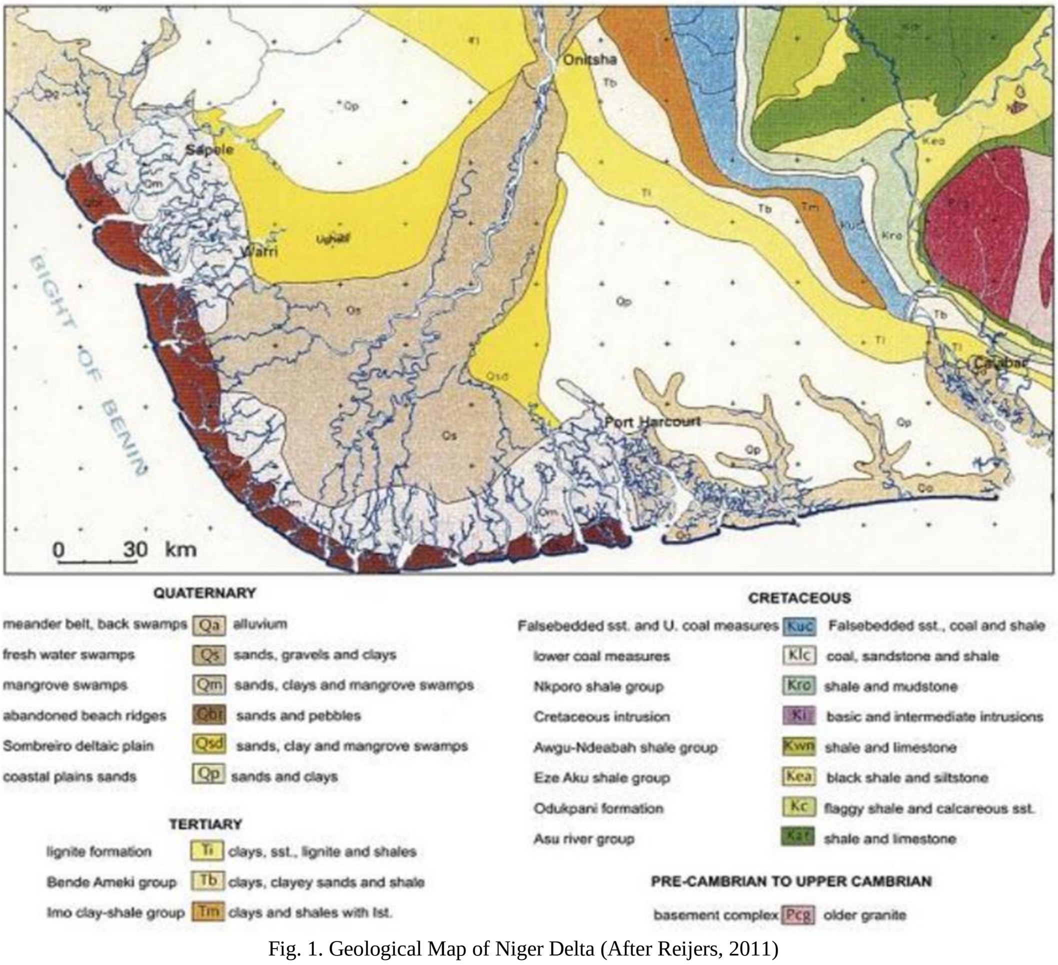

Fig. 1. Geological Map of Niger Delta (After Reijers, 2011)

Uduaka is located within Longitudes 005° 39' 18" E - 005° 39' 25" E, Latitudes 5° 56' 38" N - 5° 56' 45" N and elevation of 87 - 90 m. Uduaka community is located in Oghara, Ethiope West Local Government Area of Delta State, Nigeria.

The study area occupies the Northern part of Delta State which is a sedimentary terrain and is underlain by sedimentary rocks of Paleocene to recent age. The sedimentary rock contains about 90% of sand stone and shale intercalations (Alile et al., 2011). Delat State is situated in South-Southern part of Nigeria. It is an important sedimentary basin in Nigeria due to the closeness to the oil fields within the Niger-Delta region.

2.2. Data Acquisition and Processing

2.2.1. 2D ERI

Twelve (12) traverses were occupied in Uduaka and the data acquired in grid formats (Fig. 2). 2D Wenner resistivity data were acquired along the traverses. The 2D ERI data was processed by inversion of the apparent resistivity data using the DIPRO to generate the 2D inverted resistivity section. The 2D data were collated in RES3D to generate the 3D depth slice. The collated 3D data sets were inverted using EarthImager which automatically determines a 3D model of resistivity distribution using apparent resistivity data obtained from a 3D resistivity imaging survey (Li and Oldenburg 1994; White *et al*. 2001).

2.2.2. Physicochemical analysis

Five water samples from two boreholes and three hand-dug wells were collected from the study area. The water samples were tested for important anions and cations and other parameters based on WHO standards. Important parameters tested are Turbidity, P^H, Conductivity, Alkalinity, Acidity, Chloride, Total Suspended Solids, Total Dissolved Solids, Total Solids, Oil & Grease, Dissolved Oxygen, Biological Oxygen Demand, Sulphate, Nitrate, Nickel, Copper, Chromium and Iron. A characteristic pattern of occurrences of these parameters in the water samples above the minimum standard could effectively suggest the presence of contamination of the groundwater with the septic tank effluents.

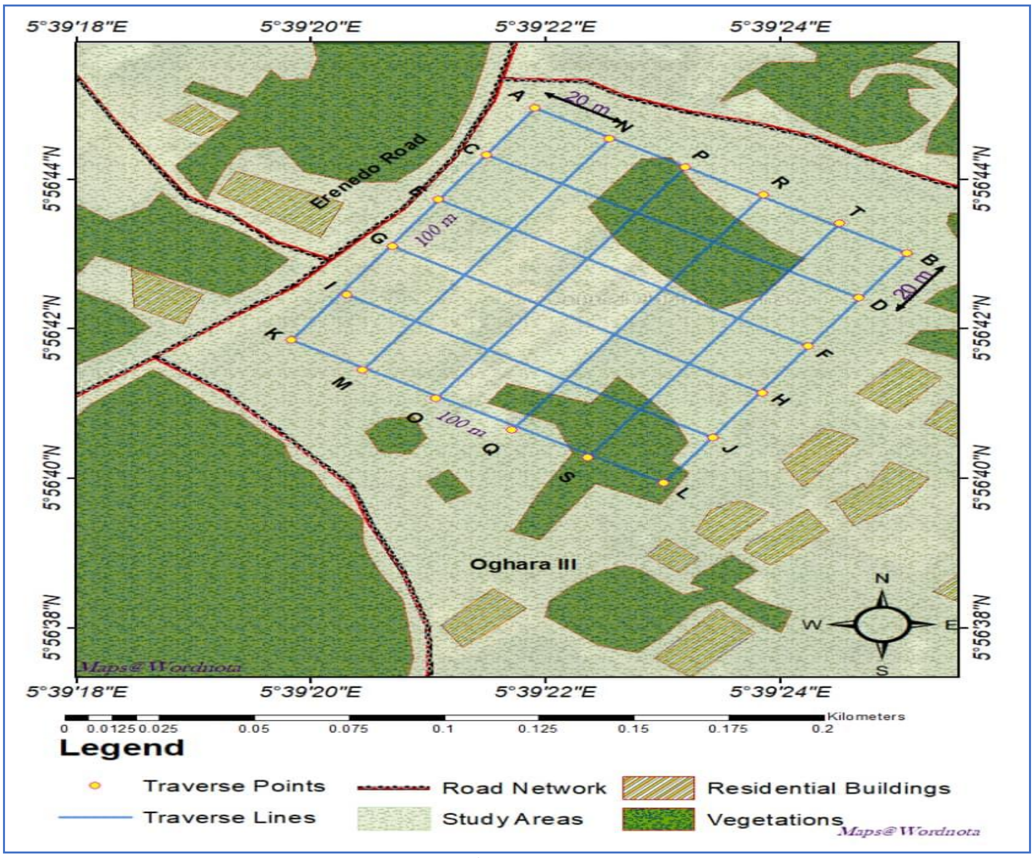

Fig. 2. Field basemap of the study areas showing Uduaka

III. RESULTS AND DISCUSSION

3.1. 2D ERI

Figure 3 (a) and Figure 3 (b) present the 2D ERI sections across traverse 1 – 8 and traverse 9 – 12 respectively. Lateral distance of 100 m was covered and a maximum depth of 25 m was imaged across all the twelve traverses. Resistivity generally varies from 238 – 2563 Ωm in the entire study area. The 2D ERI reveal three (3) to four (4) resistivity structures across each of the twelve traverses which are symptomatic of sand each. The resistivity of the four sandy resistivity structures varies from 238 - 388 Ωm, 471 – 672 Ωm, 816 – 1891 Ωm and 1988 – 2563 Ωm respectively (Fig. 3a and b). It is intuitive to note that two successive 2D sections appear to be similar and this shows that in the study area, the subsurface variation is not profound. The results indicate that there are no suspected contaminations of the subsurface in the area by the supposedly breached subsurface septic tank.

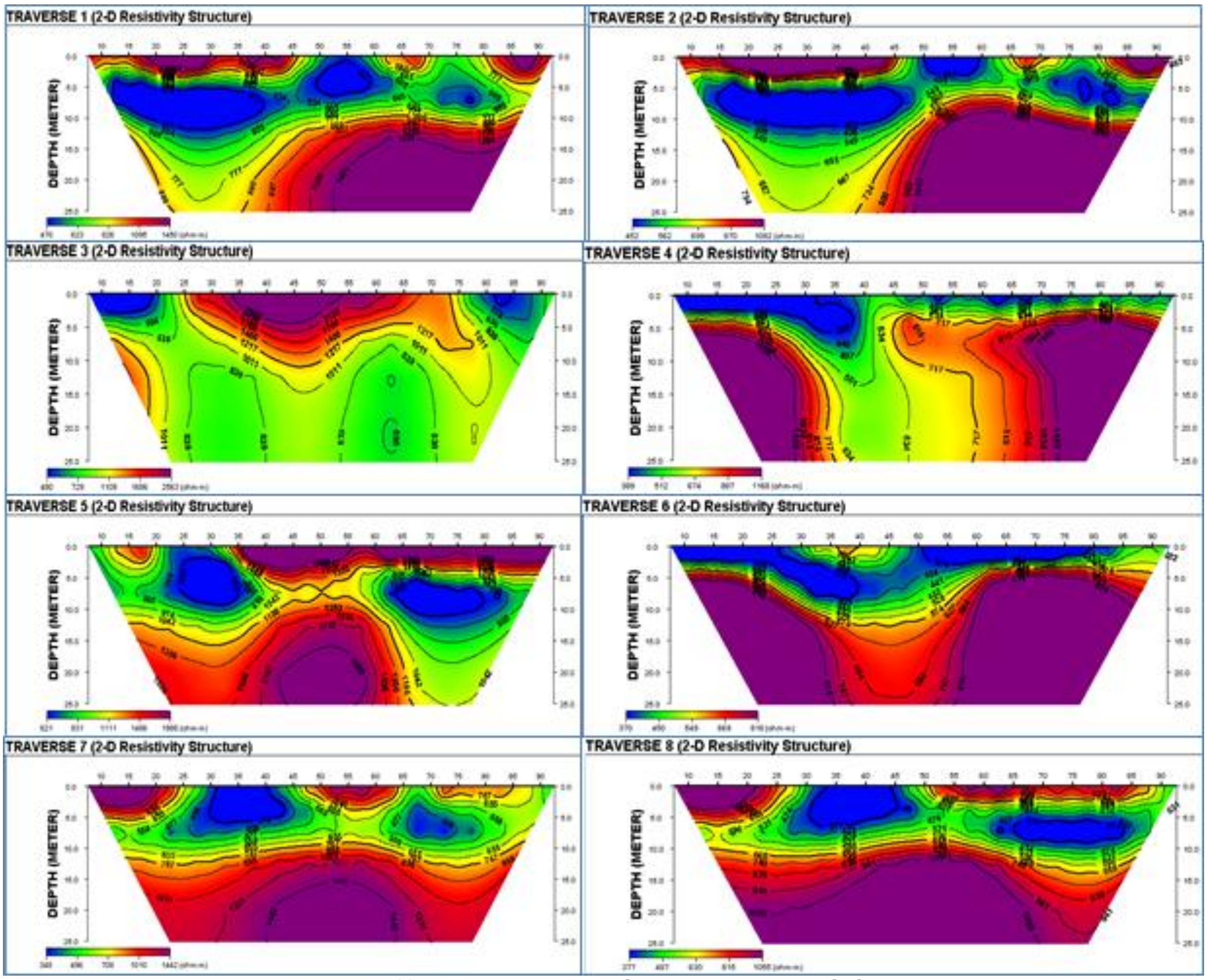

Fig. 3 (a). 2D resistivity sections along traverse 1 to 8 in Uduak

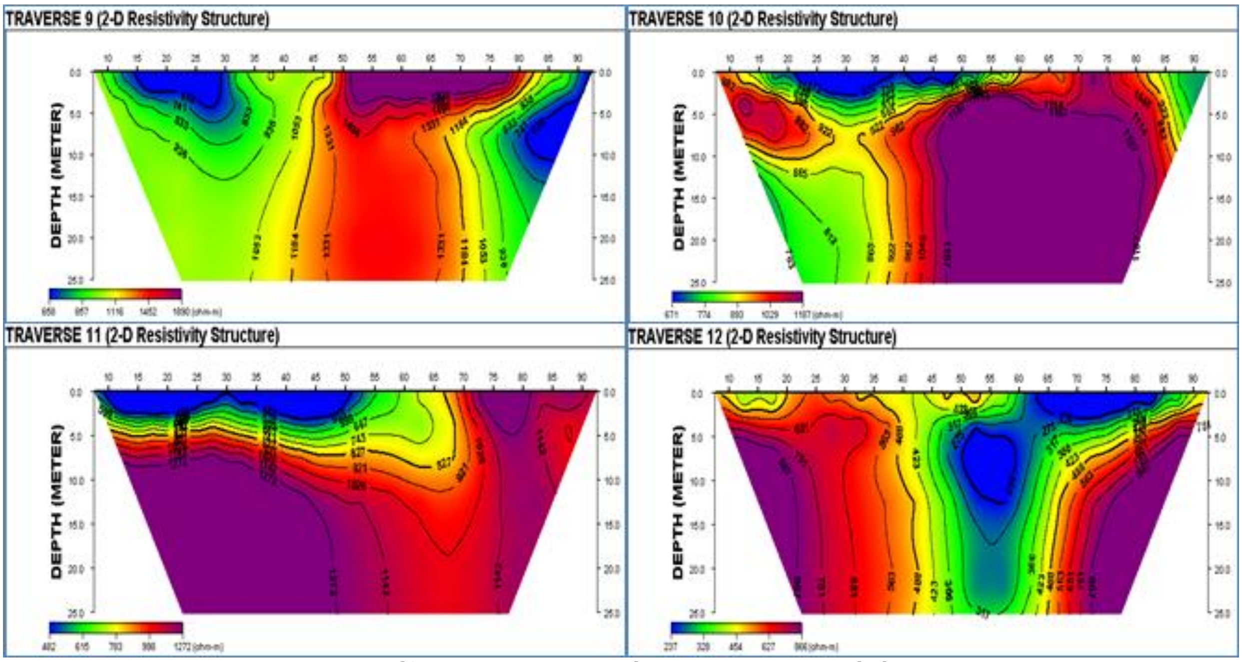

Fig. 3 (b). 2D resistivity sections along traverse 9 to 12 in Uduaka

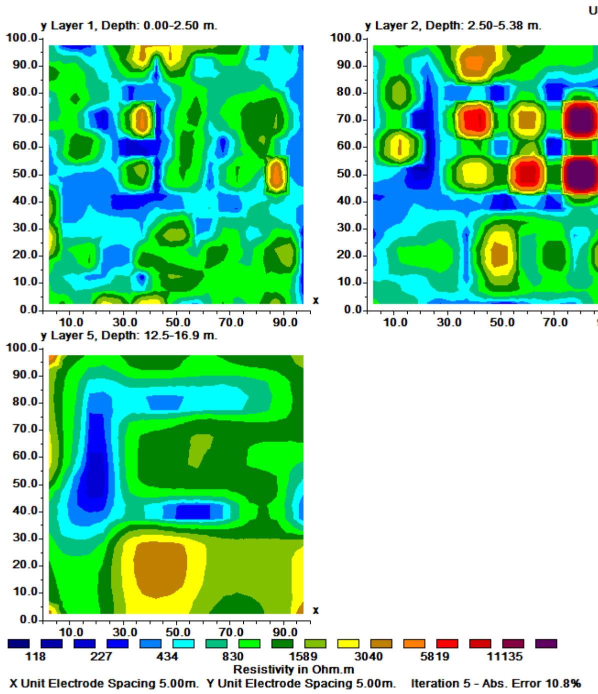

Fig. 4. 3D resistivity depth slice in Uduaka

3.2. 3D Depth Slice

The 3D resistivity depth slice reveal a five layer depth slice of 0 – 2.5 m, 2.5 – 5.38 m, 5.38 – 8.68 m, 8.68 – 12.5 m and 12 .5 – 16.9 m with corresponding resistivity values of 118 – 5819 Ωm, 118 – 11135 Ωm, 118 – 3040 Ωm, 118 – 3040 and 118 – 3040 respectively and which denote clayey sand and sand in the study area (Fig. 4). These results also reveal that no subsurface contamination exists in the study area.

3.3. 3D Resistivity Distribution

The 3D block resistivity distribution in the study area reveals a resistivity distribution of 239 – 2564 Ωm across a depth of 19.8 m (Fig. 5). The spatial distribution of subsurface resistivity in 3D across the study area gives an indication of no suspected indication of effluent contamination from the breached septic tank in the study area. This result is consistent with the results from the 2D ERI and the 3D depth slice resistivity results (Fig. 3 and 4).

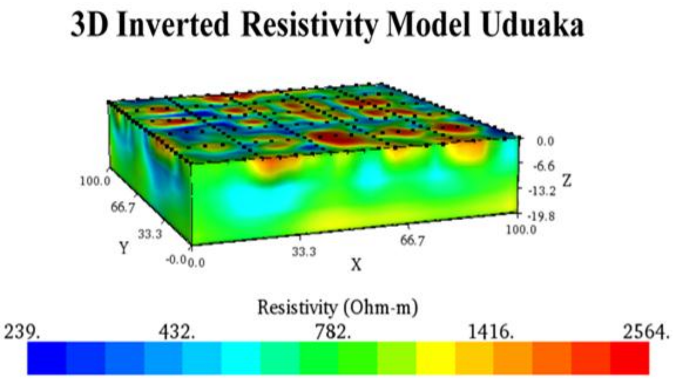

Fig. 5. 3D resistivity distribution in Uduaka

3.4. Physicochemical Analysis

Results from the physicochemical analysis reveal that all water sources tested fall below the permissible WHO limits (Table 1). This is rather consistent as well with the results obtained from the 2D and 3D resistivity imaging except in BH1 and BH2 that show elevated cases of Total Dissolved Solids and Total Solids above the allowable limit and this may be due to the presence of dissolved minerals in the BH source at deep depth.

TABLE 1. Physicochemical Analysis Result

Parameter	**BH 1**	**BH 2**	**Well 1**	**Well 2**	**Well 3**	**WHO Permissible Limit (2017)**
Turbidity NTU	0	5	0	0	0	5 *
pH	6.96	7.70	6.22	6.32	6.19	6.5-8.5
Conductivity (µS/cm)	446	348	543	387	484	1,000*
Alkalinity (mg/L)	8.60	17.3	26.2	13.5	29.0	200
Acidity (mg/L)	50.9	23.2	35.0	28.8	18.7	56
Chloride (mg/L)	88.6	58.7	105	70.5	94.2	250
Total Suspended Solids (mg/L)	ND	70	ND	20	10	
Total Dissolved Solids (mg/L)	780	680	280	200	250	500
Total Solids (mg/L)	230	250	280	220	260	200
Oil & Grease (mg/L)	ND	ND	ND	ND	ND	
Dissolved Oxygen (mg/L)	7.8	7.6	3.4	4.7	3.8	>7.5
Biological Oxygen Demand (mg/L)	28.2	25.8	18.4	14.7	7.80	40
Sulphate (mg/L)	6.71	13.1	4.97	10.6	13.5	250
Nitrate (mg/L)	0.460	2.31	6.27	9.62	8.44	10
Nickel (mg/L)	ND	ND	ND	ND	ND	0.02*
Copper (mg/L)	0.017	0.020	0.026	0.025	0.023	0.07
Chromium (mg/L)	ND	ND	ND	ND	ND	0.05
Iron (mg/L)	0.287	0.241	0.395	0.472	0.456	0.3*

IV. Conclusion

Physicochemical analysis has been integrated with 2D and 3D electrical resistivity geophysical imaging to investigate the suspected contamination of the local groundwater aquifer in Uduaka by a breached subsurface municipal septic tank in the locality.

The results from the 2D and 3D ERI reveal that resistivity values vary from 238 – 2563 Ωm and 118 - 11135 Ωm respectively. These results suggest that no contamination is suspected in the subsurface across the study area. The physicochemical analysis results show that all tested water sources from the study area for important contaminant indicators all fall below the allowable limit except for water sources in BH1 and BH2 with elevated cases of Total Dissolved Solids and Total Solids far above the maximum allowable limit. This is suspected to be due to mineral dissolution in the BH water sources at the deep depth aquifer from which the BHs tap water.

These results are largely consistent with one another. These imply that at present, the local aquifers in Uduaka are suspected to be uncontaminated, not by the failed municipal septic tank in the locality or by any other known source of compromise in the locality. However, it is important to keep a continuous monitoring of the aquifer to detect an onset of contamination. Tracers such as lithium bromide and endospores of Bacillus *globigii* placed in other standing septic tank could help to keep a real time monitoring of the aquifer.

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