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Preprint statement: This article is a preprint and has not been peer-reviewed, under consideration and submitted to ScienceOpen Preprints for open peer review.

DOI: 10.14293/S2199-1006.1.SOR-.PP22T3K.v1

Preprint first posted online: 18 April 2020

Keywords: Aquifer, Pseudosection, Vertical Electrical sounding , 2d resistivity imaging , Leachate, Contaminated zones, Geoelectric section , Shale, Sand , Sandy shale

AN INVESTIGATION OF GROUNDWATER CONTAMINATION AROUND NSUKKA MUNICIPALITY DUMPSITE USING RESISTIVITY METHOD

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Abstract

An investigation using electrical resistivity method was conducted around a solid waste dumpsite at Nsukka in Nsukka L.G.A of Enugu State, Nigeria to investigate the level of groundwater contamination. Electrical Sounding (VES) and 2-D resistivity imaging were used with a digital read out resistivity meter (ABEM SAS 1000) to acquire data in the area. A total of eight (8) sounding and six (6) 2D resistivity imagings were carried out in the area. A contaminant leachate plume was delineated in 2D resistivity sections as low resistivity zones while the VES shows the depth of aquifer. In 2D pseudosections where bluish colours with low resistivities (less than $20.80\Omega\text{m}$) with the depth ranging from 1.28m to 17.1m in the Line 1 and 2 are seen as contaminated zones. The rest of the lines are not contaminated because of their high resistivities (greater than $20.80\Omega\text{m}$). The result of the electrical resistivity survey also showed 4 - 5 layers geo-electric sections and an AA and AK type sounding curves. The VES result shows that VES 1A, 1B, 2A and 2B which are carried out on line 1 & 2 of the wenner lines showed signs of contamination with low resistivity values less than $20.80\Omega\text{m}$ complementing the wenner results. The contamination has not yet got to where the aquifer is located on the lines. Since the depth to the aquifer ranges from 30.26m to 155.43m while maximum depth of contamination is 17.1m. It is believed that the leachate has not percolated down to the aquiferous zones as such aquifers are presumed to be free.

Keywords: aquifer, aquiferous zone, pseudosection, geoelectric section, vertical electrical sounding, 2d resistivity imaging

Introduction

Management of solid waste landfills has been a major problem of our urban centers in Nigeria and other developing economies worldwide. In these urban centers, wastes are generated daily and disposed indiscriminately in rivers and landfills without recourse to the environment, local geology and their proximity to the living quarters.

Wastes, which are described as materials that result from an activity or process but have no immediate economic value or demand and must be discarded, have been managed in a manner that has made the quest of the government to positively actualize the mega city status a difficult task. In Nsukka, like in most other cities, wastes are generated daily and most of the wastes are discarded in improperly situated and dumping sites that are not engineered. Most of the dumping sites are located within residential areas, markets, farms, roadsides, and others. This threatens the groundwater and road facilities, not sparing the aesthetics of such affected areas. Unarguably, uncontrolled citing of boreholes as the source of potable water in most of our urban and rural communities as the government seemingly no longer provides the populace with water has become a serious challenge. However, maintaining a portable groundwater supply that is free from microbial and chemical contaminants is far from reality in most of our urban centers, and in particular Nsukka municipality, due to poor waste disposal and management practices. The challenge is worsened by the fact that there are inadequately trained waste disposal personnel and equipment, poor waste collection, sorting and disposal methods, and indiscriminate location of disposal sites without regards to the local geology and hydrogeology of the area. All these contribute significantly to the contamination of soil and ground water. Recent industrial development and increased urbanization in the municipality have resulted to enormous generation of all kinds of waste ranging from municipal to industrial. The type of waste generated varies widely with many human activities located close to dumpsites. During the peak of the rainy season, some part of the dumpsite is covered by flood water and this contributes to the formation of leachate. It is this contaminated liquid that enters into the soil and also eventually into the underlying groundwater at such dumpsites. The manner of disposal points to the fact that solid waste management is one of the greatest challenges facing state and local government environmental protection agencies in Nigeria.

Solid waste landfills (SWL) have become a popular waste management system for the disposal of all manner of waste materials in the municipality. As a result of the imminent impact of solid waste landfills,

it has become necessary to investigate the potential for the contamination of soil and groundwater around a municipal solid waste landfill.

Over the past few decades, growing populations have increased the pressure on natural resources, raising demands for water supply, housing and infrastructure. This pressure can be expected to rise, and combined with environmental stress caused by population. There is a growing need for detailed geological studies connected to environmental protection and infrastructural development (Dahlin, 2001). In developing countries, the lack of resources is the key issue for waste and landfill management. Disposal of waste into open landfill is a cheap method, and it will continue to be the dominant method of waste disposal for the foreseeable future. The most common way of waste disposal in Nigeria and other developing countries is open dumping. Dumping sites are usually uncontrolled, creating considerable health, safety and environmental problems (Pugh, 1999). Maintaining and protecting current water supplies and developing new sources of clean water are essential as modern society expands and civilization continues to develop. Moreover, open waste disposal site often lack reliable geological or artificial barriers, so that leaching of pollutants into the groundwater is a concern, particularly for waste dumped in borrow pits, many of which extend to below the groundwater table. Details on the contents of a dumpsite may be difficult to acquire but are essential for evaluating the level of risk associated with leaking pollutants. In such context, the integrated use of geophysical methods provides an important tool in the evaluation and characterization of contaminants generated by urban residues (domestic and/or industrial), (Soupio *et al.*, 2005 ; Soupios *et al.*, 2006). Among those geophysical methods, electrical methods have been found very suitable for such kind of environmental studies, due to the conductive nature of most contaminants. The use of electrical methods applied to environmental studies is well documented (Karlik and Kaya, 2001; Aristedemou and Thomas-Betts, 2000)

Location and Accessibility of Study Area

The study area is located behind Old Ikenga Hotel off UNN- Ezeimo road Nsukka, Nsukka Local Government Area of Enugu State, Southeastern Nigeria. The area lies between longitudes 7°21'6.3"E - 7°22'12.0"E and latitudes 6°50'4.05"N - 6°50'52.0"N. It spreads over area of about 89.6 km² as shown in fig. 1.1. The study area can be accessed through the notable Ezeimo Road off Odenigbo Junction. Nsukka is located in the Northern fringes of Enugu State. It is about 53.5 km North of Enugu Metropolis. Nsukka is situated in Enugu North Senatorial Zone and is notable for hosting the popular University of Nigeria Nsukka. Towns that share a common border with Nsukka are Edem Ani, Alor – uno, Opi, Orba, Ede –

Oballa and Obima. Nsukka Local Government Area has an area of 484 km² and a population of 309,633 at the 2006 census (National Population Commission of Nigeria, 2006).

Before landfilling, the study area was an excavation site and landfilling started in the second quarter of 2011 by open dumping from the hotel management and the residents before it became a permanent dumpsite for Nsukka municipality. Fig. 1 shows a part of the dumpsite and its constituents.

N06° 50' 52.0"
E007°21'6.3"
Elev 456.2m

N06° 50' 52.0"
E007°22'12.0"
Elev 435.5m

LEGEND:

	Profile line
	Old Ikanga House
	VES point
	Area of ranges of soilings
	Dumping concentration
	Dumping

AREA OF STUDY = 89600m²

Fig 1.1: A sketch of Nsukka municipality dumpsite

Fig. 2: Nsukka Municipality Dumpsite showing its surface compositions (Photograph)

Materials and Methods

The basic equipment used for this geophysical survey is the ABEM SAS 1000 resistivity meter.

The resistivity meter is equipped with a 12 volts battery, two current transmission cables on reels, two potential cables, four metal electrodes and a salt solution. Auxiliary equipment for the survey consisted of a Global Positioning System (G. P. S), to determine the resistivity survey locations and topography, geologic hammers for driving electrodes into the ground, two measuring tapes and cutlasses for clearing traverses.

The study involved the use of electrical resistivity method. The methods adopted are Vertical Electrical Sounding (VES) in combination with 2D resistivity imaging. The sounding was used to characterize the various lithologic units and to determine the depth to water table while the resistivity

imaging was used to substantiate the result of the sounding as well as to determine the presence of leachate contaminants and the direction of groundwater flow.

Results and Discussions

A total of eight (8) Vertical Electrical Sounding (VES) using Schlumberger array and six (6) 2D resistivity imaging using Wenner array were conducted around the dumpsite.

The VES field data were processed using the Schlumberger automatic INTERPEX analysis software, which generates model curves using initial layer parameters while the 2D resistivity field data were processed using the RES2DINV inversion software, which subdivides the subsurface into blocks and uses the square inversion to determine the values of each block.

4.1 The Qualitative Interpretation for VES 1

Sounding curve analysis aims to obtain the equivalent subsurface layering of the apparent resistivity curve. The qualitative interpretation of the profile and depth sounding curve were carried out based on distinctive geoelectric parameters on the number of layers represented by the four types of auxiliary curves (A, H, K and Q). VES I curve type is AA and it has four geoelectric layers. The summary of qualitative interpretation of VES curves is shown in Table 1.

TABLE 1: SUMMARY OF QUALITATIVE INTERPRETATION OF VES CURVES

VES	CURVE TYPE	RESISTIVITY PROFILE	NUMBER OF LAYERS
1A	AA	$\rho_1 < \rho_2 < \rho_3 < \rho_4 < \rho_5$	5
1B	AA	$\rho_1 < \rho_2 < \rho_3 < \rho_4$	4
2A	AK	$\rho_1 < \rho_2 < \rho_3 < \rho_4 > \rho_5$	5
2B	AK	$\rho_1 < \rho_2 < \rho_3 < \rho_4 > \rho_5$	5
3A	AK	$\rho_1 < \rho_2 < \rho_3 > \rho_4$	4
4A	AK	$\rho_1 < \rho_2 < \rho_3 > \rho_4$	4
5A	AA	$\rho_1 < \rho_2 < \rho_3 < \rho_4$	4
6A	AA	$\rho_1 < \rho_2 < \rho_3 < \rho_4 < \rho_5$	5

Out of the eight VES curves four (4) showed AA type of curve (VES 1A, 1B, 5A and 6A) as deduced from the resistivity profile while the others depicted AK type of curve.

VES 1A, 2A, 2B and 6A showed 5 geoelectric layers while the others only had 4 geoelectric layers.

1.2 Quantitative Interpretation

The stations were represented and interpreted as VES 1A to 6A as shown in Table 4.2. VES 1A and 1B were carried out at 25m and 75m respectively on profile 1. The same also goes with 2A and 2B but 3A to 6A were carried out at 45m mark of their respective profiles.

TABLE 2: SUMMARY OF VES INTERPRETATION RESULTS

VES	Layers	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology	Curve type
1A	1	0.81	2.53	2.53	Contaminated lateritic clay	AA
	2	38.31	27.00	29.53	Clay	
	3	61.14	43.33	72.86	Shale	
	4	340.44	56.22	129.08	Aquiferous sand	
	5	3225.40	-	-	Ferrogenized siltstone	
1B	1	2.40	5.03	5.03	Contaminated lateritic clay	AA
	2	9.14	24.03	29.07	Clay	
	3	95.00	73.21	102.28	Shale	
	4	420.25	-	-	Aquiferous sand	
2A	1	18.33	5.33	5.33	Contaminated lateritic clay	AK
	2	120.44	35.44	40.77	Sandy shale	
	3	530.23	48.33	89.10	Sand	
	4	1010.30	66.33	155.43	Ferrogenized siltstone	
	5	530.33	-	-	Aquiferous sand	
2B	1	20.21	6.54	6.54	Contaminated lateritic clay	AA
	2	196.40	35.31	41.85	Sandy clay	
	3	460.15	68.91	110.76	Aquiferous sand	
	4	900.34	77.44	188.20	Sandstone	
	5	440	-	-	Aquiferous sand	
3A	1	71.94	30.26	30.26	Shale	AK
	2	369.40	46.49	76.75	Aquiferous sand	
	3	948.86	69.78	146.53	Sandstone	
	4	640.44	-	-	Sandstone	
4A	1	130.33	5.33	5.33	Sandy shale	AK
	2	200.87	40.32	45.65	Aquiferous sand	
	3	1300.30	66.83	112.48	Ferrogenized siltstone	
	4	730.87	-	-	Sandstone	
5A	1	75.98	5.84	5.84	Shale	AA
	2	126.33	30.26	36.10	Aquiferous sandy shale	
	3	624.55	61.69	97.78	Sandstone	
	4	1100.20	-	-	Ferrogenized siltstone	
6A	1	90.58	5.45	5.45	Shale	AA
	2	153.50	25.05	30.50	Sandy shale	
	3	266.14	49.50	80.00	Aquiferous sand	
	4	785.34	65.34	145.34	Sandstone	
	5	1120.33	-	-	Ferrogenized siltstone	

Field Results and Discussion for Wenner,

The electrical resistivity images of the earth's subsurface obtained in the study area are presented in Fig. 6 - 11. The results of the Interpreted 2D Electrical resistivity data are presented in a colour coded format consisting of the Inverted 2D Resistivity structure. The horizontal scale on the section is the lateral distance while the vertical scale is the depths which are both in meters. The resistivity models shown were obtained by the optimization technique of RES2DINV by minimizing the difference between the calculated and measured pseudosections of the apparent resistivity data sets in unison with the result of Kumar *et. al.*, (2009) and Udom *et. al.*, (1999). This is done by plotting apparent resistivity against the pseudo-depth. The contaminated zone resistivities ranges from 0 – 20.8Ωm

Fig. 3: Wenner interpreted 2D pseudo section for profile 1

Fig. 4: Wenner interpreted 2D pseudo section for profile 2

Fig. 5: Wenner interpreted 2D pseudo section for profile 3

Fig. 6: Wenner interpreted 2D pseudo section for profile 4

Fig. 7: Wenner interpreted 2D pseudo section for profile 5

Fig. 8: Wenner interpreted 2D pseudo section for profile 6

Discussions on the Profiles

Profile 1: Profile 1 showed a total of 8 layers with the total depth of vertical probe being 17.10m and horizontal being 92.5m. From the surface down to approximately depth of 13m, there are indications of contaminated or leachate plume zones as represented by low resistivity values ranging from $1.19\Omega\text{m}$ – $10.30\Omega\text{m}$ and indicated by the bluish colour on the section. The contaminated zone covers the entire surface of the line.

Profile 2: Profile 2 showed a total of 8 layers with the maximum probed vertical depth being 17.1m while horizontally 92.5m was probed.

At the surface distances of 7.5m to 10m, 26m to 34m and 53m to 68m, there are indications of contamination as seen in the dark bluish colour in the pseudo – section. This contaminated zone is represented by low resistivity values of $20.8\Omega\text{m}$ and has percolated the entire probed depth of 17.1m, where it appears concentrated.

Percolation is suspected to be through pore spaces of clayey materials at the top.

Profile 3: This Profile is located at the Eastern end outside the dumpsite. It runs in the North to South direction. In this profile the total depth of vertical probe is 17.1m while horizontal is 92.5m. Eight (8) layers were encountered. Characteristically, profile 3 does not show any evidence of contamination at the surface as captured by the resistivity values. Topographically, profile 3 is atop the higher plains of the gently sloping site terrain with the shale exposed at the surface. This runs from about 10.1m to 92.5m laterally with a depth ranging from the beginning of the line which is 1.28m to 17.1m.

Profile 4: This Profile is located at the Northern end of the dumpsite. It runs in the Northeast to Southwest direction. Profile 4 showed a total of 8 layers with the total depth of 17.1m and the lateral probe of 92.5m. Profile 4 does not show any evidence of contamination at the surface as indicated in fig 4.4 by the resistivity values. Significantly, these values represent sandy shale exposure seen at the surface. The sandy shale covers the entire surface and almost the entire model. Profile 4 sits at the upper part of the dumpsite.

Profile 5: Profile 5 is located at the Southern end of the dumpsite. It runs in the West to East direction. Profile 5 showed a total of 8 layers with the total depth of vertical probe being 17.1 while horizontally 92.5m was investigated. The surface layer indicates shale with resistivity values ranging from 89Ωm to 99Ωm.

Notably, Profile 5 is also situated on the upper plains of the site and runs across the site. From the higher plains down to the lower plains.

Profile 6: This Profile is located at the Southern end outside the dumpsite. It runs in the West to East direction.

It was used as a control line in the cause of this work. Profile 6 was about 100m away from the dumpsite. Subsequently, profile 6 did not show any evidence of contamination.

However, a shale body was revealed by the survey with a depth running from 3.85m down to about 14.4m, laterally from 48m to 78m

This body was depicted by the resistivity values of 80Ωm, 86Ωm and 90Ωm.

Profile 6 depicted the shale nature of the soil surface within the vicinity as was indicated by resistivity values of 51Ωm and 54Ωm.

Conclusion

Groundwater pollution in urban areas is a growing environmental problem worldwide, especially as many urban areas in Nigeria and beyond depend on groundwater for drinking purposes. The results of the electrical resistivity investigation of solid waste using VES and 2D resistivity imaging at Nsukka in Nsukka Local Government Area of Enugu State, Nigeria has enabled us establish contamination of the subsurface environment and the depth of aquifer.

The result of the electrical resistivity investigation of solid waste using VES and 2D resistivity imaging revealed that maximum depth of migration of leachate plume is 17.1m as shown in profile 2 while the minimum depth is from the surface as shown in profiles 1 & 2.

In the course of this study six (6) lines were investigated of which 2 were determined to be contaminated (profile 1 & 2). The contaminated zones or leachate plumes were observed to have resistivity value ranging from 1.19 – 20.80Ωm and were suspected to be migrating through the fractures, joints and weathered zones in the shaley clay layers that characterized the upper parts as seen in the geoelectric sections of VES.

Profile 3, 4, 5 & 6 did not reveal any evidence of contamination from the VES and horizontal profiling resistivity values. This is suspected to be due to the impermeable shale and ferrogitized siltstone. Overburdens combined with the gentle sloping topography of the dumpsite as profiles 1 & 2 lie in the lowest plain of the site.

VES carried out at the dumpsite showed that the aquiferous zone ranges from 30.26m to 155.43m.

Out of the 8 soundings done, 4 indicated pollution at the surface. VES 1A, 1B, 2A & 2B which were done on profiles 1 and 2 showed contaminated surface lithologies. Marked by low resistivity values, with a maximum depth of 6.45Ωm. The geoelectric layers revealed litho – units as shale, clay, sand, siltstone and ferrogitized siltstone with sand being the water bearing unit.

Consequently, since the depth to the aquifer ranges from 30.26m to 155.43m while maximum depth of contamination is 17.1m. It is believed that the leachate has not percolated down the aquiferous zones as such aquifers are presumed to be free.

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