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Delineation of leachate plume migration by electrical resistivity methods *Ile Epo dumpsite, Lagos, Southwestern Nigeria*

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Abstract

Five traverses 2D resistivity survey and 20 Vertical Electrical Sounding (VES) points were carried out on Ile Epo Dump Site with a view to inferring the extent of migration of leachate plumes in the subsurface for possible contamination of groundwater. The surveys were carried out with Omega model resistivity meter. The Schlumberger configuration was employed for the VES while Wenner configuration was employed for the 2D resistivity survey (Constant Separation Techniques). The obtained VES and CST data were interpreted using WinResist and DIPRO respectively. The integrated results revealed three to four geo-electrically polluted materials as highly saturated fills (less than 15 Ωm, 1.9 – 27.4m), saturated fills (15 - 30 Ωm, 3.6 – 29.9m) and unsaturated fills (30 - 70 Ωm, 8.1 – 37.1m) underlain by sand formation. The resistivity values of the highly saturated zone mostly did not exceed 7 ohm m as appears in figure 3, 4, 5, and 6. A good correlation was established between the thickness of the different fills delineated from the VES and CST results to a depth of 30m. Based on the integrated geophysical investigation, it is therefore concluded that aquifer units within and underlying the sand layer around Ile Epo Dumpsite and environs are potentially polluted. However, for groundwater exploration, aquifers at deeper depth are likely to be free from contamination but required time to time monitoring because the underlying sand layer serves as possible migration path to the pollutants, thereby contaminating aquifers within underlying sand layer.

Keywords: electrical resistivity, groundwater, Ile ekpo, pollutants

Introduction

Characterization of groundwater conditions of landfills and the location of subsurface contaminants have always been challenging. Conventional environmental monitoring that is used to determine the spread of groundwater contamination is performed by the expensive and labor intensive task of drilling closely spaced boreholes for point sampling [1].

More advanced, non-invasive geophysical techniques that are less costly and more environmental friendly have been developed as tools for interpreting the subsurface structures undisturbed. Contaminant plumes usually have a sufficiently high contrast in physical properties against the host media due to an increase in dissolved salts in the groundwater and a resulting decrease in pore water resistivity. Therefore they may be detected by geo-electrical techniques [2]. The generation of leachate in a landfill results principally from the flow of percolating water through waste materials [3].

The evolution of leachate composition in a waste landfill site typically follows a four-stage decomposition process from aerobic, anaerobic, methanogenic and returning to aerobic conditions as degradation nears completion [4]. The aerobic and methanogenic phases generate high concentration and acidic leachate, which has high contaminative potential and the potential to mobilize metals.

In Nigeria, a lot of households in the urban and peri-urban areas rely on groundwater abstracted from boreholes and hand-dug wells for domestic uses. However, rising population, changes in land use

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and rapid industrialization is increasingly placing soil and groundwater at risk of contamination. Contamination of the subsurface can take place in many ways: pollution of groundwater or soil through direct contamination, saltwater intrusion, or leakage from buried waste, landfills and even cemeteries [5]. Land use such as landfilling, which produces leachate has been found to be one of the major sources of contamination of groundwater [6].

Non-organic (ionic) groundwater contamination from leachate usually results in an increase in the conductivity of the groundwater [7].

Groundwater contamination is defined as the introduction into water of any substance in undesirable concentration not normally present in water. The contaminant spreads mostly laterally in the direction of groundwater movement. Groundwater contamination can be from natural sources or from man-made activities or both [8].

Wastes may be loosely defined as any material that is considered to be of no further use to the owner and is, hence discarded [9]. Waste is generated universally and is a direct consequence of all human activities. They are generally classified into solid, liquid and gaseous.

In most low to medium income developing nations, almost 100 per cent of Municipal Solid Waste (MSW) generated goes to landfills [9]. Land filling remains the most important technology for municipal solid waste management [10].

Lagos State as an industrialized city generates very high amounts of waste annually but does not have a technologically advanced means of waste disposal. Iyana Ipaja is one of the busiest parts of Lagos. It can be described as one of the most populated areas in Lagos metropolis hence contributes significantly to the amount of waste generated in the state. The means of waste disposal like that of many industrialized towns in developing countries is the use of open dump landfills. This is an improper solid waste management system which is globally accepted as the major cause of environmental pollution in the world.

A number of works have been done using electrical resistivity survey. Leachate contamination effect on groundwater was investigated [11]. Karlik and Kaya (2001) worked on investigation of groundwater contamination, but the methodology involved was very low frequency electromagnetic method (VLF-EM), a case study of Isparta Turkey [12].

Spalding et al (2008) investigated the effects of sludge disposal on groundwater nitrate concentration which was aimed at delineating plume of nitrate contamination using geo-electrical and hydro-chemical survey [13].

Amidu and Olayinka (2006) worked on the environmental assessment of sewage disposal system using 2D electrical resistivity imaging and geotechnical analysis; a case study from Ibadan, Nigeria [14].

Hamzah et al (2007) dealt on groundwater investigation, a case study in Kuala Selangor using Vertical Electrical Sounding (VES) resistivity method [15].

This study is driven by the desire to investigate the geologic structure of the aquifer with a view to assessing the pollutant risk of the aquifer to the seepage of contaminants near Ile- Epo landfill in the Agbado Oke - Odo Local Council Development Area. This became necessary as the inhabitants in the study area depend mostly on groundwater for their water supply needs.

Geologic Setting

Ile Epo Lagos falls between N6^{0}62’ to N6^{0}65’ and E3^{0}28’ to E3^{0}32’ within the eastern Dahomey Basin of southwestern Nigeria Figure-1

Lagos is basically a sedimentary area located within the Western Nigeria coastal zone, a zone of coastal creeks and lagoons developed by barrier beaches associated with sand deposition.

The subsurface geology reveals two basic lithologies; clay and sand deposits. These deposits may be inter-bedded in places with sandy clay or clayey sand and occasionally with vegetable remains and peat [16]. The entire area is covered by mangrove forest, raffia palm trees, scrub, scattered cultivated areas, and stilt rooted trees. The tall grasses and woody plants cover the sandy plains. The main relief features of the area is the low lying nature of its terrain, more than half of the entire area has an elevation of between 3 and 6 meters high above the sea level [17]. It is identified that the geology is made up of sedimentary rock mostly of alluvial deposits. These consist of loose and light grey sand mixed variously with varying proportion of vegetation matter on the lowland, while the reddish and brown loamy soil exits in the upland.

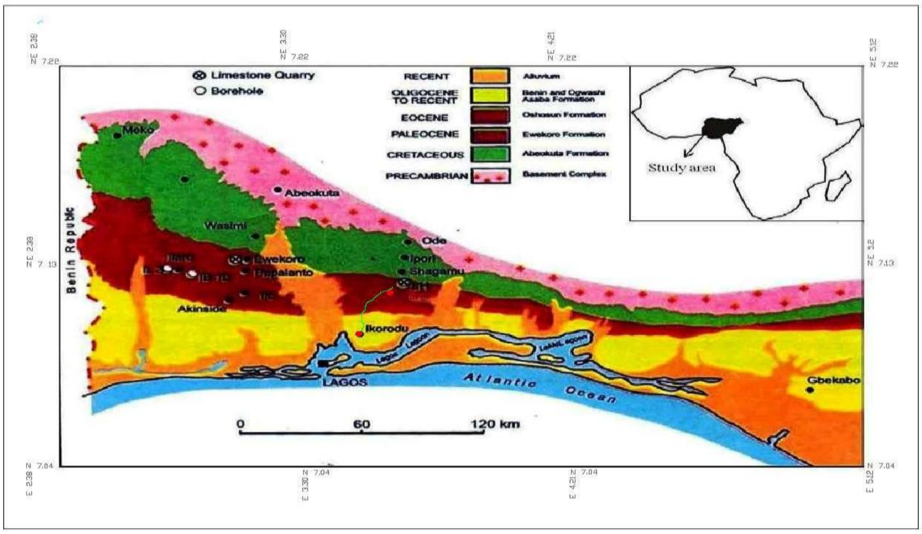

Figure 1-Geological map of Lagos State [7].

Methodology

A five (5) traverses of electrical resistivity imaging were carried out using a four-electrode system using Wenner Array. The spacing "a" was 10m at the beginning and progressively increased until a maximum of 60m was attained on each traverse with the aid of Omega resistivity meter. Each of the 2D resistivity imaging extends through traverse of 200m along the west east direction. The 2D inverse resistivity models of the subsurface were obtained from the input resistivity data.

20 Vertical Electric Sounding (VES) where carried out (4 VES points along each traverse) to investigate the change in earth resistivity with depth at each location. The electrodes were arranged symmetrically about a center, with increasing distances between electrodes for progressive increase depth of exploration.

The Schlumberger array was employed with a spread varying between 1m to 200m and station interval ranging from 25m to 30m Figure-2.

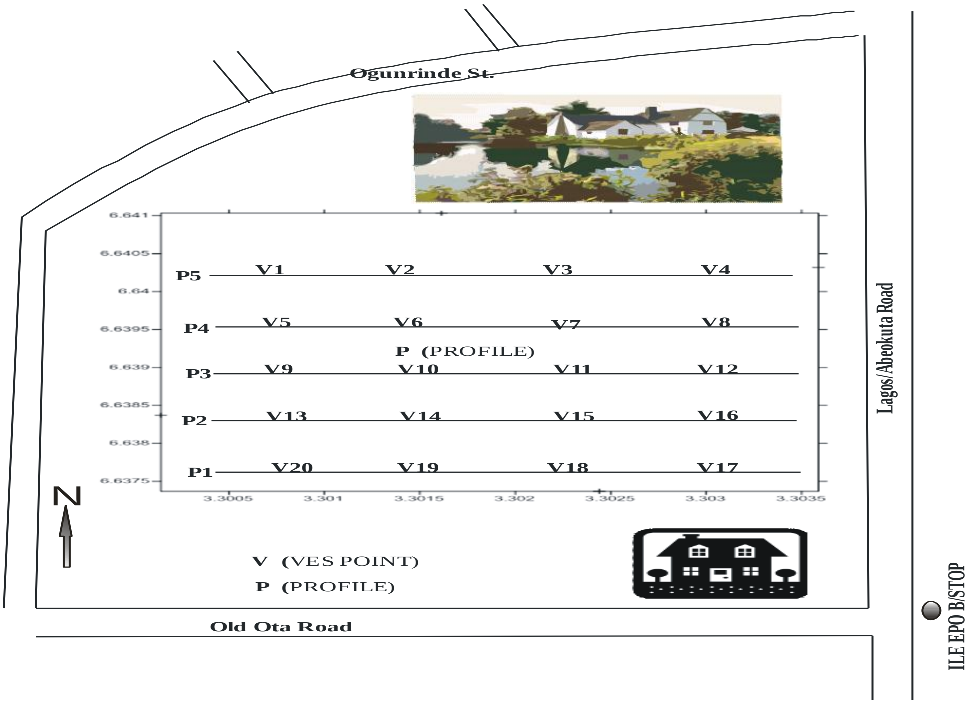

Figure 2-Map of study area

The VES apparent resistivity data at each station were plotted against half current electrode spacing (AB/2) on bi-logarithmic graph sheets, using a transparent tracing paper superimposed on the log-log paper. The curves obtained were matched using the electrode configuration master and auxiliary curves to determine lithologic layer resistivities and thickness.

The resulting geologic parameters were fed into the computer as a starting model in an iterative forward modeling technique using WinRESIST to eliminate erroneous interpretations arising from manual techniques. The processed data were presented in the form of 1-D resistivity models, inferred sediments and geo-electrical sections.

Results And Discussion

Figure-3 shows the 2D resistivity inversion along traverse 1. It describes polluted materials ranging from highly saturated to unsaturated fills down to a depth of about 30m. The envisaged pollutant in the area is a composite one from diverse sources and substances: refuse comprising waste, metallic and non-metallic substances, and other anthropogenically derived materials. Hence the resistivities measured reflect the composite nature of the pollutant.

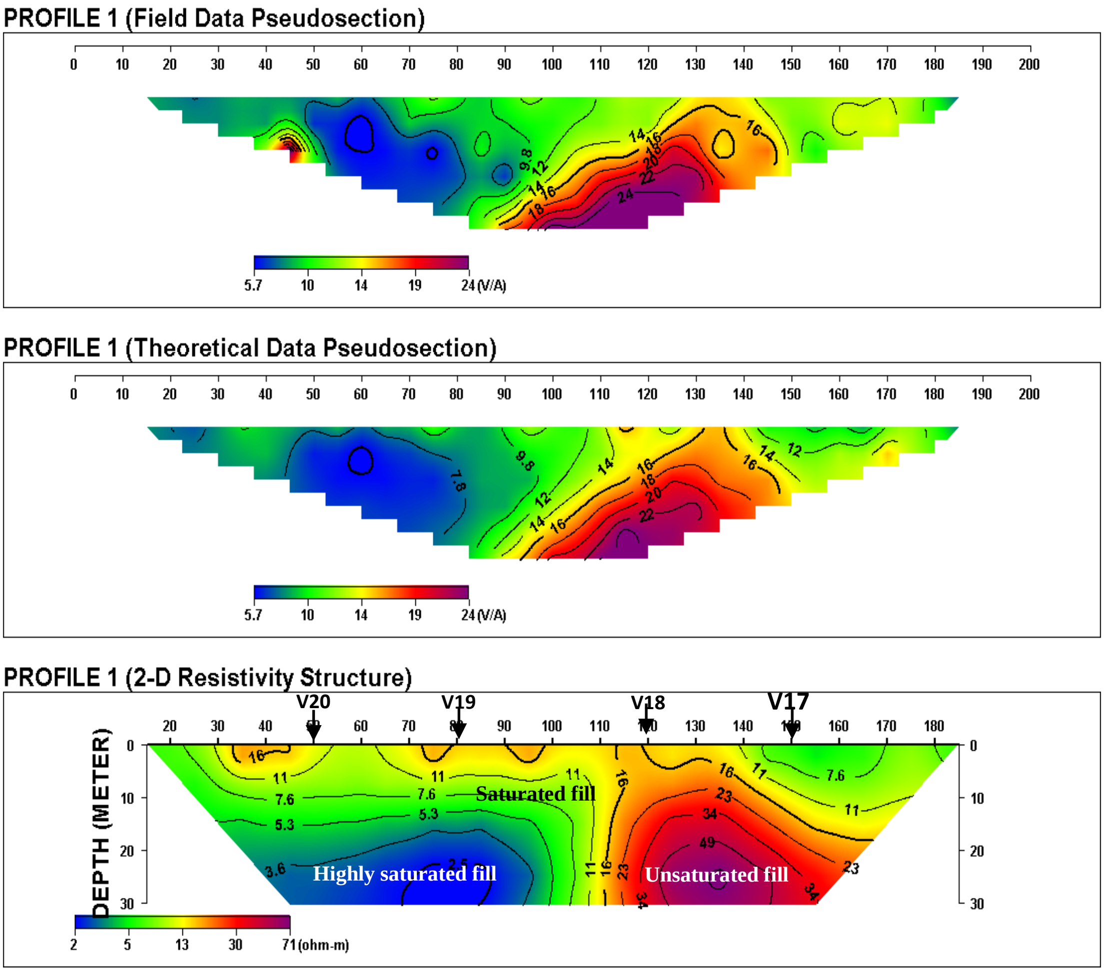

Figure 3-the 2D resistivity inversion along traverse 1

Figure-4 shows the 2D resistivity inversion along traverse 2. This profile is 30 m northward of profile 1, is characterized with resistivity contrast of 2 – 111 Ωm and illustrating saturated, highly saturated and unsaturated fills to a depth of 30 m.

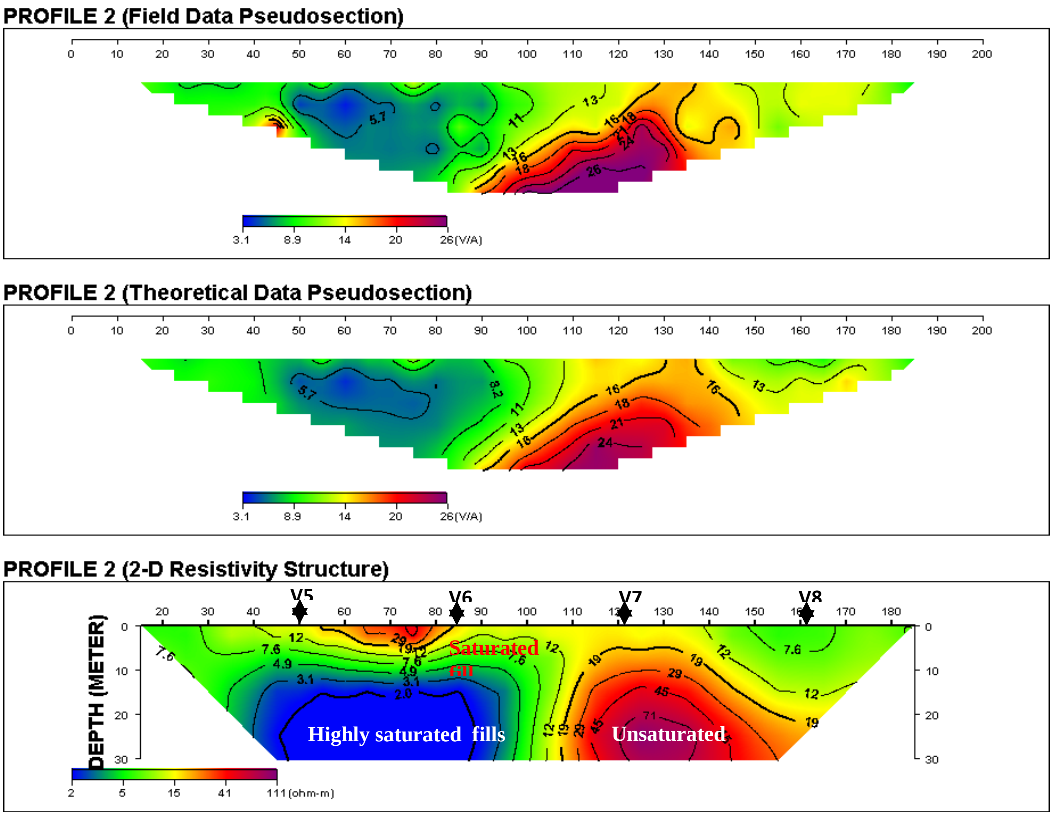

Figure 4-the 2-d resistivity inversion along traverse 2

Figure-5 shows the 2D electrical resistivity inversion along traverse 3 which is situated at 25m northward from profile 2. It is characterized by polluted zones which ranges from highly saturated, unsaturated and saturated fills. The highly saturated fill as in previous profiles are mapped in the left hand side of the profile and unsaturated fills also mapped in the right hand side of the profile while saturated fills overlie the highly saturated and unsaturated fill.

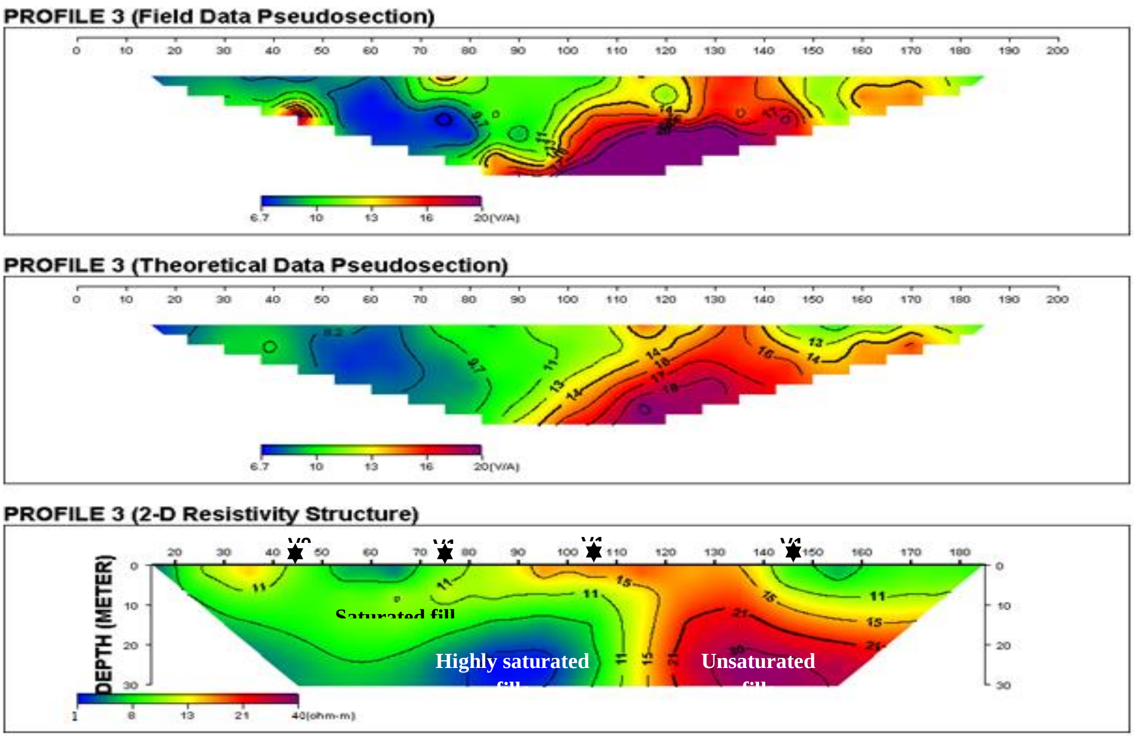

Figure 5-2D resistivity inversion along traverse 3

Figure-6 shows the 2D electrical resistivity inversion along traverse 4 which is close the site entrance from the northern axis of the study area. It shows polluted zones as unsaturated fill with thin lenses of the saturated fills. The saturated fills comprise thin lenses overlying the unsaturated fills. Highly saturated fill is conspicuously absent in this traverse.

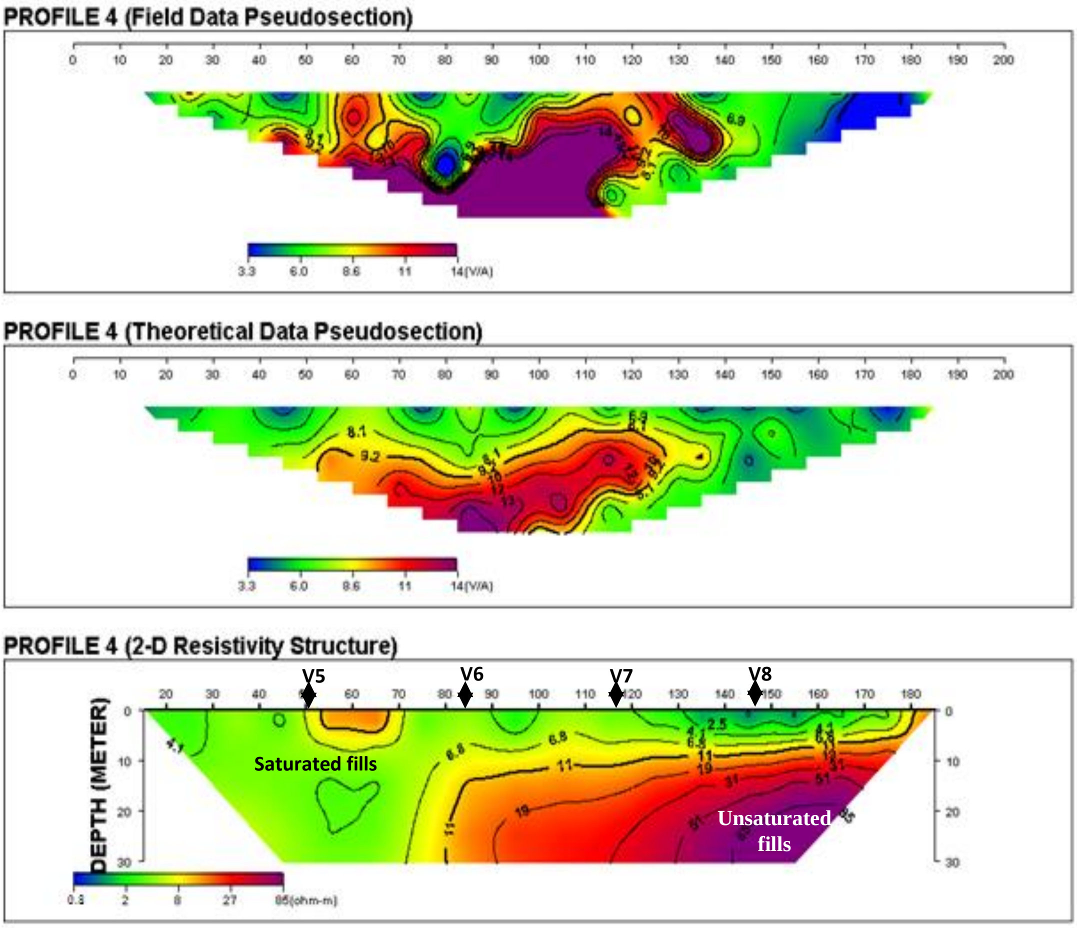

Figure 6-2D resistivity inversion along traverse 4

Figure-7 shows the 2D resistivity inversion along traverse 5. This profile depicts polluted zones as saturated and unsaturated fills. The highly saturated fill is absent in this profile.

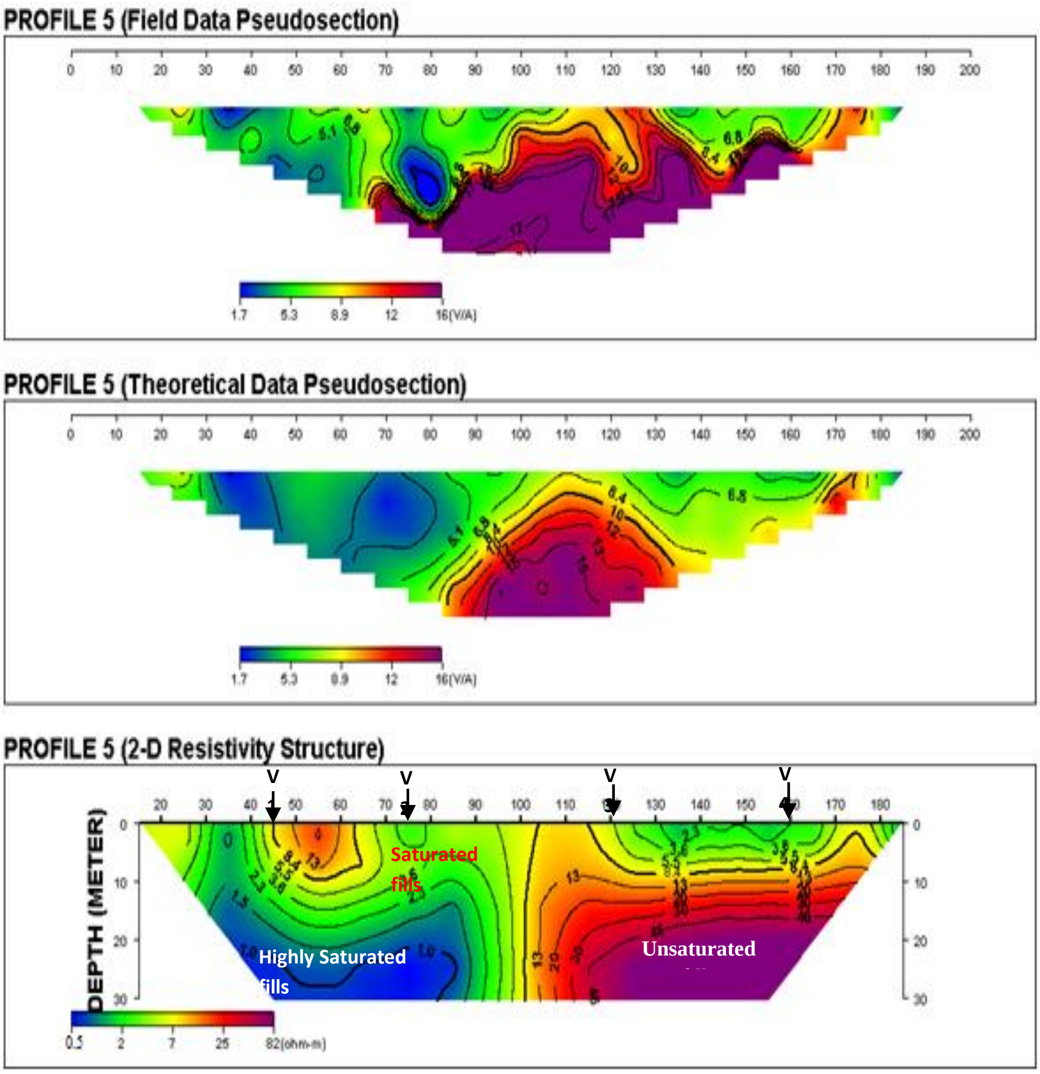

Figure 7-2D resistivity inversion along traverse 5

Figure-8 shows the VES 17 – 20 along traverse 1 stationed at 150, 120, 80 and 50 m from the western to eastern axis. Three geo-electric layer were identified which comprise high saturated fill/saturated fill, unsaturated fill and sand formation.

The first geo-electric layer represents the topsoil and constitute highly saturated fill and saturated fill. The second geo-electric layer on VES 17 and 18 constitutes unsaturated fill but the second layer of VES 19 and 20 is highly saturated fill. The third geo-electric layer constitutes sand formation which underlies the polluted fills and serves as migration path for the polluted fills.

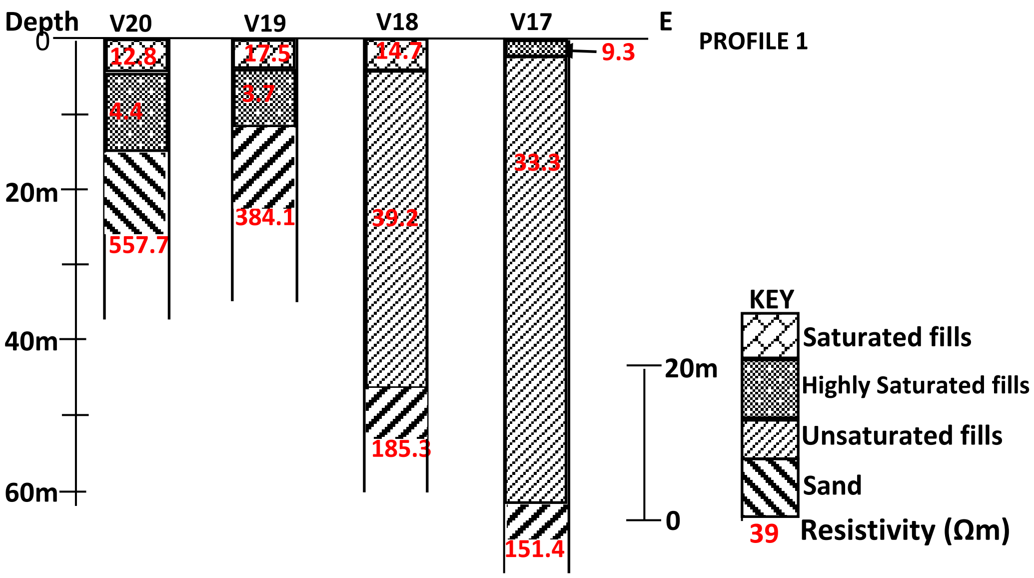

Figure 8-Geo-electric section along traverse 1 relating VES 17, 18, 19 and 20

Figure-9 shows the VES 13 – 16 along traverse 2 stationed at 55, 85, 125 and 160 m. Three to four geo-electric layer were identified which comprise of high saturated fill, unsaturated fill, saturated fill and sand formation.

The first geo-electric layer represents the topsoil and constitutes the highly saturated fill and unsaturated fill. The second geo-electric layer beneath VES 15 and 16 constitutes unsaturated fill and the second geo-electric layer beneath VES 13 and 14 is saturated to highly saturated fill. The third geo-electric layer beneath VES 14, 15 and 16 constitute sand. The third and fourth geo-electric layers beneath VES 13 are highly saturated fill and sand respectively.

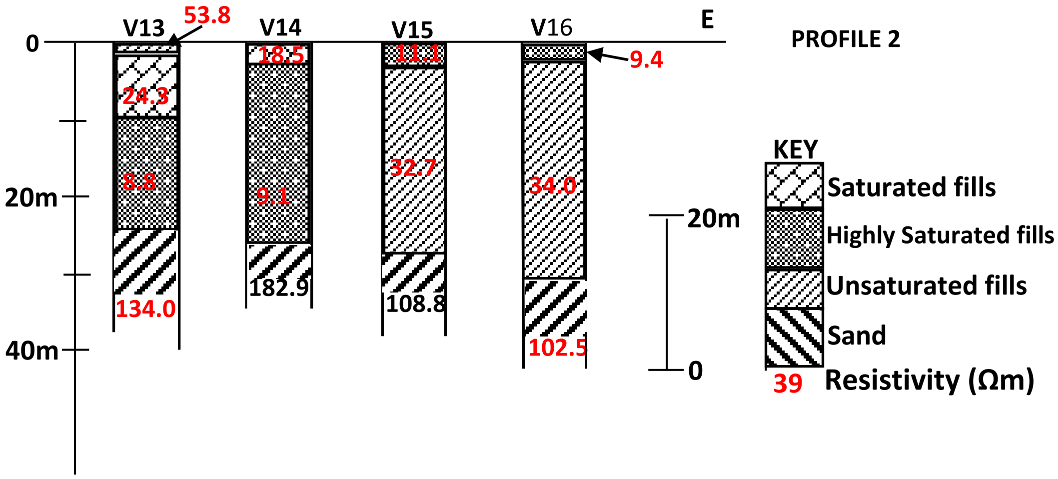

Figure 9-Geo-electric section along traverse 2 relating VES 13, 14, 15 and 16

Figure-10 is the geo-electric section relating VES 9, 10, 11 and 12 along traverse 3. The first geo-electric layer represents the topsoil which constitutes the highly saturated fill and saturated fill, the second geo-electric layer beneath VES 9, 10 and 11 constitutes highly saturated fill but beneath VES 12, the second geo-electric layer constitutes unsaturated fill. Underlying the second geo-electric layer is sand.

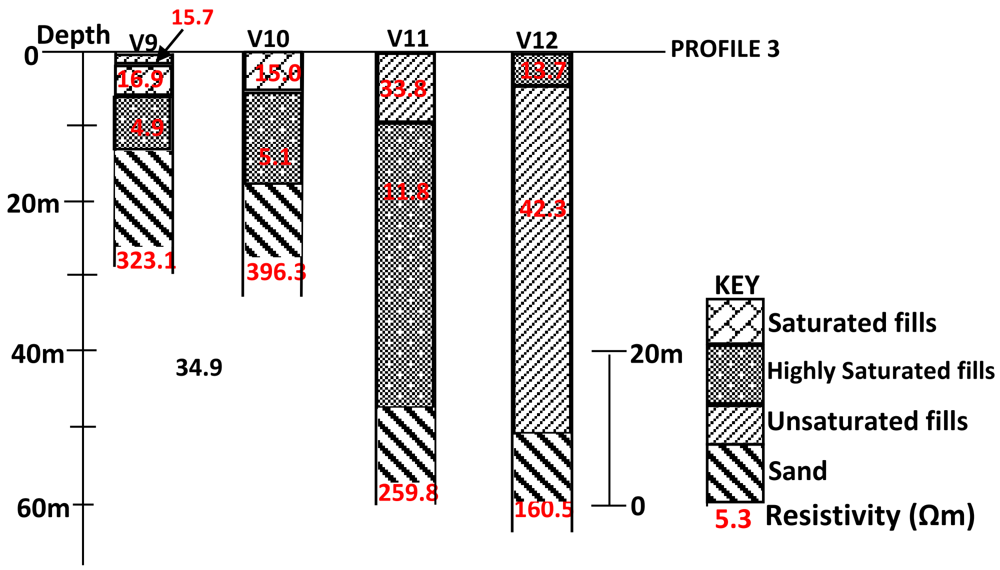

Figure10-Geo-electric section along traverse 3 relating VES 9, 10, 11 and 12

Figure-11 shows the geo-electric section of VES 5 – 8 along traverse 4. Three to four geo-electric layers were identified which comprise high saturated fill, saturated fill, unsaturated fill and sand formation. The first geo-electric layer represents the topsoil which constitutes the highly saturated fill and saturated fill.

The second geo-electric layer on VES 6, 7 and 8 constitutes saturated fill but on VES 5, the second geo-electric layer constitutes highly saturated fill. The third geo-electric layer on VES 5 and 6 comprises sand but the third layer on VES 7 and 8 is delineated as unsaturated fill. The fourth geo-electric layer on VES 7 and 8 is comprises sand which is the possible migration pathway to the polluted fills overlying it.

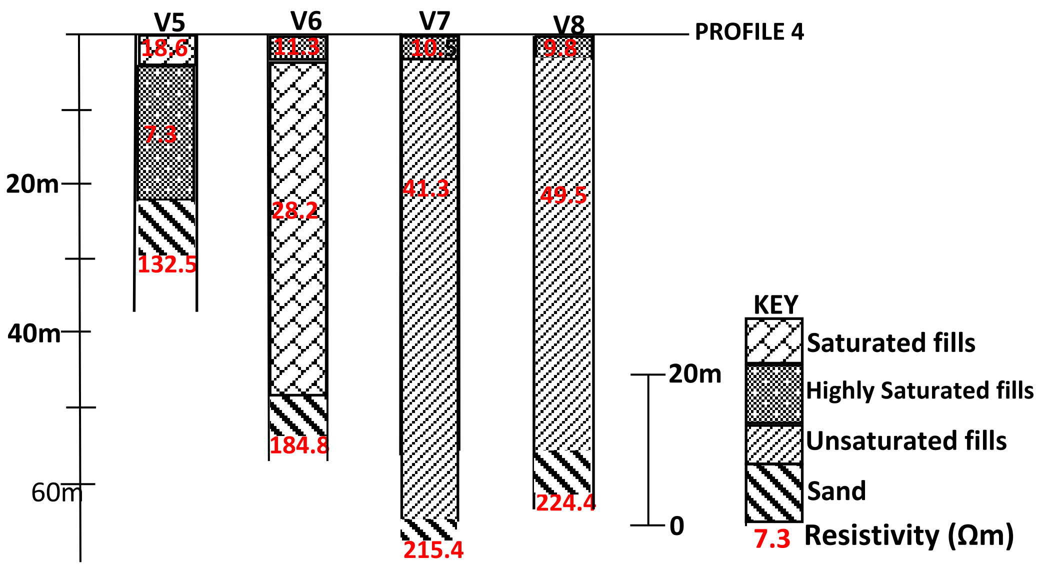

Figure 11-Geo-electric section along traverse 4 relating VES 5, 6, 7 and 8

Figure-12 shows the geo-electric sections of VES 1 – 4 along traverse 5 stationed at 45, 75, 120 and 160 m from the western axis of the study area. Three geo-electric layers comprise highly saturated fill, saturated fill, unsaturated fill and sand formation.

The first geo-electric layer represents the topsoil constituting the highly saturated fill and saturated fill. The second geo-electric layer on VES 1, 2, 3 and 4 constitutes highly saturated fill but on VES 3, the second geo-electric layer constitutes unsaturated. Underlying the second geo-electric layer is composed of sand but this layer (third layer) on VES 4 is delineated as unsaturated fill.

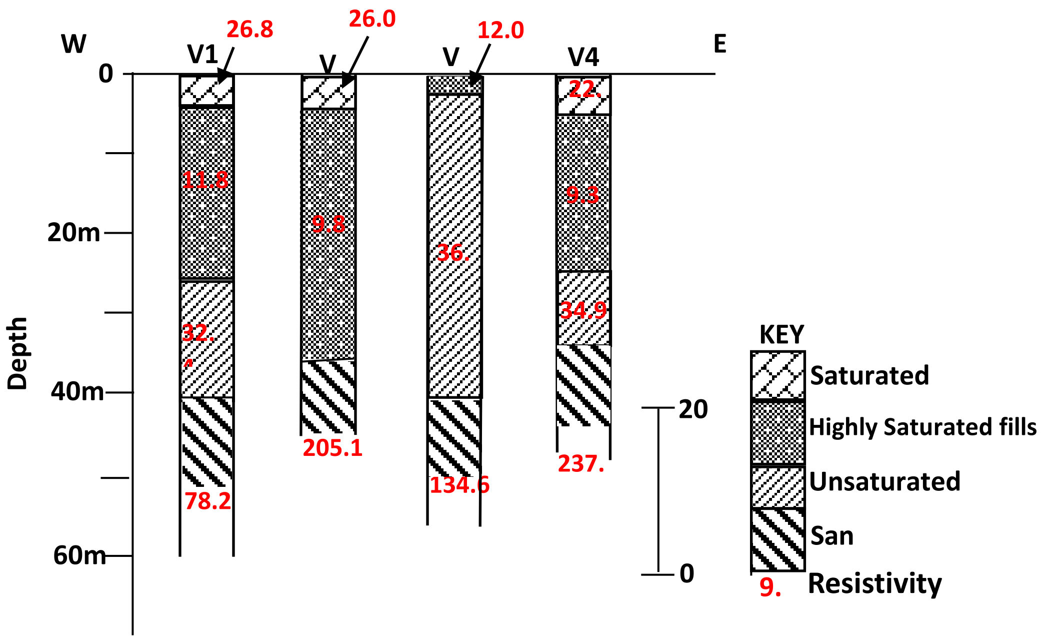

Figure 12-Geo-electric section along traverse 5 relating VES 1, 2, 3 and 4

Table-1 shows the summary of all the layers, their corresponding resistivity, thickness, depth and lithologies

Table 1-Measured parameters and inferred sediments

VES POINT	LAYER	RESISTIVITY (Ohm-m)	THICKNESS (m)	DEPTH	DESCIPTION OF LAYERS
1	1	20.2	4.3	4.3	Saturated fill
	2	3.2	20.1	24.4	Highly Saturated fill
	3	219.9	- - -	- - -	Sand
2	1	16.2	5.5	5.5	Saturated fill
	2	3.1	15.7	21.2	Highly Saturated fill
	3	180.6	- - -	- - -	Sand
3	1	12.0	2.1	2.1	Highly Saturated fill
	2	36.3	37.1	39.3	Unsaturated fill
	3	143.6	- - -	- - -	Sand
4	1	22.1	4.6	4.6	Saturated fill
	2	9.3	18.9	23.5	Highly Saturated fill
	3	34.9	9.1	32.6	Unsaturated fill
	4	237.9	- - -	- - -	Sand
5	1	18.6	3.9	3.9	Saturated fill
	2	7.3	17.7	21.5	Highly Saturated fill
	3	132.5	- - -	- - -	Sand
6	1	6.3	7.0	7.0	Highly Saturated fill
	2	18.2	29.9	36.9	Saturated fill
	3	184.8	- - -	- - -	Sand
7	1	2.1	6.4	6.4	Highly Saturated fill
	2	18.2	9.9	16.3	Saturated fill
	3	42.5	18.2	34.5	Unsaturated fill
	4	92.1	. . .		Sand
8	1	2.4	2.3	2.3	Highly Saturated fill

	2	20.6	10.6	12.9	Saturated fill
	3	40.2	19.2	32.1	Unsaturated fill
	4	177.9	----	-----	Sand
9	1	15.7	4.3	4.3	Saturated fill
	2	7.2	26.1	30.4	Highly Saturated fill
	3	112.2	- - -	- - -	Sand
10	1	14.6	4.9	4.9	Saturated fill
	2	6.6	21.4	26.2	Highly Saturated fill
	3	78.0	- - -	- - -	Sand
11	1	25.8	10.1	10.1	Saturated fill
	2	8.0	26.4	36.4	Highly Saturated fill
	3	114.2	- - -	- - -	Sand
12	1	8.1	3.1	3.1	Highly Saturated fill
	2	40.1	32.2	36.3	Unsaturated fill
	3	103.5	- - -	- - -	Sand
13	1	43.8	4.1	4.1	Unsaturated fill
	2	24.3	8.1	12.2	Saturated fill
	3	8.8	14.7	27.9	Highly saturated fill
	4	134.0	- - -	- - -	Sand
14	1	18.5	3.6	3.6	Saturated fill
	2	9.1	23.6	27.2	Highly Saturated fill
	3	182.9	- - -	- - -	Sand
15	1	11.1	2.9	2.9	Highly Saturated fill
	2	32.7	24.5	27.5	Unsaturated fill
	3	108.8	- - -	- - -	Sand
16	1	9.4	1.9	1.9	Highly Saturated fill
	2	34.0	28.6	30.4	Unsaturated fill
	3	102.5	- - -	- - -	Sand
17	1	9.3	2.2	2.2	Highly Saturated fill
	2	33.3	28.9	31.1	Unsaturated fill
	3	151.4	- - -	- - -	Sand
18	1	16.7	9.2	9.2	Saturated fill
	2	39.2	21.8	31.0	Unsaturated fill
	3	185.3	- - -	- - -	Sand
19	1	17.5	3.6	3.6	Saturated fill
	2	3.7	7.4	11.0	Highly Saturated fill
	3	384.1	- - -	- - -	Sand
20	1	12.8	4.1	4.1	Saturated fill
	2	4.4	27.4	30.5	Highly Saturated fill
	3	557.7	- - -	- - -	Sand

Conclusion

Geophysical site investigation involving electrical resistivity method was conducted at Ile Epo Dumpsite, Lagos State, to determine the groundwater conditions around the dumpsite. The integrated results revealed three to four geo-electrically polluted materials as highly saturated fills, saturated fills and unsaturated fills underlain by sand.

The highly saturated fills with resistivity value less than 15 Ωm have thickness value that ranging between 1.9 – 27.4m. The thickness of the saturated fills ranges from 3.6 – 29.9m with resistivity that ranges from 15 - 30 Ωm while the thickness of the unsaturated fills ranges from 8.1 – 37.1m with resistivity ranging from 30 - 70 Ωm. Due to its high permeability, the underlying sand serves as a pathway for contaminant migration to the underlying aquifers.

A good correlation was established between the thickness of the different fills delineated from the VES and CST results to a depth of 30m. Based on the integrated geophysical investigation, it is therefore concluded that aquifer units within and underlying the sand layer around Ile Epo Dumpsite and environs are potentially polluted.

However, for groundwater exploration, aquifers at deeper depth are likely to be free from contamination but required time to time monitoring because the underlying sand layer serves as possible migration path to the pollutants, thereby contaminating aquifers within underlying sand layer.

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