Investigating Groundwater Pollution by Integrating Geophysical and Physiochemical Methods

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Abstract-- Pollution of groundwater by leachate generated from the solid waste at the Olushosun landfill, Ojota, Lagos has been investigated using integrated geophysical and physiochemical analysis methods. The geophysical survey involved a total of 11 Vertical electrical sounding (VES) stations. The physiochemical analysis involved collection of five (5) samples of groundwater from boreholes. The samples were analyzed for physio-chemical and microbial parameters such as pH, conductivity, total hardness, total dissolved solids (TDS) total suspended solids (TSS), Ca, Mg, Chloride, Sulphate, Alkalinity, Fe, Nitrate, Phosphate, Turbidity, Salinity, Coliform bacteria and Mesophilic bacteria as total viable count in order to determine possible impact of leachate percolation into the groundwater. The results show that resistivities obtained from the VES stations closer to the refuse heap are relatively low (15.3Ωm), this indicates the presence of electrically conductive materials of higher ionic constituents, this is suspected to be the leachate generated from the solid waste deposited at this dumpsite. Conversely, the resistivities obtained from VES stations free of refuse and very far from the refuse heap which serve as control shows a strong contrast of very high values (1235.9 to 16508.6Ωm). The physiochemical analysis indicates conductivity of 500µS/L, Fe^{2+} (15mg/L) and TSS (250mg/L) from water sample obtained from borehole located in the immediate vicinity of the landfill. The result of the resistivity and physiochemical correlate, which shows that the groundwater in the South east direction has been polluted by leachate from the landfill.

Index Terms -- Electrical Resistivity, Vertical Electrical Sounding, Groundwater Pollution, Solid waste, Physiochemical Analysis, Landfill, Leachate

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1 INTRODUCTION

Groundwater is the water contained in a subsurface geological formation known as aquifer. Over 90% of the populace obtained water from this source. Groundwater has been conventionally assumed free of contaminations, but numerous discoveries of contaminants in groundwater have proven this assumption false.

Groundwater pollution occurs when contaminants from point source or non point source such as pesticides, fertilisers livestock, waste sewage-disposal system, landfill, saltwater intrusion, spillage of petroleum products or any foreign materials percolate into an aquifer groundwater and cause it to become unclean, unsuitable, unhygienic and unsafe for human use, a significant source of groundwater contamination comes from solid wastes [1], [2], [3], [4], [5]. Geophysical methods such as electrical resistivity and electromagnetic induction have been used to investigate groundwater pollution [6], [7]. Integrated use of physiochemical and geophysical methods is often recommended for investigating groundwater pollution [3], [6], [8], [9] the electrical resistivity method can clarify the subsurface structure, delineate contaminated zones of groundwater and it is economical [10] hence the electrical resistivity survey and physiochemical analysis methods were employed to investigate groundwater pollution due to leachate from the solid waste disposed at the Olushosun landfill.

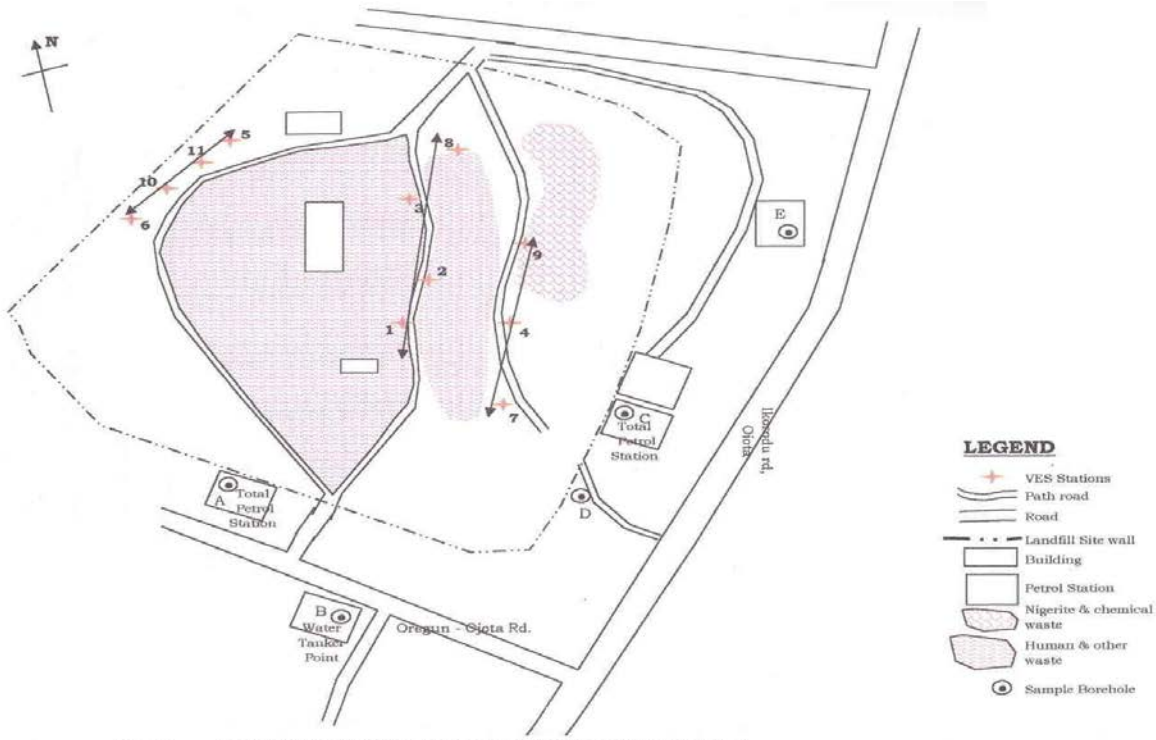

Fig. 1. BASEMAP OF THE STUDY AREA (Olusosun Dump Site), Olusosun Ojota.

2 SITE LOCATION, CHARACTERISTICS AND CLIMATE

The Olushosun landfill site (Fig1) is located at Olushosun-Ojota, North East of Lagos State (Latitude 6º27'N and Longitude 3º24'E) Nigeria. The study area falls within the hot humid tropical region which is characterized by rainy season and dry season. The average annual rainfall is estimated to be about 1500mm and seasonal average temperature is 21C to 31C. The site is about 42 hectares and it was established in 1992 with a life span of 35 years, it receives an average of 1,000,000 tonnes of waste annually [11].

3 HYDROGEOLOGY

The aquifer in the study area is divided into four with the first aquifer representing the recent sediments, the second and third aquifers are within the coastal plains these aquifers are referred to as upper and lower coastal plain sands respectively while the fourth aquifer represents the Abeokuta formation [12], [13], [14]. Aquifer from the recent sediment is shallow hence contamination of water from sewage and waste disposal facilities is common [15] Over 95% of all boreholes in Lagos state obtains their water from the Upper and Lower coastal plain sand.

4 FIELD TECHNIQUES AND MATERIALS

4.1 ELECTRICAL RESISTIVITY

An ABEM Terrameter SAS 300B was used for the vertical electrical sounding, a total of eleven VES were carried out across the site using the Schlumberger array. The maximum current electrode spacing (AB) used for this survey is 600m while the maximum potential spacing is 20m. VES 1, 2, 3, 4, 7 and 9 were conducted close to the refuse heap while VES 5, 6, 10 and 11 were conducted around the excavation pit in the virgin area (free of waste) this serve as control because it represents the natural lithology of the study area.

4.2 PHYSIOCHEMICAL METHOD

Water samples were collected from five (5) locations A, B, C, D and E (Fig1). The water samples were carefully analyzed for the determination of physio-chemical and microbiological parameters. A total of seventeen 17 parameters were determined, comprising of pH, conductivity, total hardness, total dissolved solids (TDS) total suspended solids (TSS), Ca, Mg, Chloride, Sulphate, Alkalinity, Fe, Nitrate, Phosphate, Turbidity, Salinity, Coliform bacteria and Mesophilic bacteria as total viable count.

5 RESULTS AND DISCUSSION

5.1 VERTICAL ELECTRICAL SOUNDING (VES)

The vertical electrical sounding curves were interpreted using the method of partial curve matching and computer-aided iteration techniques. The sounding curves show four to six geoelectric layers of various resistivities and thicknesses (Table 1). The resistivity's obtained from VES stations close to the refuse heap (less than 0.5m), that is, VES 1, 2, 3 and 9; are relatively low (15.3 to 584.6Ωm), this indicates the presence of electrically conductive materials of higher ionic constituents. This is suspected to be the leachate generated from the solid waste deposited at this dumpsite. Conversely, the resistivity of VES stations very far from the refuse heap (about 400m) i.e. VES 5.6,10 and 11 shows a strong contrast of very high values (1235.9 to 16508.6Ωm).

TABLE 1: Summary of the Computer Aided Iteration

VES No.	Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)
1	1	36.8	0.6	0.6
	2	45.3	3.0	3.6
	3	36.0	4.0	7.6
	4	584.6	-	-
2	1	136.7	0.6	0.6
	2	62.4	13.7	14.3
	3	176.4	-	-
3	1	74.9	0.9	0.9
	2	18.8	2.6	3.5
	3	281.9	-	-
4	1	15.3	0.6	0.6
	2	36.3	0.6	1.2
	3	99.1	17.3	18.5
	4	291.6	12.0	30.5
	5	3368.3	-	-
5	1	3301.7	0.8	0.8
	2	3918.3	1.9	2.7
	3	2554.8	1.5	4.2
	4	8657.0	19.2	23.4
	5	2664	74.8	98.2
	6	16508.6	-	-
6	1	3550.1	0.6	0.6
	2	1235.9	3.3	3.9
	3	7552.2	23.5	27.4
	4	2106.5	65.8	
	5	51144.8	-	-
7	1	63.3	0.6	0.6
	2	33.4	2.0	2.6
	3	84.8	5.4	8.0
	4	37.0	33.2	41.2
	5	1058.6	-	
8	1	190.1	0.6	0.6
	2	55.5	1.9	2.5
	3	142.4	3.7	6.2
	4	227.8	11.4	17.6
	5	111.6	-	
9	1	33.9	0.7	0.7
	2	59.2	2.6	3.3
	3	19.7	10.0	13.3
	4	43.0	-	
10	1	766.9	0.4	0.4
	2	4807.7	1.3	1.7
	3	655.5	3.8	5.5
	4	5631.5	29.0	34.5
	5	488.7	-	
11	1	1243.5	3.1	3.1
	2	6684.1	34.7	37.8
	3	776.0	-	

TABLE 2: Summary of Physio-chemical Analysis

Parameter	A	B	C	D	E	*WHO Accepted Level
Ph	7.20	5.90	6.80	6.80	5.80	6.5 – 8.5
Conductivity μS/cm	63	84	504	105	210	400
Total Hardness (mg/l)	15	20	120	25	50	
Ca^{2+} Hardness (mg/l)	12.0	15.0	90.0	18.0	32.0	100
Mg^{2+} Hardness (mg/l)	3.0	5.0	30.0	7.0	18.0	30
TDS (mg/l)	32.0	43.0	200.0	56.0	105	250
TSS (mg/l)	0	0	250	0	0	0
Cl^- (mg/l)	n.d	0.10	0.50	n.d	0.20	25
SO_4^{2-} (mg/l)	1.0	2.0	4.0	1.0	2.0	-
Alkalinity (mg/l)	54.0	27.0	32.0	33.0	25.0	-
Fe (mg/l)	0.10	0.30	15.0	0.10	0.05	0.3
NO_3^- (mg/l)	0.40	0.40	1.0	0.30	0.40	25
PO_4^{3-} (mg/l)	0.10	0.10	0.10	0.10	0.10	-
Turbidity (NTU)	0	0	0	0	0	< 1.0
Salinity ‰	0	0	0	0	0	0.25
T.V.C (cfu/ml)	230	74	62	48	69	
Coliform Count (MPN/100ML)	0	0	0	0	0	

5.2 PHYSIOCHEMICAL ANALYSIS

Table 2 Show the Results of the Physio-Chemical and microbial analysis of the water samples. The result of the water analysis shows that water sample C obtained from borehole located in the immediate vicinity of the landfill have high concentration of Fe^{2+} (15mg/L), TSS (250mg/L), TDS (200mg/L), Ca^{2+} (90mg/L), Mg^{2+}(30mg/L) and conductivity of(504 μS/cm) compare to the water samples A,B,D and E taken at locations farther from the landfill.

Drinking-water should be colourless and have no visible colour. Colour in groundwater is usually due to the presence of coloured organic matter associated with the humus fraction of soil. Colour is also strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products.

From field observation, sample C shows brownish colouration due to the formation of ferric oxide and a colloidal suspension of ferric precipitate which gives the water a murky colouration. This colouration along with its associated astringent taste and odours makes the water unfit for usage. Reduction of oxide, cement and degrading of organic matter in the Nigerite waste zone (Fig 1) may have contributed to the high concentration of Fe in sample C (15mg/L). When organic matter decomposed under aerobic condition, carbon dioxide is produced, this combines with the leaching water to form Carbonic acid. The Carbonic acid will act upon metals in the refuse resulting in increased hardness of water as characterized by samples C which shows high value of Mg^{2+} Hardness and Ca^{2+} Hardness of values 30 and 90mg/l respectively as compared to other samples. This may have been due to the

action of Carbonic acid upon scrap metals at this site. Similarly a high value of TDS (200mg/l) and conductivity of 504 μS/cm was obtained in this sample in agreement with the low resistivity (i.e. high conductivity) obtained in VES location close to the refuse. Furthermore, water samples (A, B, D and E) obtained from borehole farther from the site does not indicate contamination because all the physio-chemical parameters were below WHO regulatory limits.

Any investigation of microbial water quality must include the analysis of faecal indicator microorganism coliform bacteria e.g. Escherichia coli (E. coli). The E. coli is a sub-group of coliform bacteria and also a Mesophilic bacterium. Mesophilic bacteria are species of bacteria that grows best at moderate temperatures, typically between 25 and 40 °C. Bacterial infections in humans are mostly caused by mesophilic bacteria that find their optimum growth temperature around 37°C which is the normal human body temperature. The analysis show coliform count as zero i.e. undetected while the mesophilic bacteria total viable count is between 48 and 230 cfu/ml. Though water sample that have zero coliform can be regarded as safe bacteriologically, but the results should be monitored over a certain period in order to identify significant changes in total viable count of the mesophylic bacteria

6 CONCLUSION

The survey has demonstrated that integrated use of electrical resistivity and physiochemical analysis methods is an efficient and a reliable means of investigating groundwater pollution because there is a good correlation between the results of physiochemical and the electrical resistivity method, borehole located in the immediate vicinity of the landfill indicates high conductivity of 504 μS/cm while the VES result in the landfill vicinity shows a very low resistivity(high conductivity) of (15.3 to 584.6Ωm). Borehole located in the immediate vicinity of the landfill in the South east direction has been polluted by leachate from the landfill thus making the groundwater unsuitable for use. Though the physio chemical analysis of parameters in the samples is below the WHO limits and the microbial test show that the coliform count is zero which make the water suitable for use but the total viable count of the mesophylic bacteria is between 48 and 230 cfu/ml in all the samples hence it is recommended that the wells should be monitored periodically in order to identify any significant changes in total viable count of the mesophylic bacteria.

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