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ELECTRICAL RESISTIVITY SOUNDINGS TO DETERMINE SUBSURFACE CONTAMINATION IN THE VICINITY OF REFUSE DUMP

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ABSTRACT

Four Wenner apparent pseudosections and a vertical electrical sounding were made at the Orita Aperin refuse dump site, Ibadan, South West Nigeria, to map the gross layered structure of the refuse as well as the extent of groundwater contamination. Wood, leaves, newspaper, cloth, polythene bags, plastics, glass and metal refuse interspersed with soil exhibited resistivity of 11.6 ohm-m and layer thickness of 0.7m as obtained from the inversion of the sounding. The unsaturated layer has a resistivity of 6.8 ohm-m and thickness of 0.6m while leachate-saturated is characterised by low resistivity of 2.9 ohm-m; 1.2 m thickness.

The fractured saturated layer exhibited resistivity of 49.6 ohm-m. The accurate determination of the refuse thickness in geoelectrical model is primarily due to a strong resistivity contrast between the leachate saturated (2.9 ohm-m) and underlying saturated fractured rock (49.6 ohm-m). Despite this contrast, models generated from electrical resistivity soundings are reasonably accurate in their depictions of internal structure of the dump site. The hydrochemical analysis of the surface and groundwater samples collected within the vicinity of the dump site were analysed for physico-chemical parameters. The results produced higher concentration of TDS, total hardness, Cl^-, NO_3^-, Mg^{2+}, Na^+, K^+ and pH value for water collected at close locations to the dump site than those far away from the site:an evidence for a quantitative assessment of groundwater contamination.

KEY WORDS: Resistivity, groundwater, leachate-saturated, contamination, layer.

INTRODUCTION

Refuse disposal is a major environmental problem in most Nigerian cities; for instance, Ibadan South-West Nigeria is regarded as the largest city. Most of the streets in the metropolis are not accessible and thus pose problem of refuse collection. Refuse (domestic and industrial solid wasted) has been defined as useless, unwanted materials which arise from human activities and are not free floating (WHO, 1971). Poor management of solid waste materials has resulted to a lot of disastrous effects such as aesthetic, environmental hazards (breeding mosquitoes, flies, cockroaches, rats etc.) and pollution (water pollution occurs as rain washes debris out of piles of refuse into surface water). Groundwater pollution may also occur due to the contamination potential of leachate from the waste(Makeig, 1982). Various methods by which solid waste can be disposed are open dumps, sanitary landfill, incineration on-site disposal, swine feeding and compositing. For this study, the site is an open refuse dump. Leachates from open dumps and sanitary landfil normally contain both chemical and biological constituents (Schneider, 1970). The leachate has high biochemical oxygen demand (COD) in both landfills and open dumps where decomposition is accomplished by actions of bacterial. Leachates from these dump and landfills are classical sources of groundwater contamination. When more rainfall occurs, the solute penetrate the soil deeper and the organic matter disintegrates under anaerobic condition, producing carbondioxide and thus forming carbonic acid when mixed with the leaching water. The reaction of this carbonic acid with the metals in the refuse and with calcareous materials in the soil and rocks will finally result to increasing hardness of water. Rainwater penetrating the refuse will percolate downward to the soil zone and eventually to the water table. During percolation, the water leaches both organic and inorganic constituents of the refuse thereby becoming part of the groundwater flow system immediately it get to water table. In areas of shallow water table where refuse is in contact with groundwater, leaching is a continual process, which produces maximum potential for groundwater contamination. Permeable soils allow rapid movement of leachate while less permeable soil like clay reduces leachate movement.

Several researchers have identified contaminant plumes from refuse dumps and landfills using resistivity profiling and sounding

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(Sietz et al., 1972; Klefstal et al., 1975; Stollar and Roux, 1975; Kelly, 1976; Urish, 1983; Grady and Haeni, 1984; Rumbaugh et al., 1987). Some other methods are also found useful in the investigation of landfill and refuse dump (Electromagnetic, ground-penetrating radar and seismic methods). But for this study, the feasibility of using electrical resistivity to investigate the internal refuse dump structure is assessed for Orita Aperin refuse dump. The scope and objectives of this survey includes: to estimate the extent and thickness of refuse, the leachate levels and thickness of the cover material. Finally to investigate the hydrochemical analysis so as to access the level of contamination of both groundwater and surface water.

SITE LOCATION AND DESCRIPTION

The study area is located at Orita Aperin in the southeastern part of Ibadan, South West Nigeria; latitude 3E 45'N to 4E 31'E and longitude 6E 45'N and 7E 30'N. The area of the refuse dump site is 260m by 220m, well accessible with well connected roads and footpaths (see figure 1). The Orita-Aperin refuse dump site used to be a valley. It was converted to a dump site because of the urban-drift and population increase. The dump site is now abandoned and is being designed as refuse recycling plant by Ibadan Solid Waste Management Authority. Trees like Eucalytus citiodora, verbenaeae and grass are being grown on the site for stabilization of he refuse dump and erosion control. despite this, the repulsive odour still disturbs the inhabitants of this area. This survey was carried out on 3rd May 1998.

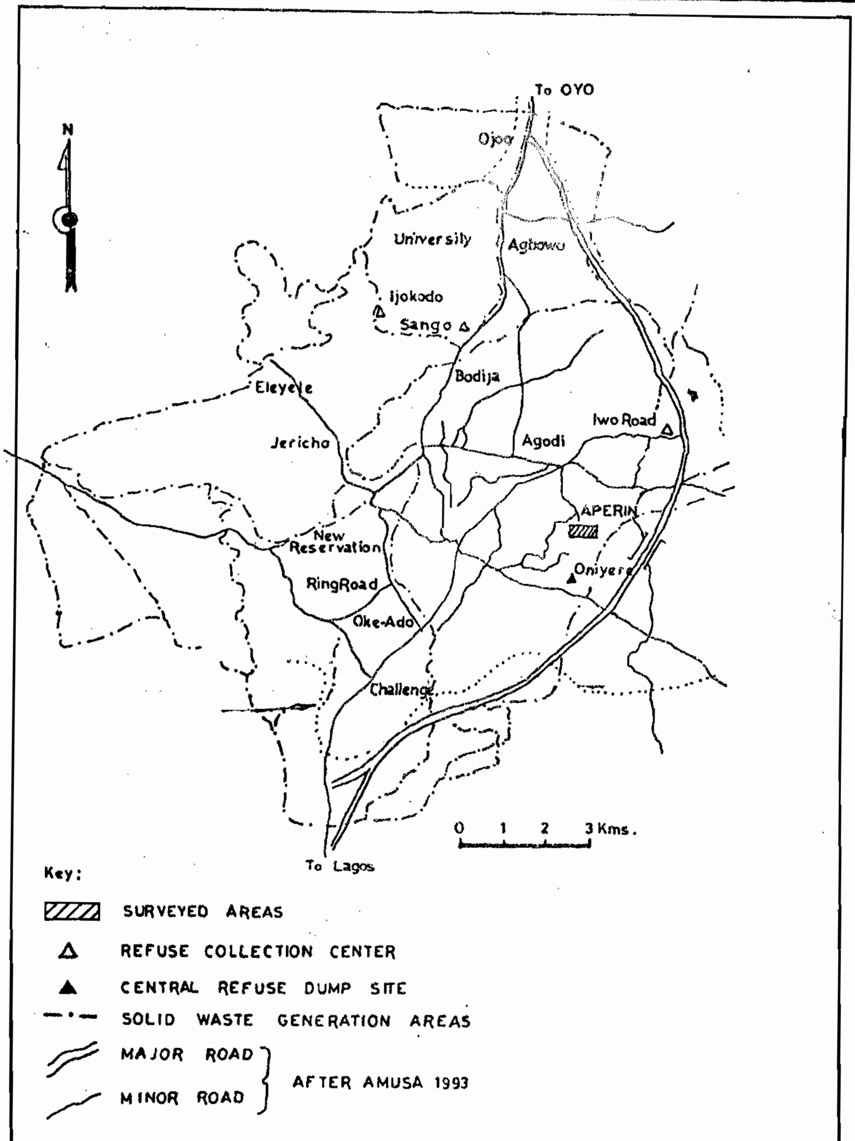

Fig. 1-Location of refuse dump site and solid waste generation areas.

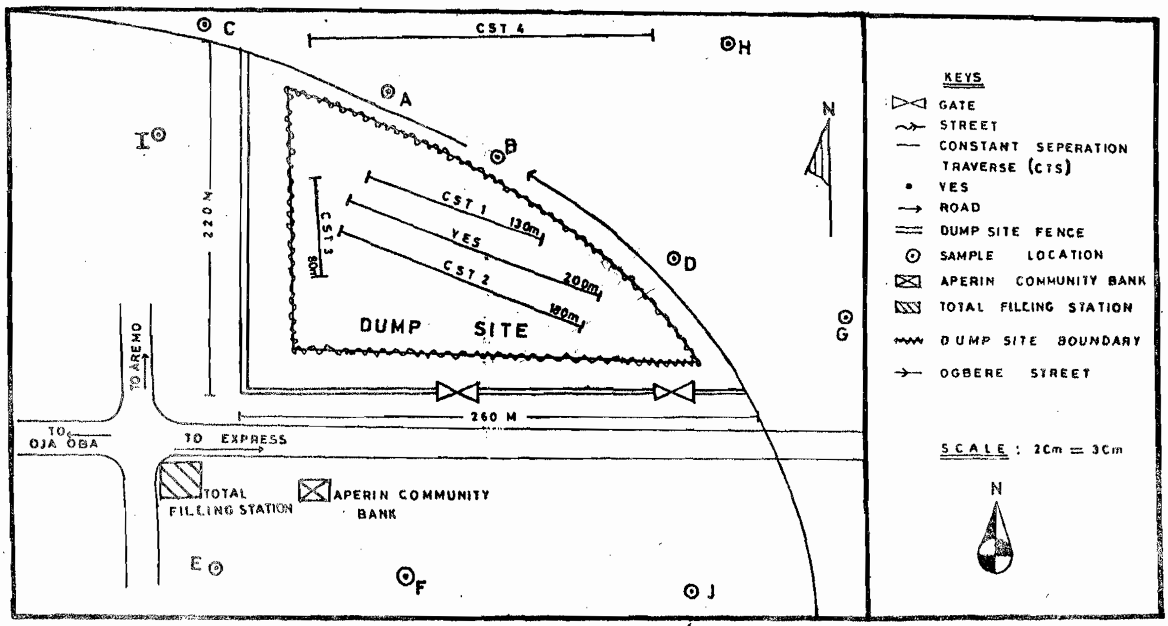

FIG 2. GEOPHYSICAL DATA AQUISTITION MAP SHOWING CST/VES STATION AND SAMPLE LOCATIONS

Table 1: **Range of Values of Chemical Parameters from Location near the Refuse Dump compared with Location away from Refuse Dump and WHO Guide for drinking water (After WHO, 1984)**

Parameters	Sample A,B,C, and I		Sample D,E,F,G, and J			
	Range	Mean	Range	Mean	Acceptable level	Maximum permissible level
Temperature EC	28.6-34.2	30.10	28.30-30.50	29.10		
PH	7.10-8.10	7.50	5.7-7.10	6.40	6.50	8.50
Conductivity Fs/cm	1075-1349	1215.00	432.0-840.0	596.30		1.40
TDS mg/l	698.75-876.85	789.80	49.4-546.0	387.60	500.00	1000.00
Total Hardness mg/l	184.8-239.6	207.50	74.0-102.0	94.70	100.00	500.00
$Na^{+}+K^{+}$mg/l	5.84-145.80	114.00	9.80-91.45	50.70		200.00
Ca^{2+}mg/l	46.20-78.72	55.60	3.76-32.80	17.50	75.00	200.00
Mg^{2+} mg/l	5.08-30.28	16.70	3.42.21.50	12.40	50.00	150.00
Fe^{2+} mg/l	0.20-073	0.40	0.03-1.04	0.50	0.30	1.00
Ca^{2+} mg/l	0.10-0.30	0.02	0.01-1.30	0.40		
HCO_3^- mg/l	80.0-404.0	206.00	16.0-42.0	28.70		
Cl^-mg/l	20.0-224.0	120.00	32.0-174.0	96.30	200.00	250.00
SO_4^{2-} mg/l	9.0-76.0	56.80	25.0-38.0	32.70	200	400.00
NO_3^- mg/l	32.0-120.0	73.10	1.60-30.07	15.60	50.00	100.00
PO_4^{3-} mg/l	0.60-2.27	1.22	0.01-0.52	0.20		

The cover layer of Orita-Aperin refuse dump is composed of topsoil of thickness 0.7m across the top of the dump but it is thin radially along the edge and base of the dump where refuse is occasionally exposed. The refuse consists of wood, paper, cloth, glass, plastic, and small amount of metals.

FIELD TECHNIQUES

Electrical resistivity surveys have been employed for many years in routine hydrogeological investigation. This technique is particularly useful in the area of complex geology (Griffiths and Barker, 1993), in archeology (Noel and Walker, 1970), and in other shallow subsurface investigations. For the geoelectric soundings carried out in this study, an ABEM Terrameter SAS300B and its accessories were used. A total of four constant separation traverse (CST) and a geoelectric sounding (VES) were carried out across relatively flat parts of the refuse dump using wenner array to examine areas of different internal structure of the dump. Three of the CST readings were taken on the dump site while the fourth CST reading was taken along the road which is about 50m away from the dump site. CST1 has bearing 32E, about 140m long and located 20m away from the dump site boundary, CST2 is 200m long with bearing 308E and 30m away from the CST1. CTS3 is located on the eastern part of the dump site with a bearing 170E and 80m long while CST4 is 200m long with bearing 180E (figure 2).

Wenner resistivity pseudposection data for all CSTs (a profile of resistance measurements) were carried out first with unit electrode space "a" and later increase to "2a". The procedure was repeated by increasing the electrode spacing each time in multiples of N of initial unit spacing. The unit electrode spacing was 10m and the data were collected from N=1 to N=6. Vertical electrical sounding (VES) was taken midway between between CST1 and CST2, 200m long with bearing 315E. Using Wenner electrode array (see figure 2). These values were then used to calculate respective apparent resistivity, which later used for the interpretation.

For a comprehensive study, a short term field survey of the stream and hand dug open-wells in the vicinity of the refuse dumpsite were also carried out. This involved taking the total depth of those wells (depth to water level) using a graduated tape and also collecting water samples in plastic bottles. The water samples were collected from 10 locations (see figure 2). All the samples were groundwater samples except sample A, which was surface water sample. Taking all the standard sampling precautions into consideration, measurement of sensitive quality parameters such as Temperature, Total Dissolved Solid (TDS), pH and conductivity were carried out in the field with the aid of a portable Hach DR-EL/4 laboratory kit. Hydrochemical analyses of the water samples were also carried out in the laboratory and a total of 14 parameters were identified and measured.

RESULT AND DISCUSSON

Based on the result of isoresistivity contoured maps, it was observed that contours generally have SE trend with resemblance trend of leachate flow (see figures 3a, 3b and 3c). The pseudposection revealed broad, low resistivity anomalies between the electrode positions in CSTs 1 and 2, along W-E while similar case occurred between the electrode positions in CSTs 3 and 4 along W-E. The VES curve has been interpreted as a 4-layer model, using methods of curve matching and computer aided iteration techniques. The layer resistivities are 11.6 ohm-m, 6.8 ohm-m 2.9 ohm-m and 49.6 ohm-m respectively and the corresponding layer thicknesses are 0.7m, 0.6m and 1.2m. From the interpreted results, the four subsurface layers are distinguished as cover (top soil) layer, unsaturated refuse layer, leachate saturated layer and saturated layer. The cover layer consists of wood, cloth, leaves, newspaper, polythene bags, plastics, glass and metal refuse interspersed with soil. These materials exhibit resistivity value of 11.4 ohm-m and layer thickness of 0.7m as obtained from the inversion of the sounding. The unsaturated layer has a resistivity value of 6.8 ohm-m and layer thickness of 0.6m. However, leachate saturated layer is characterised by low resistivity value of 2.9 ohm-m and thickness of 1.2m; this low resistivty value is due to contamination in that zone. The resistivity contrast between mineralised leachate and unsaturated refuse allows the top of the leachate layer to be delineated accurately. Accurate determination of the refuse thickness in geoelectrical model is primarily due to a strong resistivity contrast between the leachate saturated refuse (2.9 ohm-m) and underlying saturated fractured rock (49.6 ohm-m). for CSTs 1, 2, and 3, the refuse resistivities are 5.0 ohm-m, 9.0 ohm-m and 7.0 ohm-m respectively. Using longitudinal conductance hypothesis (where overburden is much more conductive than the

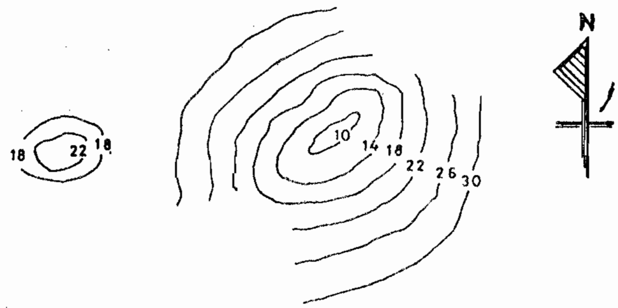

FIG. 3a, ISORESISTIVITY CONTOUR MAPS FOR N = 1

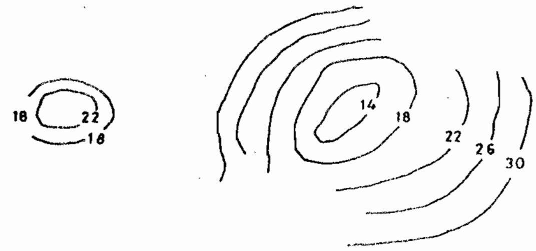

FIG. 3b, ISORESISTIVITY CONTOUR MAPS FOR N = 2

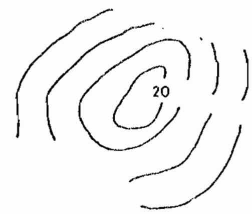

FIG. 3c, ISORESISTIVITY CONTOUR MAP FOR N = 3

bedrock), the equation:

$$S = \frac{1.38a}{\rho_a} = \frac{H}{\rho_l}$$

where s longitudinal conductance, H total overburden thickness (total refuse thickness), ρ_a apparent resistivity and ρ_l the equivalent overburden resistivity (Keller and Frichknedt, 1966; Zohdy, 1969; and Worthington, 1977); the corresponding total refuse thickness of CSTs 1, 2 and 3 are 6.6m, 12.9m and 2.88m as estimated by this equation.

The chemical analysis also showed the impact of leachate on the water quality: it increases total hardness, calcium, magnesium, sodium, potassium, sulphate, TDS, conductivity, pH, ammonium, nitrate (Zanoni, 1973). However, high value of TDS, nitrate and chloride has resulted to high contamination of these wells. Water samples at locations A, B, C and I which are close to the refuse dump site are contaminated by leachate and such water is termed as Alkaline water predominantly So_4^{2-} and Cl^- while water samples from locations D, E, F, G, H and J which are away from the site are not affected by leachate and are classified as

Earth alkaline water predominantly So_4^{2-}. All parameters in these water samples have low concentrations of Fe^{2+}. Samples A, B, C, and I are characterised by high value of TDS of 789.8 mg/l and pH value of 7.5 because of generation of carbondioxide, ammonia and methane as a result of refuse decomposition (see table 1).

CONCLUSION

Quantitative interpretation of a geoelectric sounding of refuse dump site has yielded information on groundwater contamination as indicated by the measured values of refuse resistivity and thickness, isoresistivty, and hydrochemical parameter of water samples. The refuse thickness was obtained from longitudinal conductance hypothesis, which could have been compared with the inversion technique, otherwise known as numerical modeling but the non-availability of necessary facility has restricted this work to the technique used.

The main goal is to show the combined relevance of the results of quantitative interpretation technique with the standard interpretation technique in determining the subsurface contamination in the vicinity of refuse dump. Therefore a combination of electrical tomography and hydrochemical analysis is a unique and powerful technique for monitoring the groundwater contamination at disposal sites as well as examining shallow complex subsurface structure; an approach suitable in the studies of water quality.

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