African Journal of Environmental Science and Technology Vol. 4(1) pp. 001-005, January, 2010
Available online at http://www.academicjournals.org/AJEST
DOI: 10.5897/AJEST09.185
ISSN 1991-637X

Full Length Research Paper

Subsurface probe and hydrochemical analysis for the purpose of siting waste landfill

O. M. Alile[1]*, S. I. Jegede[2] and R. E. Emekeme[3]

[1]Department of Physics, Covenant University, Ota, Ogun State, Nigeria.
[2]Ambrose Alli University, Ekpoma, Edo State, Nigeria.
[3]Delta State University, Abraka, Delta State, Nigeria.

Accepted 25 November, 2009

This paper deals with the probing of the subsurface by electrical resistivity method and hydrochemical analysis for the purpose of siting waste landfill. The landfill design made provision for secured containment of the segregated waste and associated leachate from man and industrial activities. The waste types that are disposed of in the landfill are mainly domestic and non-hazardous industrial wastes. The hydrochemical analysis of the surface/groundwater and geophysical exploration were carried out at Egbeleku landfill dump site in Delta state. Two vertical electrical sounding (VES) locations around the waste landfill were carried out. Both VES have a total Cumulative thickness of 94.10 and 71.90 m with resistivities of 263.00 and 274.00 ohm-m, respectively. The hydrochemical analysis of the groundwater samples collected at boreholes within the waste landfill site environ was analyzed for physio - chemical parameters to test for water quality. In this study, the geophysical investigation revealed the presence of aquifer layer and the tendency of groundwater pollution but appropriate installation of a well-designed basal lining system to monitor groundwater quality through well-placed monitoring boreholes are determined.

Key words: Dc, resistivity, interpretation, hydrochemical, waste landfill.

INTRODUCTION

Landfills are land disposal sites for non-hazardous solid wastes at which the wastes is spread in layers, compacted to the smallest volume and cover material applied at the end of operating day per period. In landfill system, internal biochemical processes act to stabilize and breakdown the waste over a period of several decades (Green, 1999), (Fervolden and Hughes, 1976). The breakdown of waste is very essential as a study because waste disposal is a major environmental problem of refuse collection. Poor management of solid waste materials has resulted to disastrous effects such as aesthetic, environmental hazards (breading mosquetoes, flies, cockroaches, rats etc) and thus water pollution occurs as rain washes debris out of piles of refuse into surface water (Pamela, 1994). Moreover, groundwater contamination potential of leachate (garbage juice) from the waste matures within municipal solid waste as well as those which enters into precipitation and in groundwater for those landfills sited below the water table generate landfill leachate. These leachates contain a whole variety of conventional and non-conventional contaminants and hazardous chemicals at concentrations where small amounts of leachates in groundwater renders the groundwater unusable for domestic water supply and many other purposes (Chilton and Foster, 1995; Milson, 1939). These solid wastes can be categorized into hazardous and non - hazardous wastes.

Non - hazardous wastes are derived from all human activities and animal activities. They could be classified as rubbish, garbage, ashes, trash etc. The hazardous wastes can also be gotten from human activities. These include manufacturing, industrial and mining activities. Most of these hazardous wastes are mainly of ordinance materials, remnants or wastes from manufacturing company and some industrial chemicals, liquids and gases. Radioactive wastes are produced from human activities during mining of radioactive materials, milling, burning nuclear fuels, storing and processing of used fuels. (Department of Environmental Waste Management, 1986; Attenuation of Landfill Leachalo Pollutants in Aqui-

*Corresponding author. E-mail: owenalile@yahoo.co.uk.

fers - Critical reviews in Environmental Service and Technology, 1994; Landfill Design, Construction and Operational Practice, 1995).

EXPERIMENT

In this research work, the Schlumberger Array of electrical resistivity survey was adopted for the VES data (Dorbrin and King, 1976). The interpretation of the data was carried out by the Schlumberger automatic analysis (Asokhia, 1995; Asokhia et al, 2000; Osemeikhian and Asokhia, 1994; Koefoed, 1979).

For the hydrochemical investigation, surface water sampling locations were established as found necessary around each location. Water samples were collected during the sampling visit from the boreholes that were drilled specifically for the monitoring programme. At each surface water sampling location, samples from three to ten sampling points were pooled to obtain samples for that location. The water samples were collected in previously cleaned one liter Pyrex glass bottles with glass stoppers using a water sampler.

THEORY

Maillet (1947), expounded the fundamental theory behind the resistivity method and the theory has been adequately covered by Keller and Frischknecht (1966), Grant and West (1965) and Bhattacharaya and Partra (1968).

Feynman et al. (1965), express the Maxwell's equation for earth materials having dielectric and magnetic properties as:

$$\nabla \times \underline{H} = \underline{J} + \partial D / \partial t \qquad (1)$$

$$\nabla \times \underline{E} = -\partial B / \partial t \qquad (2)$$

$$\nabla \cdot \underline{B} = 0 \qquad (3)$$

$$\nabla \cdot \underline{D} = Q \qquad (4)$$

Where H = magnetic flux density = $\dfrac{B - \mu_0 M}{\mu_0}$

The equation of continuity is obtained by taking the divergence of Equation (1) that is

$$\nabla \cdot \nabla \times \underline{H} = \nabla \cdot \underline{J} + \nabla \cdot \partial D / \partial t$$

But the divergence of a curl is zero

$$\nabla \cdot \underline{J} = -\nabla \cdot \partial D / \partial t$$

$$\therefore \nabla \cdot \underline{J} = -\partial / \partial t \, \nabla D \qquad (5)$$

This is so because the order of derivatives with respect to co-ordinate and time can be reversed. Substituting Equation (4) into Equation (5) we have:

$$\nabla \cdot \underline{J} = -\partial / \partial t \, Q \qquad (6)$$

The resistivity method operates in the absence of a field of induction and is based on observations of an electric field maintained by direct current. However, for source free regions of the earth, Equation (2) and (6) becomes:

$$\nabla \cdot \underline{E} = 0 \qquad (7)$$

$$\nabla \cdot \underline{J} = 0 \qquad (8)$$

Equation (7) suggests that the electric field strength may be expressed as the gradient of a scalar potential (v):

$$\underline{E} = -\nabla V \qquad (9)$$

However, Ohm's law provides the relationship between E and j and it states that the current density is proportional to the electric field strength:

J = σE

This proportionality constant is called conductivity.

It must be noted that for an isotropic medium, the conductivity will be a scalar quantity so that J and E will be in the same direction. In general, J and E are not in the same direction because conduction might be easier in one direction than another.

Such a medium is said to be anisotropic and the conductivity is a tensor of second rank, the subscripts i and j may be any of the x, y or Z spatial directions in a rectangular co-ordinate system. Ohm's law becomes:

$\underline{J} = \sigma_\eta \underline{E}$ or, more fully

$$\begin{bmatrix} J_x \\ J_y \\ J_z \end{bmatrix} = \begin{bmatrix} \sigma_{xx} & \sigma_{xy} & \sigma_{xz} \\ \sigma_{yx} & \sigma_{yy} & \sigma_{yz} \\ \sigma_{zx} & \sigma_{zy} & \sigma_{zz} \end{bmatrix} \begin{bmatrix} E_x \\ E_y \\ E_z \end{bmatrix} \qquad (10)$$

Combining Equations (8), (9) and (10) gives a differential equation which is the basis of all resistivity prospecting with direct current:

$$\nabla \sigma_\eta \nabla V = 0 \qquad (11)$$

In this isotropic case where the conductivity at a point in the ground is independent of direction, Equation (11) reduces to Laplace's equation:

$$\nabla^2 V = 0 \qquad (12)$$

Solutions to Equations (11) and (12) may be developed for a particular model of the earth by selecting a co-ordinate system to match the geometry of the model and by imposing appropriate boundary conditions. Where: B = Magnetic flux density, μ_0 = Permeability of free space, $\underline{M}$ = Magnetization, $\underline{J}$ = Current

Table 1. Results of physio-chemical characteristics of groundwater at Egbeleku landfill.

Parameter	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9	BH10	Mean values	EIA values	WHO limits
PH	6.15	5.68	5.96	5.77	6.78	5.65	6.90	6.48	6.78	5.59	6.17	5.84	6.5 - 9.2
Temp.° C	28.62	28.76	27.93	28.36	8.56	28.92	28.16	28.37	27.87	28.70	28.43	26.40	40
DO mg/1	5.75	5.24	4.92	5.22	5.64	5.68	5.12	4.11	5.13	5.34	5.22	2.70	5.00
BOD_5MG/l	1.05	1.06	0.96	1.24	1.55	1.18	0.88	1.24	0.68	0.95	1.08	N/A	10
TDS mg/l	18.64	14.50	12.34	9.58	11.58	12.12	15.46	21.32	9.21	10.56	13.53	7.33	500 - 550
COD mg/l	7.32	6.12	7.44	5.92	6.89	5.78	8.45	8.23	5.18	5.17	6.65	N/A	N/A
TSS mg/l	10.56	9.78	8.97	6.66	10.20	5.12	10.48	5.92	5.70	8.10	8.15	2330.5	N/A
CondµS/cm	34.32	29.46	22.56	20.88	27.89	27.22	41.45	21.34	18.58	26.98	27.07	170	2000
Sal mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.25	200 - 600
NO_3-Nmg/l	0.79	0.44	0.55	0.38	0.43	0.38	1.28	0.46	1.38	0.89	0.70	0.33	50 - 100
HCO_3 mg/l	5.95	5.57	7.28	4.12	5.66	6.54	7.52	5.84	5.98	6.65	6.01	N/A	N/A
THC mg/l	0.27	0.18	0.08	0.07	0.08	0.09	0.08	0.08	0.09	0.06	0.11	N/A	20
SO_4^{2-} mg/l	4.66	6.12	4.78	6.40	4.36	4.78	5.81	5.08	6.16	3.44	5.16	2.77	200 - 400
Ca^{2+} mg/l	3.12	1.76	3.55	2.59	3.68	3.81	4.76	3.28	4.34	5.69	4.23	N/A	200
Mg^{2+} mg/l	1.44	1.26	1.65	1.05	1.85	1.24	1.41	1.96	2.83	2.14	1.68	N/A	150
Turb(NTU)	15.21	12.23	7.20	5.58	11.23	7.08	7.07	11.23	9.76	9.76	9.63	N/A	25
Static water level (m)	1.66	1.40	0.88	1.62	0.82	1.34	0.99	1.56	1.72	1.54	1.34	N/A	N/A

N/A means not available.

density, $\underline{D}$ = Electric displacement = $\varepsilon_0\underline{E} + \underline{P}$, ε_0 = Permittivity of free space, $\underline{E}$ = Electric field strength, $\underline{P}$ = Polarization, t = time and Q = electric charge density.

RESULTS AND DISCUSSION

The Table 1 showed the results of physio-chemical characteristics.

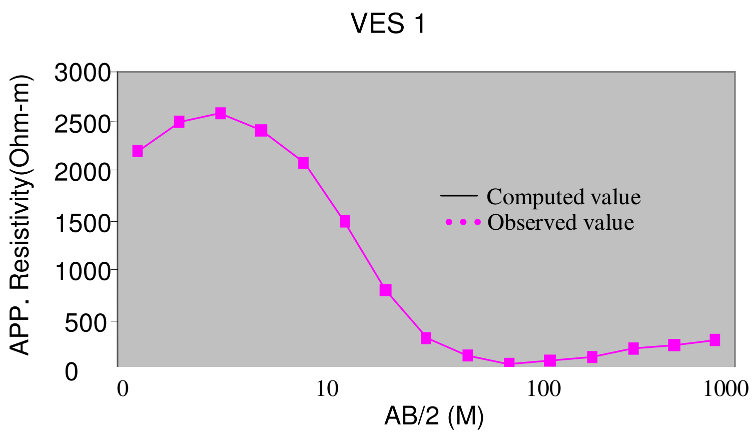
The interpreted results of vertical electrical sounding (VES) data are shown in Figures 1 and 2.

From Table 1, the *in situ* measurements readings indicate a mean pH value of 6.17 for the boreholes. These values imply that the pH of groundwater at Egbeleku Landfill area are slightly acidic and are probably due to the leaching of organic acids from decaying vegetation. These values are in compliance with the EIA value of 5.84, though slightly lower than the WHO limit of 6.5 - 9.2.

The temperature values of groundwater varied from 27.87°C at BH9 to 29.45°C. This shows compliance with the World Health Organization (WHO) limit of 40°C.

Turbidity is a measure of the amount of suspended and colloidal material present in groundwater. Turbidity values are low in all the monitoring boreholes. The values which ranged from 5.58 NTU at BH4 to 15.21 NTU at BH1 are below the WHO tolerable limit of 25 NTU.

Total dissolved solids (TDS) in a sample of the groundwater include all dissolved solids materials in solution, whether ionized or not. TDS values ranged from 7.61 mg/l at NBH4 to 68.21 µS.CM at NBH5. These values fall below the WHO regulatory limit of 500 – 5000 mg/l, thus making the groundwater suitable for domestic, farm, municipal or industrial use. The groundwater of Egbeleku landfill area according to Hem's classification is less than1000 mg/l indicating fresh



Observed (Field) and computed (Theoretical) data.

$\frac{AB}{2}(m)$	Observed value ($\rho_a(ohm-m)$)	Computed value ($\rho_a(ohm-m)$)
1.00	2200.00	2200.00
1.47	2500.00	2500.00
2.15	2700.00	2580.00
3.16	2500.00	2400.00
4.64	2100.00	2070.00
6.81	1650.00	1490.00
10.00	800.00	800.00
14.70	320.00	320.00
21.50	175.00	140.00
31.60	53.00	53.00
46.40	80.00	80.00
68.10	120.00	120.00
100.00	210.00	210.00
147.00	280.00	250.00
215.00	300.00	300.00

Model parameters 1.

Geoelectric layer	Resistivity (ohm-m)	Thickness (m)	Cumulative thickness(m)
1	2410.00	4.70	4.70
2	155.00	6.20	10.90
3	39.80	25.50	36.40
4	279.00	26.50	62.90
5	263.00	31.20	94.10
6	1490.00	Infinity	Infinity

RMS error (%): 2.40.

Figure 1. Field measurements and data interpretations by O.M. Alile, S.I. Jegede, and R.E. Emekeme.

natural water (Attenuation of Landfill Leachalo Pollutants in Aquifers - Critical reviews in Environmental Service and Technology, 1994). Biological oxygen demand (BOD_5) empirically measures the amounts of oxygen utilized for biodegradation of organic matter while dissolved oxygen (DO) is the amount of oxygen present in the water. Analysis of BOD_5 showed low level of biodegradation activities in the groundwater system. The BOD_5 values varied from 0.94 mg/l at BH10 to 1.55 mg/l at BH5. Consequently, the DO ranged from 4.05 mg/l at NBH5 to 5.34 mg/l at BH10.

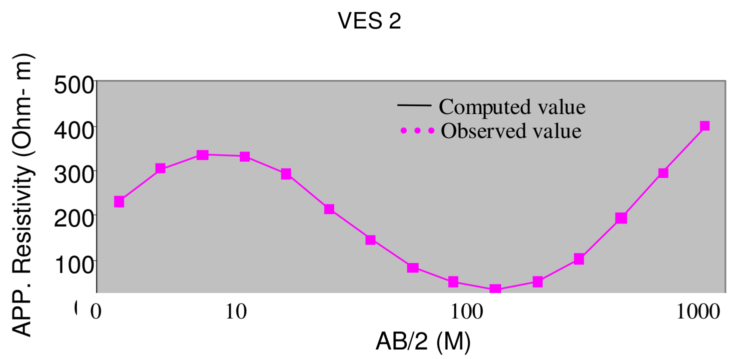
Chemical Oxygen Demand is a measure of oxygen required for complete oxidation to carbon (iv) oxide (CO_2) and water of organic matter present in a sample of groundwater. The values ranged from 5.18 mg/l at BH9 to 8.45 mg/l at BH7.

From Table 1, the routine analysis of THC content of the groundwater samples in the study area showed 0.13 mg/l for the boreholes. The values ranged from 0.08 mg/l at BH7 to 0.27 mg/l at BH1. These values are below WHO limit of 20 mg/l.

From the results, Figures 1 and 2, Six geoelectric layers were delineated with resistivity values as shown in the model parameters 1 and 2. VES 1 is KH curve type with $\rho_1 < \rho_2 > \rho_3 < \rho_4$. VES 2 is also a KH curve type with $\rho_1 < \rho_2 > \rho_3 < \rho_4$. Both VES have a total Cumulative thickness of 94.10 and 71.90 m, respectively with their resistivity values as shown in the model parameters 1 and 2. In correlation with the lithologic log of an existing borehole data from a nearby borehole, the VES results of both locations presents a high correlation of the above values with an existing functional borehole. This study showed a clear aquifer presence in the study area.

Conclusion

From the vertical electrical sounding (VES) analysis, it is established that the study area is of great aquifer potential. The physiochemical analysis for quality of water at Egbeleku site revealed that some parameters agree with World Health Organization's limit while some do not.



Observed (field) and computed (theoretical) data

$\frac{AB}{2}(m)$	Observed value ($\rho_a(ohm-m)$)	Computed value ($\rho_a(ohm-m)$)
1.00	263.00	231.00
1.47	310.00	305.00
2.15	355.00	334.00
3.16	330.00	330.00
4.64	300.00	292.00
6.81	150.00	214.00
10.00	146.00	146.00
14.70	85.00	85.00
21.50	58.00	52.00
31.60	37.00	37.00
46.40	52.00	52.00
68.10	152.00	104.00
100.00	240.00	195.00
147.00	348.00	295.00
215.00	400.00	400.00

Model parameters 2

Geoelectric layer	Resistivity (ohm-m)	Thickness (m)	Cumulative thickness(m)
1	303.00	4.50	4.50
2	167.00	5.70	10.20
3	17.20	15.60	25.80
4	310.00	22.10	47.90
5	274.00	24.00	71.90
6	8500.00	Infinity	Infinity

RMS Error (%): 2.40.

Figure 2. Field measurements and data interpretations by O.M. Alile, S.I. Jegede, and R.E. Emekeme.

But on the final analysis, the water is suitable for domestic use.

Since the landfill is on the surface, to avoid ground-water pollution by leachates, it is therefore necessary to install a well designed basal lining system to monitor the groundwater quality through well placed monitoring boreholes. Also, to avoid pollution from landfill gases, there is need to install properly constructed gas collection and venting system to control gas movement.

REFERENCES

Asokhia MB (1995). Engineering Geology. Samtos Services Ltd Lagos, Nigeria.

Asokhia MB, Azi SO, Ujuanbi O (2000). A simple computer iteration technique for the interpretation of vertical electrical sounding 269 pp. “J. Nig. Assoc. Math. Physics.

Bhattacharya PK, Patra HP (1968). Direct Current geoelectric sounding. Elsevier, Amsterdam. p 135.

Chilton PJ, Foster SSD (1995). Hydrogeological and characterization and water supply potentials of basement aquifers in tropical Africa. Hydrogeol. J., 3: 36-49.

Dorbrin MD, King RF (1976). Introduction to Geophysical prospecting. Mc Graw-Hill book, New York p. 630.

Fervolden RN, Hughes GM (1976). Hydrogeological Implications in Solid Waste disposal. Bulletin on Int. Assoc. Hydrogeal. pp. 146-158.

Feynman RP, Leighton RH, Sands M (1965). The Feyman lectures on Physics. Addison Westley reading (3 Vol).

Grant FS, West OF (1965). Interpretation theory in applied geophysics. McGraw-Hill, New York, pp 583.

Green J (1999). An Evaluation of Proposed Sanitary Landfill. http://Green Juris.tux.nu. www.geocities.com/green_juris.

Keller GV, Frischknecht FC (1966). Electrical methods in geophysical prospecting. Pergamon, oxford. p. 517.

Mailet R (1947). The fundamental equations of electrical prospecting. Geophysics, 12(4): 529-556.

Milson J (1939). Field Geophysics – a handbook of geophysical society of London. John Wiley & Sons NY, Toronto, Singapore.

Osemeikhian JEA, Asokhia MB (1994). Applied Geophysics, Samtos Services ltd. Lagos Nigeria.

Koefoed O (1979). Geosounding Principles 1, ESPC-Amsterdam-Oxford- New York.

Pamela C (1994). Waste Management Licensing Regulation: Business and the Environment- practitioner Series.

Department of Environmental Waste Management (1986): Paper No.28.

Attenuation of Landfill Leachalo Pollutants in Aquifers (1994). Crit. Rev. Environ. Service Technol. 24(2): 119-220.

Landfill Design, Construction and Operational Practice (1995). Dept. of Environ. Waste Management paper Draft for Construction. No. 26B.