DE GRUYTER OPEN

Analele Universităţii de Vest din Timişoara
Vol. LIX, 2016
Seria Fizică

DOI: 10.1515/awutp -2016-0004

DETERMINATION OF MAXIMUM HORIZONTAL DISTANCE (X_{MHD}) TRAVELLED BY LANDFILL LEACHATE FROM LAPITE DUMPSITE IN IBADAN, SOUTHWESTERN NIGERIA

Olatunde I. Popoola[1], Mutiu A. Fakunle[2]

[1]*Physics Department, University of Ibadan*

E-mail:latunde.popoola@gmail.com

[2] *Mathematical and Physical Sciences Department, Osun State University, Osogbo.*

Corresponding Author's E–Mail: *mutiu.fakunle@uniosun.edu.ng*

Article Info

Received: 23.03.2017
Accepted: 14.09.2017

Keywords: Leachate migration, Mathematical Model, Maximum Horizontal distance travelled by leachate

Abstract

This study was designed to determine Maximum Horizontal Distance (X_{MHD}) travelled by landfill leachate. Twenty - nine Schlumberger Vertical Electrical Soundings (VES) were conducted at 10.0m intervals away from four sides A, B, C and D of Lapite dumpsite. One VES point conducted outside the vicinity of the dumpsite served as a control. VES data were processed. Lowest resistivity values (Y) of VES points and the control point (Y_c) were extracted. Curves of Y against X fitted best to yield an equation. X_{MHD} was determined from the generated equation when $Y = Y_c$. The determined (X_{MHD}) on the four sides ranged from78.95m to 179.86m.

1. Introduction.

The activities of human and animals at homes, industries and commercial centers may result in the generation of Solid Wastes (SW). In other to keep the surroundings and environment clean and neat, solid wastes have to be disposed off. Several methods of disposal are in existence among which is landfilling. Landfilling can be below or above the land surface. When on the land surface, it is referred to as open dump. Open dump is predominant in Ibadan. [1] Reported that about seventy percent (70%) of solid wastes disposal is by landfilling especially in the developing countries such as Nigeria. This is because it offers the lowest cost and is most easily managed. Although, disposal of solid wastes using the mentioned method offers the said advantages, it has been identified as one of the major threat to groundwater resources by the production of landfill leachate. Landfill Leachate is the highly toxic fluid (liquid and gas) that is produced as a result of the decomposition of the SW by the action of bacterial, viruses and fungi and the presence of precipitation and rain water on the SW at the dumpsite. Landfill leachate accumulates at the bottom of the dumps and migrates to areas outside the landfills, leading to possible groundwater, surface water, soil and air pollution [2] if not properly controlled and designed. The rate of contaminant migration depends on the physical, chemical and biological processes in the soil profile [3, 4, 5, 6]. The contaminants (heavy metals and carbonic acids) being released at the base of the landfill migrates downward and horizontally to the groundwater. It was reported by [7] that the rate of urbanization in Nigeria is alarming and major cities are growing at rates between 10 – 15% per annum. So citing and development of residential quarters near public refuse dumpsites such as Lapite are common due to shortage of land for building to cope with the increasing rate of migration and consequently population explosion [8], [9] also reported that only 39% of people that live in cities have improved water source. Therefore, a large percentage of the population living in the neighborhood of dumpsites (60%) depends on groundwater from their private wells as their main source of quality drinking water. Therefore, it becomes imperative to monitor the transportation of landfill leachate in soil and groundwater. The aim of this study is to determine the maximum horizontal distance travelled by the landfill leachate from a dumpsite where hand – dug well could be dig so that groundwater could be safe for drinking. However, setting up of boreholes apart from being costly, provides a very limited and point source type of information, disregarding the areal extent of the contamination at the sites [10], so Electrical Resistivity Method (ERM) is used in this study. The presence of anions and cations in landfill leachate make it electrically more conductive than the surrounding rocks and soil thus, enabling a non – invasive geophysical method especially Electrical Resistivity Method (ERM) to be used. ERM was used in this study due to its credibility in landfill related studies in the determination of contaminant level of the groundwater around the vicinity and away from the dumpsite. The resistivity data generated was used to model leachate migration from a dumpsite (Lapite) and maximum horizontal distance travelled by the landfill leachate was determined. To reliably predict the fate of contaminant transport in groundwater, various mathematical models used include analytical or numerical techniques [11, 12]. Numerical models provide adaptability and capability for complicated field conditions. Simulating contaminant transport in soil by the use of mathematical model shows a better way of solving environmental issues because it provides realistic measures [13].

2. Description of the study area

The study area, Lapite dumpsite is one of the four government designated public dumpsite owned and managed by Oyo State Waste Management Authority (OYWMA) and was commissioned in 1998. Lapite dumpsite is located in Ibadan and is very active and fenced to prevent solid wastes encroachment on to the neighborhood as well as the residential buildings around the dumpsites if any. As at the time of this study, wastes were disposed off within and outside the dumpsite in different areas even at the entrance of the dumpsite. The study areas falls within the humid and sub humid tropical climate of southwestern Nigeria with an estimated mean annual rainfall of 1270 mm / yr. and mean maximum temperature of 32^{o}C [15]. The climate is characterized by two seasons namely the rainy season (April through October) and dry season (November through March) and characterized by Harmattan with little or no rainfall. Most of the precipitation is received during the rainy season [16]. Lapite dumpsite is situated along Moniya – Oyo road (Old Ibadan - Oyo Road) in Akinyele Local Government area of Oyo State on the geographic coordinate of N 07^{o} 34.121′ E 003^{o} 54.857′. The dumpsite covers land area of 10 hectares. A control point of geographic coordinate N 07^{o} 34' 52.6" E 003^{o} 54' 44.0" which was assessed to be dumps free was taken two thousand meters (2, 000 m) away from the dumpsite.

3. Geology and Hydrogeology of the Study Area

The type of rock in any area is an important factor governing the characteristics of groundwater. In general, sedimentary rocks due to their high porosity and permeability and layered nature are invariably good aquifers. On the other hand, Ibadan area is underlain by crystalline basement complex rocks of Precambrian age, comprising the migmatite, gnesis, the older granites and the meta – sediments [17]. The survey areas are underlain mainly by variably migmatized – undifferentiated biotite and biotite hornblende gnesis with interrelated amphibotite (Fig.1). The basement rocks composed mainly of metamorphic and igneous rock type relatively poor aquifer. Therefore in Ibadan area, one expects low groundwater production in comparison with areas underlain by sedimentary rocks. The basement complex nature of rocks in Ibadan does not however, completely rule out the possibility of the presence of isolated good productive aquifer if proper exploratory tools are used. The occurrence of groundwater in the crystalline rocks occur within soft overburden saprolite regolith aquifer and fractures within the basement rocks. The regolith aquifer holds a great quantity of groundwater and most hand – dug wells are located in this shallow aquifer for domestic water supply [18].

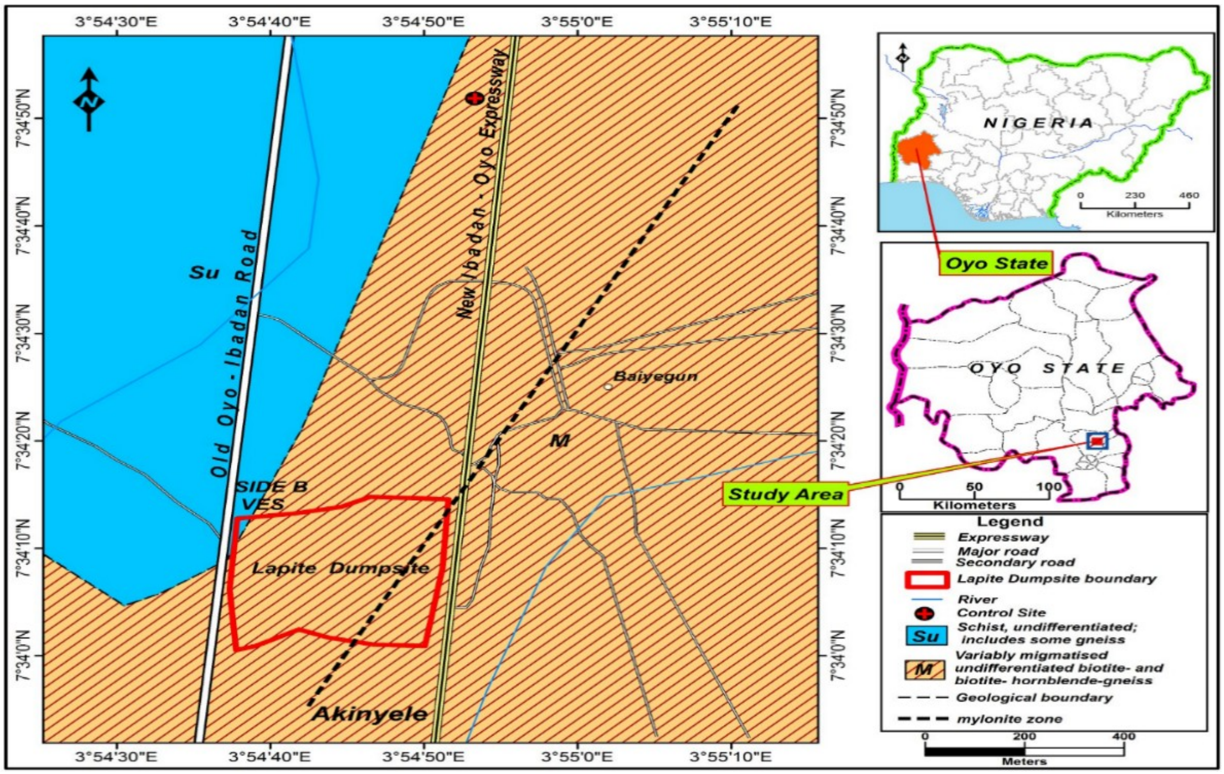

Fig.1*: Geological map of Lapite dumpsite and the control point (modified from Grant, 1970).*

4. Acquisition and Processing of Resistivity Data

A total of twenty – nine (29) Schlumberger Vertical Electrical Soundings (VES) points were conducted on the four sides of the dumpsite namely A (West), B (North), C (East),and D (South) at an approximately 10.0 m intervals away from the wall of each side of the dumpsite (Fig. 2). The electrodes were expanded from a minimum current electrode spacing (AB/2) of 1.0 m to a maximum of 65.0 m covering a total distance of 130.0 m. The locations of each VES point as well as each traverse line were recorded with the aid of Global Positioning System (GPS) meter. ABEM SAS 300 (STING RI Earth Resistivity Metre) resistivity meter was used to acquire the resistivity data in all the VES points. A VES point was conducted two thousand meters (2,000 m) away from the dumpsite to serve as a control point. This point was adjudged to be dump free. The field apparent resistivity data (ρa) were plotted against electrode spacing (AB/2) on a bi – logarithmic coordinate transparent paper. The best smooth curve through the points were interpreted using partial curve matching and the appropriate auxiliary charts. The crude layered models were obtained. These were fed into a computer using a software package called WIN RESIST that was developed by (Vander Velpen, 1988). The software processed the crude estimate of the layered parameters and display both the field and the model curves simultaneously and also produced the statistical parameters to describe the closeness of the fit. Optimization of the interpretation was achieved by successive iterations to reduce the degree of misfit until it falls within a specified and acceptable statistical limit.

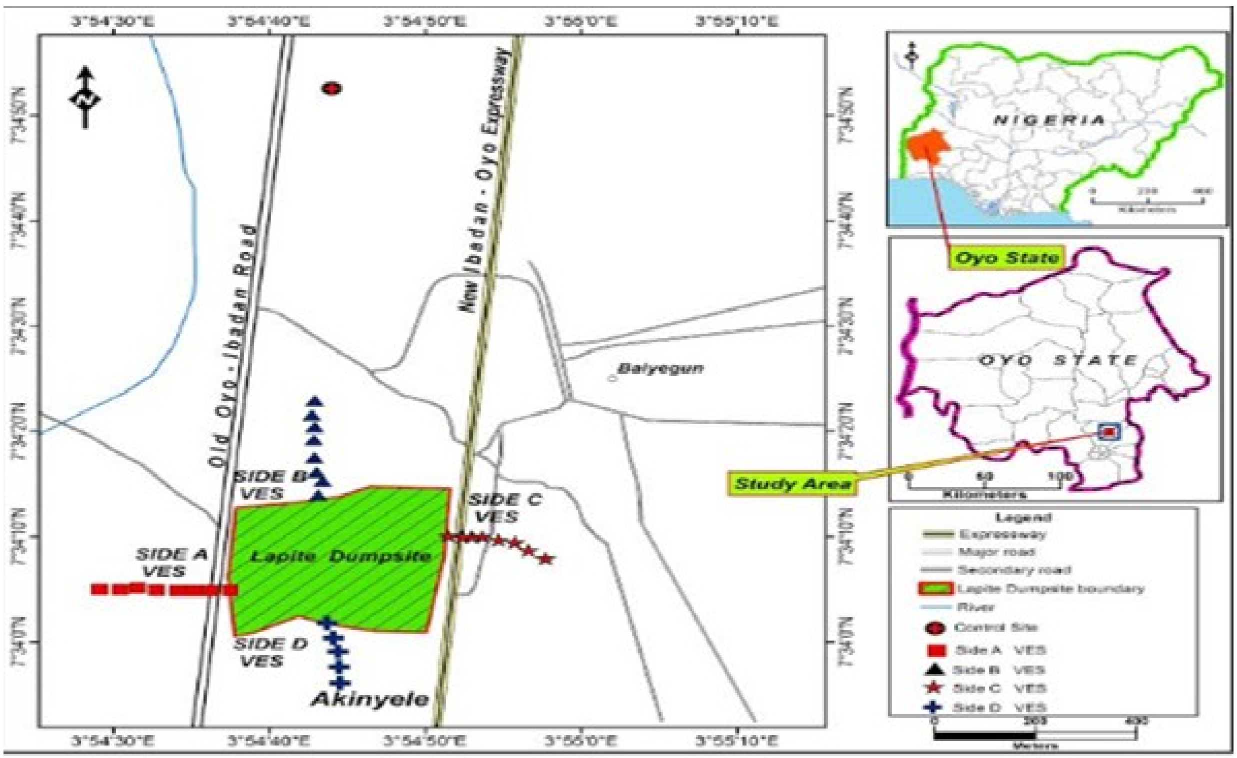

Fig. 2: *Data Acquisition map of all the VES points*

5. Mathematical Model Formation and Determination of Maximum Horizontal Distance

From the results of the inversion algorithm, the lowest resistivity values (Y) of all VES points on each side were extracted. The extracted lowest resistivity values (Y) were plotted against the corresponding horizontal distances (X) of the VES points from the wall boundary of each side of the dumpsite using a software called Origin 7 to yield a mathematical model.

$$Y = Me^{NX} \quad (1)$$

where M and N are constants

Using this equation, the Maximum Horizontal Distances (X_{MHD}) travelled by the landfill leachate for each side was determined by substituting the value of $Y = Y_c$ into the modelled equation. Where Y_c is the lowest resistivity value of the control.

6. Results and Discussions

The results of the lowest resistivity value (Y), ground level, geographic coordinate and the distance (X) of each VES point from the wall boundary on each side of the dumpsite were shown in Tables 1 to 4. The curve of lowest resistivity values (Y) against horizontal distances (X) of each side yielded $Y = Me^{NX}$ where M and N are constants and their values ranged from 15.523 to 38.699 and 0.0062 to 0.0236 m^{-1} respectively. The correlation coefficient of these curves ranged from 0.8266 to 0.9715 as shown in Figs. 3 to 6. From these figures, it is evident that the resistivity (Y) increases as the horizontal distance (X) increases away from the dumpsite which is in accordance with the findings of [20, 21, 22, and 23]. All these researchers established that landfill leachate actually migrated away horizontally from the point of production (the dumpsite). This is an indication that the landfill leachate concentrations decreases away from the dumpsite. When the value of Y_c is substituted in equations (2), (3), (4), and (5)

$$Y = 38.699\,e^{0.0062X} \tag{2}$$

$$Y = 15.523\,e^{0.0167X} \tag{3}$$

$$Y = 19.211\,e^{0.0236X} \tag{4}$$

$$Y = 27.439\,e^{0.0154X} \tag{5}$$

of side A, B, C, and D respectively of the dumpsite, the distance (X_{MHD}) obtained were 179.86m, 121.51m, 78.95m and 94.78m for side A, B, C and D respectively. These distances represent the maximum distance travelled by the landfill leachate since $Y = Y_c$. At these distances, the effect of the leachate has been reduced drastically. Beyond these distances hand – dug well could have been free from the effect of landfill leachate. Since the control is judged to be dump free, the landfill leachate has not travelled to the determined distances on all the four sides of the dumpsite. This is an indication that groundwater from any hand – dug well beyond these distances is safe for drinking. But less than these distances groundwater is unfit for drinking

Table 1: *Variation of lowest Resistivity (Y) with distance (X) of each VES point from the boundary of the dumpsite.*

	Geographic coordinate				
VES	Latitude (° N)	Longitude (° E)	Distance (X) of each VES point from the boundary of the dumpsite (m)	Lowest Resistivity Value (Y) (Ω m)	Ground Level (m)
1	7.56826	3.91139	10.0	42.2	256.0
2	7.56825	3.91131	20.0	46.5	258.0
3	7.56825	3.91122	30.0	46.8	259.0
4	7.56824	3.91114	40.0	46.9	260.0
5	7.56824	3.91106	50.0	49.6	259.0
6	7.56825	3.91093	60.0	50.1	259.0
7	7.56823	3.91085	70.0	64.4	258.0
8	7.56824	3.91077	80.0	67.7	257.0

Table 2: *Variation of lowest Resistivity (Y) with distance (X) of each VES point from the boundary of the dumpsite.*

	Geographic Coordinate				
VES	Latitude (° N)	Longitude (° E)	Distance (X) of each VES point from the boundary of the dumpsite (m)	Lowest Resistivity Value (Y) (Ω m)	Ground Level (m)
1	7.56969	3.91466	10.0	21.2	263.0
2	7.56968	3.91475	20.0	32.8	264.0
3	7.56970	3.91482	30.0	40.9	263.0
4	7.56969	3.91491	40.0	51.9	262.0
5	7.56972	3.91502	50.0	68.3	264.0
6	7.56970	3.91509	60.0	77.9	263.0
7	7.56967	3.91526	70.0	90.7	264.0

Table 3: *Variation of lowest Resistivity (Y) with distance (X) of each VES point from the boundary of the dumpsite.*

	Geographic Coordinate				
VES	Latitude (^{o} N)	Longitude (^{o} E)	Distance (X) of each VES point from the wall boundary of the dumpsite (m)	Lowest Resistivity Value (Y) (Ω m)	Ground Level (m)
1	7.56993	3.91217	11.0	16.3	249.0
2	7.56999	3.91215	23.0	22.8	248.0
3	7.57007	3.91215	33.0	30.6	250.0
4	7.57014	3.91214	43.0	35.2	252.0
5	7.57022	3.91212	54.0	39.6	250.0
6	7.57034	3.91213	64.0	43.2	250.0
7	7.57046	3.91209	74.0	50.1	251.0
8	7.57055	3.91212	86.0	64.9	251.0

Table 4: *Variation of lowest Resistivity (Y) with distance (X) of each VES point from the boundary of the dumpsite.*

	Geographic Coordinate				
VES	Latitude (^{o} N)	Longitude (^{o} E)	Distance (X) of each VES point from the boundary of the dumpsite (m)	Lowest Resistivity Value (Y) (Ω m)	Ground Level (m)
1	7.56831	3.91196	10.0	33.3	262.0
2	7.56825	3.91204	20.0	34.7	264.0
3	7.56819	3.91212	30.0	47.3	264.0
4	7.56813	3.91220	40.0	47.5	264.0
5	7.56806	3.91226	50.0	57.2	263.0
6	7.56801	3.91233	60.0	72.2	261.0

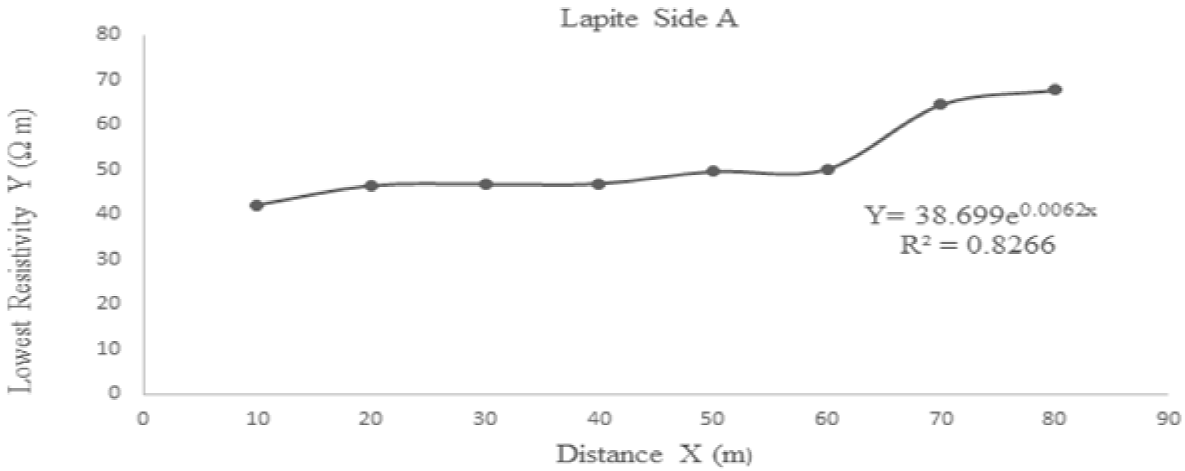

Fig.3*: Lowest resistivity values (Y) against horizontal distances (X) of VES points of side A*

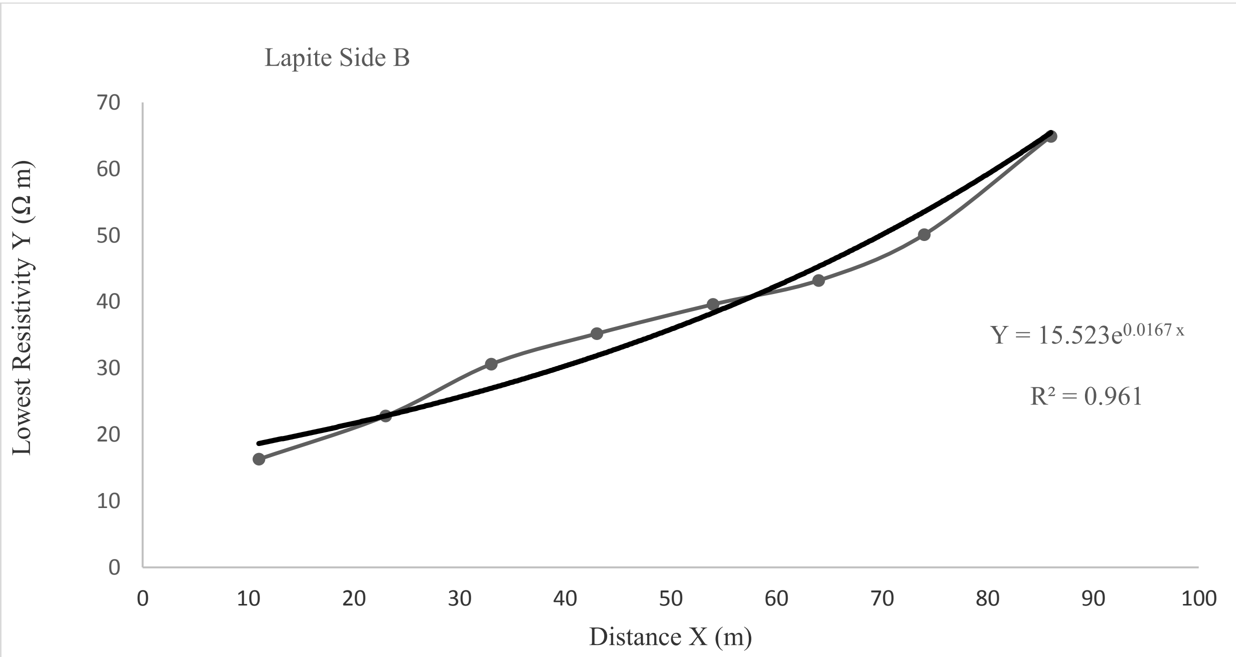

Fig.4*: Lowest resistivity values (Y) against horizontal distances (X) of VES points of side B.*

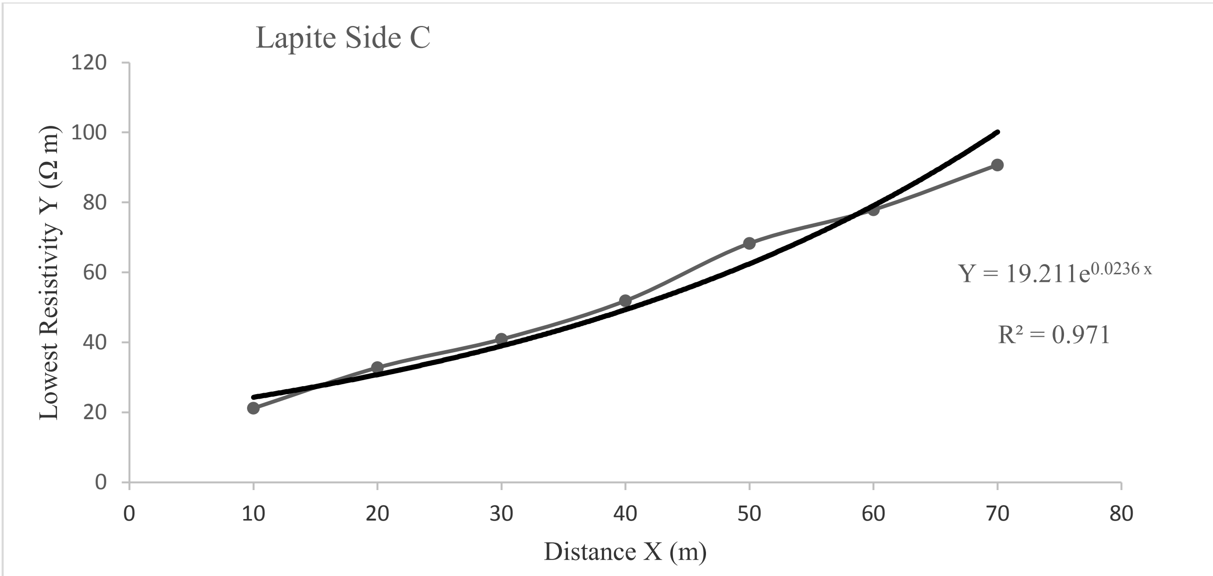

Fig.5*: Lowest resistivity values (Y) against horizontal distances (X) of VES points of side C.*

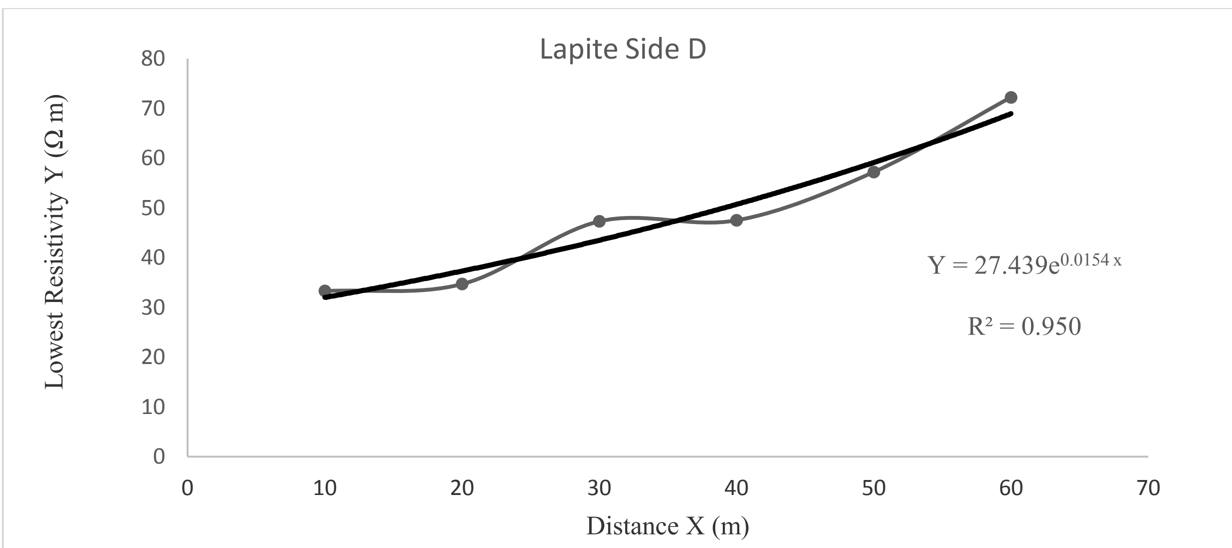

Fig.6*: Lowest resistivity values (Y) against horizontal distances (X) of VES points of side D.*

7. Conclusion

From the model equation, we have determined the maximum horizontal distance travelled (X_{MHD}) by the landfill leachate on sides A, B, C and D of the dumpsite to be 179.86m, 121.51m,78.95m and 94.78 m respectively . It is therefore recommended that hand dug wells are to be located at a distance 179.86 m, 121.51 m, 78.95 m, and 94.78 m of side A, B, C and D respectively. Beyond these distances if the groundwater has to be free from the effect of the migrated landfill leachate.

References

[1] Shao-gang Dong, Zhong-hua Tang, Bai-wei Liu, and O. D. Orodu, Numerical modeling of the environment impact of landfill leachate leakage on groundwater quality-A field application International Conference on Environmental Science and Information Application Technology. 2009: 565-568

[2] P.B Kjeldsen, M. A. Rooker, A. P. Baun, A. Ledin, A. and T. H Christensen, "Present and long-term composition of MSW landfill leachate: a review", Critical Reviews in Environmental Science and Technology. 2002: 32, 297-336.

[3] D. L. Jensen and T.H Christensen. "Colloidal and dissolved metals in leachate from four Danish landfills," Water Research. 1999: 33 (9). 2139-2147.

[4] H.D. Robinson and J.L Lucas. "Leachate attenuation in the unsaturated zone beneath landfills: instrumentation and monitoring of a site in Southern England," Water Science & Technology. 1985: 17, 477-492.

[5] J.K Oygard, A. Mage, and E. Gjengedal . "Estimation of the mass balance of selected metals in four sanitary landfills in Western Norway, with emphasis on the heavy metals content of the deposited waste and the leachate," Water Research, 2004: 38 (12), 2851-2858,

[6] D. Rapti-Caputo, and C. Vaccaro. "Geochemical evidences of landfill leachate in groundwater," Engineering Geology. 2006: 85, 111-121.

[7] World Bank. Nigeria Community Based Urban Development project NGPE 69901. The World Bank 1818h street NW Washington D.C. 20433. 2000a:

[8] A. Ikem, O. Osibanjo, M.K.C. Shridhar, and A. Sobande, Evaluation of Groundwater Quality Characteristics Near two Waste Sites in Ibadan and Lagos, Nigeria. Water, Air, and Soil pollution 2002: 140 307 – 333.

[9] World Bank. World Development indications 2000. The World Bank 1818H Street NW Washington DC 20433. 2000b:

[10] J. T. Zume, A. Tarhule, and S. Christenson. Subsurface Imaging of an Abandoned Solid Waste Landfill Site in Norman, Oklahoma. Groundwater Monitoring and Remediation. 2006: 26, 62-69

[11] T.M. Addiscott, and R.J. Wagenet. "Concepts of solute leaching in soils: a review of modelling approaches," J. of Soil Science. 1985: 36,.411-424.

[12] M.A. Martin. M.A "Mathematical modelling of leaching by irregular wetting fronts in chemically heterogeneous porous media," Geoderma. 2006: 134, 267-273.

[13] J. D. Vilomet, A. Veron, I. J. P. Ambrosi, S. Moustier, J. Y. Bottero, and L. Chatelet-Snidaro. "Isotopic tracing of landfill leachate and pollutant lead mobility in soil and groundwater,"*Environmental Science and Technology.* 2003: 37, 4586-4591.

[14] A.M. Gbadebo, J.A. Oyedepo, and A.M. Taiwo. "Variability of Nitrate in Groundwater in Some Parts of Southwestern Nigeria." *The Pacific Journal of Science and Technology* 2010: 11, (2) 572-584.

[15] J.O. Akinola, Rainfall Distribution in Nigeria 1982-1983, Impact Publishers Nigeria Limited, Ibadan, Nigeria (1986): 371.

[16] M.A. Rahaman. Review of Basement Geology of South – Western Nigeria: In Geology of Nigeria 2nd revised edition edited Kogbe, C.A. 1989.

[17] S.A. Alagbe. Environmental Geology 2002: 42, 404 – 413.

[18] B. P. A. Vander Velpen Win Resist Version 1.0 M.Sc. Research Project. ITC, Deft, Netherlands 1988.

[19] N. K. Grant. Geochronology of Precambrian basement rocks from Ibadan. Earth and Planetary Science Newsletter 1970: 10 (1), 29 – 38.

[20] T.V. Andreas, R.E. Vagner, M. Gulliana, V.Z. Lazaro and L.G. Heraldo, Case study: a 3 D resistivity and induced polarization imaging from downstream a waste disposal site in Brazil. Environ. Earth Science 2012: 66, 763 – 772

[21] S.L. Jegede, O. Ujuanbi, N.K. Abdullahi and R.E Iserhien – Ewekeme, Mapping and Monitoring of Leachate Plume Migration at an Open Waste Disposal site using Non – Invasive Methods. Research journal of Environmental and Earth Sciences, 2012: 4(1), 26-33

[22] N. Yalo, M. Lawson and C.Adihou, Geophysical Contribution for mapping the contaminant Plume of Leachate from Rubbish Dumpsite of Hervie. Benin. British Journal of Applied Science and Tech. 2014: 4(1) 127 – 143.

[23] S.A Ganiyu, B.S. Badmus, M.A Oladunjoye, A.P. Aizebeokhai and O.T. Olurin, Delineation of Leachate Plume Migration Using Electrical Resistivity Imaging on Lapite Dumpsite in Ibadan Southwestern Nigeria. Geosciences, 2015: 5 (2), 70 – 80.