



Vertical Elemental Analysis of Soil Plume down the Depth Profile Case of College Road Dumpsite, Kaduna North-Nigeria

¹Ahmed Mohammed, ²Sadiq Umar, and ³Abdulkarim M.S

¹ Department of Physics, School of Science Education, Federal College of Education (Technical), Gusau - Nigeria

² Department of Physics, Faculty of Science, Ahmadu Bello University, Zaria-Nigeria

³ Department of Applied Sciences, College of Science and Technology Kaduna Polytechnic, Kaduna-Nigeria

Corresponding Author's Email: ahmedmohammed7984@gmail.com Phone No: 07036812960, 0703776995

Received on: November 2019

Revised and Accepted on: September 2019

Published on: December 2019

ABSTRACT

Environmental samples were analyzed to determine the content and concentrations of various elements using instrumental neutron activation analysis technique. Concentrations of twenty-nine elements were determined in each of the six soil samples that were taken from the top layer down the soil profiles at a distance of 0, 25, 50, 100, 120 and 150cm respectively. The results generally revealed fluctuations in concentration of the elements from the top soil surface to the depth of 150cm. It is recommended that further research beyond the scope of this depth be investigated in other to elucidate the effect of soil texture on metal seepage.

Key words: Contaminants, infiltration, instrumental neutron activation analysis, soil texture and degraded dumpsite.

1.0 INTRODUCTION

Soil infiltration refers to the soils ability to allow leachate particles move downward by force of gravity through seepage into and through the soil profiles (Farzad *et al.* 2015). Infiltration study is important when estimates of groundwater and soils pollution are necessary. The infiltration rate is determined by the interaction of a number of physical and chemical soil characteristics or properties.

In the infiltration process, leachate penetrates the soil surface due to the combined influence of gravity and capillary forces. Both forces act in the vertical direction to cause percolation downward. Capillary forces also act to divert leachate laterally from larger pores to capillary pore spaces which are much smaller in dimension, but may be very numerous (Farzad *et al.* 2015).

Leachate percolation through the soil is governed by Darcy's law, which states that the flux is equal to the hydraulic conductivity

multiplied by the hydraulic gradient (Farzad *et al.* 2015). The hydraulic gradient is comprised of the gravity, pressure, osmotic and matric (movement of leachate contaminants from wet or full pores to dry soil) potentials (Singer and Munns, 1999). The hydraulic conductivity of soil is strongly influenced by the soil texture, that is, the relative proportions of sand, silt and clay. Clay particles are particularly important as their small size makes them able to fill the voids between larger particles while their charge orientation gives them a crucial role in binding the soil matrix into larger structures.

Childs *et al.* (1993) explained that, regions of lighter texture or sandy soil within a field often have higher intake rates. However, Van *et al.* (1991) found a positive correlation between the clay content and the initial infiltration rate while the silt content was negatively correlated.

Soil water content also has a direct impact on the degree of soil cracking which in turn has a large impact on the infiltration function (Mailhol and Gonzalez, 1993). Cracking occurs within many clay soils. Cracks serve as pathways through which water can quickly enter the soil.

Qian *et al.* (1996) reported that the influence of soil texture on metal solubility in soils is best expressed in terms of the soils division into clay, silt and sand fractions; this has prompted the use of instrumental neutron activation techniques to analyze the content and concentration of contaminants present in the soil samples. The aim of this research work therefore is to study the influence of the soil types on movement of contaminants and the objectives were to determine the contaminants contents, concentration and vertical distribution in the soil profiles and identify the samples where concentration is much accumulated and use statistical tool to explain the variations between adjacent concentrations and carry out correlation and clustering analysis on contaminants content.

2.0 THEORY OF ANALYTICAL TECHNIQUE USED

Neutron activation analysis was discovered in 1936 when Hevsey and Levi found that samples containing certain earth elements become highly radioactive after exposure to a source of neutrons. NAA is a very powerful analytical technique for identifying many elements present in samples of unknown composition performing both quantitative and qualitative multi-element analysis of major, minor and trace elements in samples (Chaubey *et al.* 2011).

An isotope of atomic mass A and atomic number Z when placed in a neutron flux will, in general, absorb a neutron to become the isotope (A+1, Z). Some resulting isotopes, being unstable, will decay, emitting one or more gamma-rays with energies and half-life characteristic of the particular isotope. During irradiation the naturally occurring stable isotopes of most elements that constitute alluvial samples are transformed into radioactive isotope by neutron capture. The number of radionuclide

3.2 Sample Collection

produced in activation of a natural isotope is given by the expression:

$$N_{(A+1)} = \frac{\phi \sigma_{aA} N_{oA}}{\lambda_{(A+1)}} (1 - e^{-\lambda_{(A+1)} T}) e^{-\lambda_{(A+1)} t}$$

and the activity is $\frac{dN_{(A+1)}}{dt}$

where: ϕ : is the neutron flux

σ_{aA} : is the neutron absorption cross-section of the original isotope

N_{oA} : is the number of nuclei of element under consideration of isotope A

$\lambda_{(A+1)}$: is the decay constant of the created isotope

T : is the irradiation time and,

t : is the time between stop of the activity and start of the counting of the activity.

The basic essentials required to carry out an analysis of soil samples by neutron activation analysis are a source of neutrons, HPGE gamma ray spectrometer coupled with MCA and printer (Chaubey *et al.* 2011).

2.1 Darcy's Law

States that fluid will flow through a porous media at a rate which is proportional to the product of the cross sectional area through which flow can occur, or the hydraulic gradient and the hydraulic conductivity.

$$Q = -KA \frac{dh}{dl}$$

Where $\frac{dh}{dl}$ = Hydraulic gradient, the negative sign is used by convention to note the water flowing from highest to lowest hydraulic head
Internet: (<http://jan.ucc.nau.edu/~doetqp-p/courses/env302/lec9/LEC9.html>).

3.0 METHODOLOGY

3.1 Site Description

College road dumpsite was chosen because it is situated within residential houses and has being in operation for the past thirty years.

A pit was dogged within the soil of polluted dumpsite to reveal its profiles and soil sample

were collected at a depth of 0, 25, 50, 100, 120 and 150cm respectively with a help of an auger and parker. The collected soil samples were emptied into polyethylene bags, which were previously cleaned using nitric acid, pure water and acetone, tied and labeled with a marker on a paper each inserted in the bags showing a labeled of respective depths and were also recorded in a record sheet to prevent interference or mix up of soil samples. The soil samples were double bagged to reduce chances of cross contamination.

3.3 Sample Analysis

The samples were first dry through an open air in a room at an ambient temperature and then dried in an oven for some days at temperature of

4.1 Descriptive Statistical Results of Vertical Distribution of Contaminants in Soil Profiles

The results of depth wise studies of metals concentration (mgkg^{-1}) in the study site revealed total of twenty nine elements with their concentration distribution as displayed in table 1.

The detection of these elements in each of the soil samples down the profiles are evidence of their migration. This fact is supported by Kirpichtchikova, (2006) and Li, (2013) that soils are the major sink for contaminants released into the environment. Adriano, (2003) is of the view that their total concentration in soils persists for a long time after their introduction. In addition, Richards, (1998) and Camobreco, (1996) are of the view that contaminants in deep soil may result in groundwater contamination. Furthermore, any contamination of soils could cause groundwater contamination because of the mobility of the pollutants in soils (Steinmann and Stille, (1997).

Generally, these contaminants concentration fluctuated with increasing depth, the result in agreements with the report of Xudong *et al.* (2015) and Latif *et al.* (2004) that metal contamination and soil leaching varies spatially across the soil profile due to soil type, geology and PH. The report of Joan and Bert, (1992) state that Metal-soil interaction is such that when

373⁰K. The samples were then crushed into fine powder using agate mortar to make then homogeneous. 200mg of each soil sample was put in a polyethylene bags and then labeled B1, B2, B3, B4, B5 and B6. The bags together with vials are washed in distilled water three times. For long irradiation all the samples and standards were packed together in an irradiation vials and irradiated simultaneously for six hours with a reactor power of 15kw and a thermal neutron flux of 5×10^{11} neutron per second at Nigeria Nuclear Research Reactor-1 situated at center of energy and training of Ahmadu Bello university Zaria, Nigeria. After irradiation the activities of the irradiated samples and standards were measured as shown in table 1.

metals are introduced at the soil surface, downward transportation does not occur to any great extent unless the metal retention capacity of the soil is overloaded, or metal interaction with the associated waste matrix enhances mobility.

Sodium is the only contaminant that shows increase concentration with depth which is in disagreement with Michael and Seldon, (2011) report that metal displayed a systematic drop in concentration with depth.

Contaminants accumulation in deeper soils might have been enhanced by the nature of the soil texture in the environment. According to Murtala *et al.* (2017) Kaduna north where the research location fall into has two major soil textural classes: the sandy loam and loamy sand. The permeability of the soil texture might have being the reason for this downward migration.

4.0 RESULTS AND DISCUSSION

Table 1: The analytical results of instrumental neutron activation analysis of six Geological samples I in site B are presented below

ELEMENT	B1	B2	B3	B4	B5	B6	MEAN
Mg	BDL	BDL	2210	3668	3437	5036	3588
Al	32860	26580	62600	74740	95050	95270	64517
Ca	4847	2548	BDL	2456	2945	6482	3856
Ti	2419	BDL	2061	3400	BDL	3065	2736.3
V	44.2	56	59	46	29	44	46.4
Mn	327	233	99	144	150	190	190.5
Dy	4.5	4.6	5.6	5.1	6.0	3.5	4.88
Na	2275	2364	3669	5701	9089	15850	649
K	1452	24260	40830	30780	33410	24010	25790
As	2.7	4.6	1.5	1.6	BDL	BDL	2.6
Br	2.3	2.7	2.3	2.9	BDL	BDL	2.55
La	109.8	45.9	52.6	39.3	70.3	56.2	62.35
Sm	16.5	5.65	6.94	5.48	10.89	7.27	7.27
U	8.6	6.2	5.3	4.7	8.7	4.01	6.25
Sc	4.42	5.02	4.95	6.4	3.96	4.9	4.94
Cr	56	103	41	73.3	19.7	39.2	55.4
Fe	31240	58680	27990	24010	16070	18090	29346.7
Co	6.04	8.02	9.4	10.5	12.9	6.5	8.89
Zn	291	122	42	40.1	35.1	43.5	95.6
Rb	90	1446	211	201.7	194	168.4	385.2
Sb	BDL	1.5	0.49	BDL	BDL	0.7	0.90
Cs	3.2	4.0	5.2	8.6	6.5	5.9	0.12
Ba	499	638	1022	788	898	642	747.8
Eu	1.34	1.0	1.3	1.1	1.1	1.3	1.19
Yb	3.1	2.2	2.0	2.3	7.9	2.3	3.3
Lu	0.59	0.42	0.4	0.3	0.85	0.23	0.47
Hf	12.3	14.5	12.4	10.00	5.01	4.4	9.77
Ta	1.07	1.1	1.4	2.1	1.46	1.4	1.42
Th	51.8	22.3	25.0	10.3	22.5	7.0	23.15

All results are in ppm

BDL: Below Detection Limit

Table 2: Pearson correlation analysis of total contaminant concentrations between soil profiles

	B1	B2	B3	B4	B5	B6
B1	1	.862**	.801**	.830**	.769**	.799**
B2	.862**	1	.756**	.681**	.569**	.561**
B3	.081**	.756**	1	.979**	.948**	.919**
B4	.083**	.681**	.979**	1	.989**	.978**
B5	.769**	.569**	.948**	.989**	1	.992**
B6	.799**	.561**	.919**	.978**	.992**	1

**Correlation is significant at the 0.01 level (2-tailed)

Table 3: Pair samples statistics between adjacent profiles

	Mean	N	Standard deviation	Standard Error Mean
Pair 1	B1	2748.6276	27	8510.12960
	B2	4339.3220	27	12777.15632
Pair 2	B3	4861.0614	29	14277.51017
	B4	5039.9579	29	15162.88124
Pair 3	B5	5568.4438	29	18529.63552
	B6	5828.8176	29	18247.60506

Table 4: Pair samples correlation analysis

	N	Correlation	Significance
Pair 1	B1 & B2	.862	.000
Pair 2	B3 & B4	.979	.000
Pair 3	B5 & B6	.992	.000

Table 6: Friedman test for mean rank

Soil profile	B1	B2	B3	B4	B5	B6
Mean rank	3.52	3.54	3.61	3.59	3.72	3.02

4.2 Clustering Analysis

A pattern of contaminants concentrations of Mg<Na<Fe<K<Al as observed in samples B3, B4, B5 and B6 except with B6 where Ca replaces Mg. In all the entire soil samples except in sample B2, Lu has the least and Al has the highest concentration. Statistics indicates 13% of the contaminants show increase concentration from B1 to B2 while 14% indicated raise in concentration from B2 to B3.

These contaminants Mg (B1, B2), Ca (B3), Ti (B2, B5), As and Br (B5, B6) and Sb (B1, B4, B5) fell below detection limit as specified in the bracket.

Tables 6 is about mean ranking test and show soil sample where accumulation of contaminant concentration is high. There is no significant difference between the sampled soils; the behavior of the contaminants is the same in each of the sample soil. The increasing order of their accumulation are B5>B3>B4>B2>B1>B6. This show that majority of the contaminants migrated down.

4.3 Pearson Correlation Analysis of Total Contaminant Concentrations in Each Soil Profiles

Table 2 summarizes Correlations statistics of twenty nine contaminant concentrations each

detected from six soil samples. Generally there are high positive correlations amongst the contaminants from different soil samples except for few cases where contaminants from B2 exhibit some positive correlations with B4, B5 and B6 respectively. The similarity in relationship indicated common anthropogenic source of the contaminants. The contaminants are not affected by chemical change.

In table 3 correlation analysis was computed between contaminants from adjacent soil samples that is the first and second, third and fourth and fifth with the view to elucidate if the soil samples from which the contaminants are obtained are different or the same. The result indicated that there was no significant difference in contaminant from each of the adjacent soil samples by implication, the soil samples are of the same single class.

5.0 CONCLUSION

The analysis of soil samples using instrumental neutron activation analysis revealed a total of twenty contaminants distributed across the soil profiles and their concentrations generally fluctuated from surface soil down the profiles. The uses of statistical tools indicate high positive correlations among the contaminants with adjacent soils samples strongly related. Furthermore, the mean ranking show high accumulations of these contaminants down the profiles with increasing order of their accumulation in the samples showing $B5 > B3 > B4 > B2 > B1 > B6$. There is almost no define trends in all the entire soil samples except cluster analysis which show that contaminants concentrations of $Mg < Na < Fe < K < Al$ as observed in samples B3, B4, B5 and B6 except with B6 where Ca replaces Mg.

6.0 RECOMMENDATION

It is recommended that further research beyond the scope this work on soil and water samples be

carried out for possibility of groundwater pollution.

REFERENCES

- Abdullahi K.N, (2009). Unpublished Phd Thesis, Ahmadu Bello University, Zaria-Nigeria
- Adriano, D.C., (1986). Trace elements in the terrestrial environment. Springer Verlag, New York, pp533
- Camobreco V.J., Richards B.K., Steenhuis T.S., Pevery J.H., McBride M. B., (1996). Movement of heavy metals through undisturbed and homogenized soil columns. Soil science, Vol.161:p740–750.
- Chaubey A.k., Awoke T., Dilbetigle A.I. & Asres Y.H., (2011). Elemental Analysis of Alluvial soil samples using Neutron Activation techniques in Blue Nile Basin, East Gojjam, Ethiopia, E-International Scientific Research Journal, Vol.3 issue 4.
- Childs JL, Wallender WW, Hopmans JW., (1993). Spatial and seasonal variation of furrow infiltration. Journal of irrigation Drainage Engineering Vol.119 (1), pp74-90.
- Farzad Haghazari, Hassan Shagholi & Mehdi Feizi, (2015). Factor affecting infiltration of agricultural soils: A review, International Journal of Agronomy and Agricultural Research, Vol.6, No.5, pp.21-35, <http://www.innspub.net>.
- Internet: (<http://jan.ucc.nau.edu/~doetqpp/courses/env302/lec9/LEC9.html>).
- Joan E. McLean and Bert E. Bledsoe, (1992). Behavior of Metals in Soils, Ground Water Issue, United States Environmental Protection Agency.

- Kirpichtchikova AT, Manceau A, Spadini L, Panfili F, Marcus MA, Jacquet T. (2006). Speciation and solubility of heavy metals in contaminated soil using X-ray micro fluorescence, EXAFS Spectroscopy, chemical extraction and thermodynamic modeling. *Geochimica et Cosmochimica Acta*, 70: 2163-2190.
- Latif SK. A., Hossain M.S. Uddin, Hafiz, M.A., Islam M.A. and Mubin M.S.H., (2004). Studies on Environmental Pollution in Bangladesh using Reactor based Neutron Activation Analysis Technique, Institute of Nuclear Science and Technology, Atomic Energy Research Establishment, Savar, Dhaka, Bangladesh
- Li X. Y., Liu L. J., Wang Y. G., Luo G. P., Chen X., Yang X. L.,(2013). Heavy metal contamination of urban soil in an old industrial city (Shenyang) in Northeast China. *Geoderma*. 192: 50–58
- Mailhol JC, Gonzalez J.M.(1993). Furrow irrigation model for real time applications on cracking Soil. *Journal of Irrigation and Drainage Engineering* 119(5), 768-783.
- Michael D. K., and Sheldon L., (2011). Heavy Metals in Urban Soils of East St. Louis, IL, Part 1: Total Concentration of Heavy Metals in Soil, *Journal of the Air and Waste Management Association*.
- Murtala Shehu Ahmed, Adamu Idris Tanko, Martin Obada Eduvie & Mohammed Ahmed, (2017). Assessment of Groundwater Vulnerability in Kaduna Metropolis, Northwest Nigeria, *Journal of Geoscience and Environment Protection*, Vol. 5, p99-117, <http://www.scirp.org/journal/gep>
- Qian, J., Shan, X-Q, Wang, Z-J. and Tu, Q. (1996). Distribution and plant availability of heavy metals in different particlesize fractions of soil. *The Science of the Total Environment*, 187, pp131–141.
- Richards B. K., Steenhuis T. S., Peverly J. H., & McBride M. B. (1998). Metal mobility at an old, heavily loaded sludge application site. *Environ Pollut*, 99(3): 365–377. PMID: 15093301
- Singer MJ, Munns, (1990). Soil: An introduction, 4th, prentice Hall, Upper Saddle River.
- Adriano, DC (1986). Trace elements in the terrestrial environment. Springer Verlag, New York, pp533.
- Steinmann M., Stille P. Rare earth element behaviour and Pb, Sr, Nd isotope systematic in a heavy metal contaminated soil. *Appl. Geochem* (1997). Vol. 12, pp607–623.
- Van Es H.M, Cassel D.K, Daniels R. B.(1991). Infiltration variability and correlations with surface soil properties for an eroded Hapludult." *Soil Science Society of America Journal* 55(2), 486-492.
- Xudong Jiao, Yanguo Teng, Yanhong Zhan, Jin Wu, Xueyu Lin(2015). Soil Heavy Metal Pollution and Risk Assessment in Shenyang Industrial District, Northeast China.