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Modelling of Leachate-Constituent Transport in the Underlying Soil of a Waste Dumpsite

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Abstract
A study on modelling of transport of heavy metals from a dumpsite in Aluu, Port Harcourt, Rivers State was carried out to understand and predict the transport regime of heavy metals within the soil. Solid waste characterization was done by sectioning and collecting a representative sample of the solid waste and calculating its percentage mass composition. Leachate sample was collected at the base of the dumpsite and analyzed in the laboratory. Soil samples were collected using soil auger, at different depths (0.5m, 1m, 1.5m and 2m) for three collection points. Multiple linear regression was used to model the transport of heavy metals within the soil. It was observed that the larger compositions of the solid waste were plastics (22.20%), biodegradable food waste (20.10%), paper (18.70%) and ferrous and nonferrous metals (5.30% and 9.10%). Heavy metals identified in the leachate sample were zinc, lead, copper and iron. Their concentrations in the soil were observed to be 111.27 to 15.44 mg/kg for zinc, 6.33 to 2.25 mg/kg for lead, 14.6 to 2.65 mg/kg for copper and 17.09 to 5.11 mg/kg for iron. The data obtained were used to develop models to predict the transport of the heavy metals with R^2 values of 0.872, 0.904, 0.831 and 0.950 for zinc, lead, copper and iron, respectively. The developed models predicted the concentrations of the heavy metals within the soil underneath the dumpsite with a high degree of accuracy.

Keywords: *Modelling, Dumpsite, Leachate, Heavy metals, Transport regime, Multiple linear regression, Aluu*

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1. Introduction

In Nigeria, the rapid urbanization, constant change in consumption pattern and social behaviour have increased the generation of waste beyond the assimilative capacity of existing waste management systems leading to severe environmental pollution (Olatunji and Horsfall, 2017). According to FMEnv, approximately ninety-four percent (94%) of solid waste in Rivers State are disposed in an environmentally unsafe manner. This disposal approach is either burned in an uncontrolled manner or dumped in unlined dumpsites with no leachate collection system, where the formed leachate (which consists of soluble and insoluble compounds) could leach into the subsoil and possibly migrate to groundwater. Such pollution of groundwater resources poses substantial health risks including water borne diseases such as typhoid, cholera and infectious dysentery to the local groundwater users (Ugwoha and Emete, 2015). However, understanding the transport regime of leachate within the soil will serve as a guide in determining the extent and type of remediation needed for polluted soil due to dumpsite leachate.

Open waste dumpsite is a common practice in Nigeria and involves rounding up the waste from different parts and dumping everything in depressions on land which may include valleys and excavations, without the consideration of the composition of the waste (Ugwoha and Emete, 2015). The dumpsite method is one that creates land pollution and, in some cases, groundwater pollution, as the waste are not subjected to segregation or any form of treatment. Both hazardous and non-hazardous wastes are simultaneously dumped in the open dumpsite (Chopra *et al*., 2009). The major concern with dumpsites is that they are often subjected to generation and transport of leachate (Torretta *et al*., 2019). Dumpsite leachate is generated from liquids existing in the waste as it comes into a dumpsite or from rain water that passes through the waste within the site. This leachate consists of fluid and water-soluble compounds from the waste that accumulate, as water moves through the dumpsite. The parameters leachate samples are commonly analysed for include pH, solids, total organic carbon, alkalinity, chloride, nitrate, sulphate, phosphate, biochemical oxygen demand, chemical oxygen demand turbidity, heavy metals (e.g., Zn, Pb, Fe, Co, Ni, Cd, etc.) and some persistent organic pollutants (Poly-aromatic hydrocarbons and polychlorinated biphenyls) (Oketola and Akpotu, 2015).

The contaminants present in leachate from dumpsites can be classified as hazardous chemicals, conventional contaminants and nonconventional contaminants. According to the Federal Ministry of Environment, a material is not classified as hazardous until a chemical is leached from it in concentrations at least 100-times the drinking water standard. Conventional contaminants include total dissolved solids, hardness, alkalinity and chemicals such as chloride, sulphate, iron, hydrogen sulphide and manganese (Bella *et al*., 2012), while non-conventional contaminants are largely organic chemicals that have not been defined. It is estimated that about 90 to 95% of leachate formed in dumpsite are of unknown composition and obviously their potential impacts on the environment are unknown (Ojoawo *et al.*, 2012).

Some studies have been conducted on dumpsites in Port Harcourt especially on the adverse effect of the leachate on public health using different approaches, including field observation, laboratory experiment and mathematical models, to identify the pollutants in leachate, and investigate the levels of soil and groundwater pollution due to dumpsite leachates (Ayotamuno and Gobo, 2004; Nagarajan *et al*., 2012; Tamunoberetonari *et al*., 2012; Oketola and Akpotu, 2015; Ugwoha and Emete, 2015; Worlu *et al*., 2016). However, little or no studies have been done on the dumpsite at Aluu to assess the extent of leachate transport within the soil beneath the dumpsite, in order to understand the transport regime. Thus, this paper used regression analysis to model leachate-component transport within the soil at Aluu dumpsite. It is anticipated that the outcome of this study will produce leachate-constituent transport model(s) that would predict the behaviour of dumpsite leachate-constituents within the soil in Aluu.

2. Materials and methods

2.1 Study area

An open dumpsite situated at Aluu in Rivers State was selected for this study. Aluu is situated in close proximity to the University of Port Harcourt, and belongs to the Ikwerre ethnic group. It is in the Ikwerre Local Government Area of Rivers State and is located between latitude 4° 56' 01" to 5° 0' 30"North and longitude 6° 54' 30"to 7° 0' 0"East. It covers an area of about 466km^2 in the North part of Port Harcourt. Aluu is characterized by two district seasons (the wet and the dry seasons). The wet season last for eight months, from mid-March to October while dry season last for four months from November to February. There are seven communities in Aluu, namely Omuoko, Omuokiri, Omohie, Omuolu, Omuonua, Omuolori and Omuokirika Communities (Eliot and Charles, 2021). Fig. 1 shows the location of Aluu in Ikwerre LGA, Fig. 2 shows the location of the studied dumpsite in Aluu, and Fig. 3 shows the sample collection points within the dumpsite.

The dumpsite started in 2014 as an undeveloped land used for open burning of non-biodegradable wastes like plastics, used fabrics, wooden furniture, paper and occasionally rapid decomposing waste. As the population within the vicinity increased, the land gradually degenerated into a dumpsite, and the practice has continued till date. The solid waste mass on the dumpsite is spread over an area of about 80m^2. The dumpsite is utilised by a population of 3000 to 5000 individuals, who reside between 20m to 1km from the dumpsite. The waste dumped at this site includes mainly domestic waste, which include kitchen waste, paper, plastic, glass, cardboard, cloths, etc. and, construction and demolition waste that consists of sand, bricks and concrete block. Thus, the site is a non-engineered low-lying open dump with a heap of waste up to a height of 3 to 4m. The waste disposal is done in an uncontrolled manner and without any segregation. The dumpsite is exposed to significant precipitation and corresponding surface run-off that contributes to the high levels of solid waste moisture content and leachate hydraulic head, which expedites the rate of leachate migration within the soil. This poses great risks of groundwater pollution for the local groundwater users whose boreholes are located between 10 to 15m from the dumpsite.

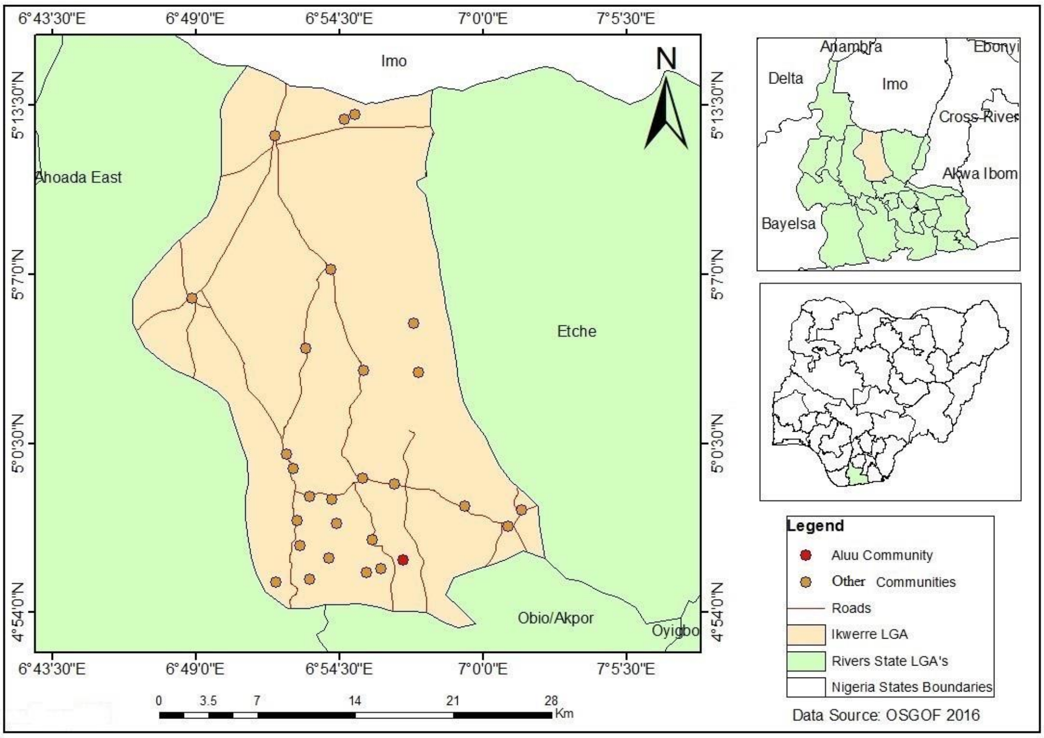

Fig. 1: Location of Aluu in Ikwerre Local Government Area

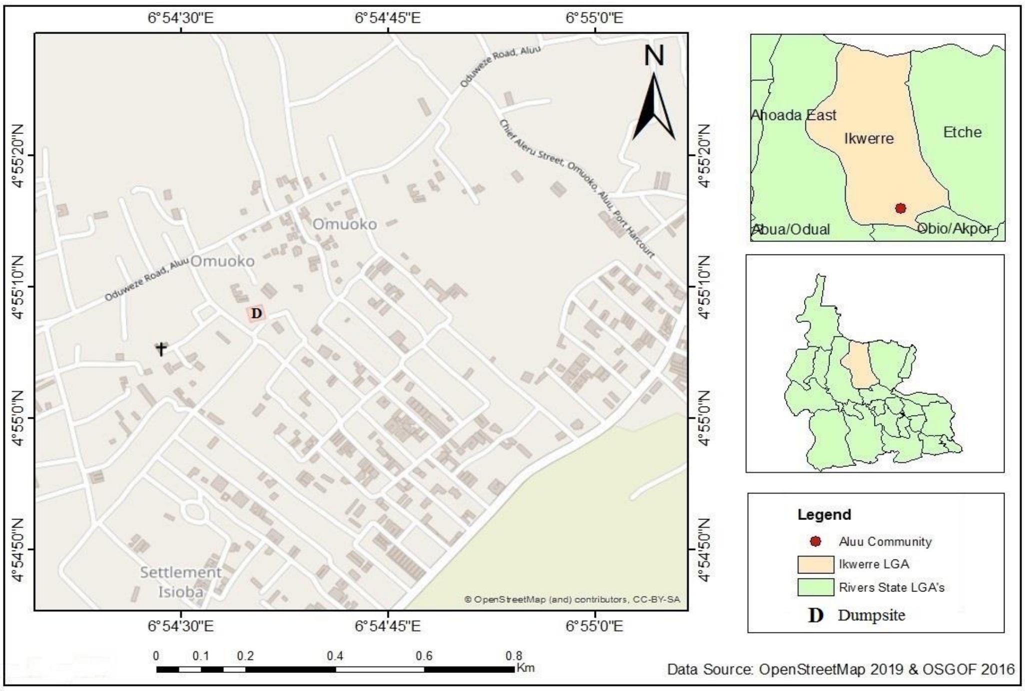

Fig. 2: Location of the dumpsite in Aluu

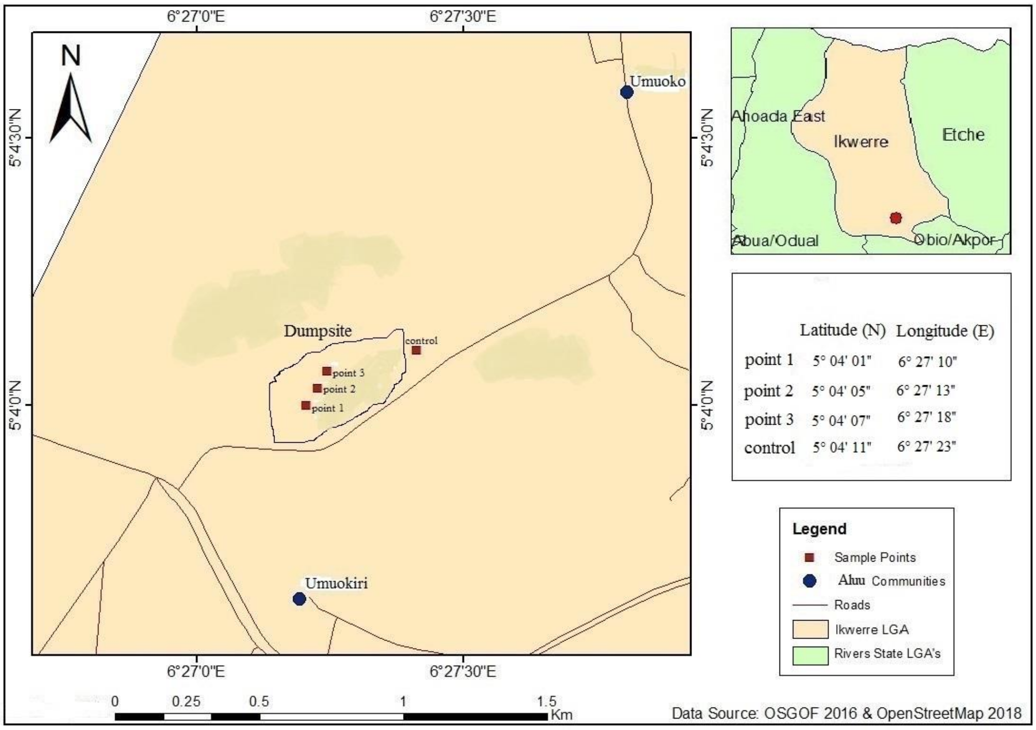

Fig. 3: Sample collection points within the dumpsite.

2.2 Solid waste characterization

Characterization of the waste in the dumpsite was carried out to determine the percentage composition of the waste by mass. This was done by the collection of a representative sample of the waste in the dumpsite. Methods used included sectioning, mixing and segregation, and calculation of the percentage composition of the waste. In the sectioning process, the dumpsite area was divided into four (4) distinct sections and approximately 5kg of waste was collected from each section. Similarly, in the mixing and segregation process, the waste samples collected from the sections were thoroughly mixed, weighed and segregated according to type (plastics, wood, metals and food waste). The percentage composition of the waste was calculated using Equation (1) (Tamunoberetonari *et al*., 2012).

$$\% \, Composition = \frac{\text{weight of segregated waste (kg)}}{\text{Total weight of waste collected (kg)}} \times 100 \qquad (1)$$

2.3 Leachate collection and analysis

Since dumpsites are not equipped with a leachate collection system, the leachate was collected at the base of the dumpsite. After collection, the leachate samples were labelled and immediately transferred to the laboratory to be analysed for heavy metals.

2.4 Soil sample collection and analysis

Leachate polluted soil samples were collected from three points and at different depths (0.5m, 1m, 1.5m and 2m) after removing the surface debris (Figure 3). Sample collection was done as the subsoil was dug to a depth of 2m using soil auger. Three sets of soil samples (0.5 kg each) were recovered at 0.5 m depth intervals from collection point and taken into the sterile containers and labelled.

After soil sampling, the collected soil sample was air dried, crushed with a wooden mallet and passed through 2.36 mm sieve. Exactly 0.1 kg of soil was taken and treated with one litre distilled water and kept for 48 hours. The supernatant was then filtered and used for the soil chemical analysis. For pH determination, soil passing through 425 micron IS sieve was used (APHA, 1995).

2.5 Development of leachate-constituent transport model

The rate of leachate transport is a function of leachate generation rate, leachate migration factor and soil-leachate interactions. Leachate generation rate is a function of precipitation, liquid addition, waste composition, age of waste, degree of compaction, decomposition rate, waste moisture content, rate of water movement and temperature. Leachate migration factor, a function of advection, convection, diffusion, infiltration and dispersion of leachate, which are the physical and chemical properties controlling the movement and storage of liquids and solutes in soil, is dependent on the particle size distribution, depth, texture, bulk density, soil profile hydrology, permeability, saturated hydraulic conductivity, porosity, tortuosity and hydraulic gradients. Soil-leachate interactions is a function of the soil profile, type and sorption processes (absorption, adsorption, chemosorption and ion exchange). Mathematically, leachate transport can be defined by Equation (2).

$$L_{tr} \propto L_{mf}, L_{gr}, I_{s-l}$$
$$L_{tr} = f\,(L_{mf}, L_{gr}, I_{s-l}) \quad (2)$$

where L_{tr} is the leachate transport, f is the transport constant, L_{mf} is the leachate migration factor, I_{s-l} is the soil-leachate interactions, and L_{gr}, is the leachate generation rate.

2.6 Modelling limitations and assumptions

The following assumptions were made: leachate generation rate is constant throughout the dumpsite area and therefore equal to one, and soil-leachate interactions is constant throughout the soil and therefore equal to one. This implies that Equation (2) can be written as Equation (3).

$$L_{tr} = f\,(L_{mf}, 1,1) \quad (3)$$
$$\therefore\ L_{tr} = f\,(L_{mf}) \quad (4)$$

This implies that leachate transport (L_{tr}) is dependent on the leachate migration factor. However, unlike other pollutants, leachate is a cocktail of organic and inorganic compounds and therefore its transport cannot be modelled directly but can be modelled using a series of predictive models that predicts the concentration of each constituent of the leachate detected in the site, in other to determine the overall leachate composition at any point in the site. The approach adopted in this study was to model the heavy metals constituents of the leachate plume at the dumpsite.

2.7 Statistical analysis

Multiple linear regression was used to model leachate transport within the soil at Aluu dumpsite due to the suitability of the model. The heavy metals constituents of the leachate (Zn, Pb, Cu and Fe) which formed the dependent variables were modelled with respect to the leachate migration factor (L_{mf}) also known as the physicochemical properties of the soil affecting contaminant transport (pH, porosity (ε), moisture content (θ_v), hydraulic conductivity (k_s), Soil organic matter (SOM) and depth) which formed the independent variables. The general equation for multiple linear regression is given by Equation (5)

$$y = a_0 + a_1x_{1i} + a_2x_{2i} + a_3x_{3i} + \cdots, +a_nx_{ni} \quad (5)$$

Therefore, the deduced normal equations for the model are defined by Equations (6) to (9)

$$y_{zn} = a_0 + a_1D_i + a_2K_{s_i} + a_3Som_i + a_4\varepsilon_i + a_5\theta_{v_i} + a_6pH_i \quad (6)$$
$$y_{pb} = a_0 + a_1D_i + a_2K_{s_i} + a_3Som_i + a_4\varepsilon_i + a_5\theta_{v_i} + a_6pH_i \quad (7)$$
$$y_{cu} = a_0 + a_1D_i + a_2K_{s_i} + a_3Som_i + a_4\varepsilon_i + a_5\theta_{v_i} + a_6pH_i \quad (8)$$
$$y_{fe} = a_0 + a_1D_i + a_2K_{s_i} + a_3Som_i + a_4\varepsilon_i + a_5\theta_{v_i} + a_6pH_i \quad (9)$$

where y_{zn}, y_{pb}, y_{cu} and y_{fe} are the dependent variables, $D_i, K_{s_i}, Som_i, \varepsilon_i, \theta_{v_i}\ and\ pH_i$ are the independent variables, a_0 is the intercept and $a_1, a_2, a_3, a_4, a_5\ and\ a_6$ is the slope or coefficient of the independent variables.

2.8 Independent variables reduction

Due to the number of soil properties (independent variables) affecting the transport of leachate constituent (dependent variable), variable reduction was carried out on the transport model using a correlation matrix in order to determine the uniqueness of each independent variable to the transport model, how closely correlated the independent variables were to each other and the elimination of the less significant independent variable from a closely correlated pair. The independent variables found to be unique to the transport models were hydraulic conductivity, moisture content, porosity and depth. The redefined transport models are given by Equations (10) – (13)

$$y_{zn} = a_0 + a_1D_i + a_2K_{s_i} + a_3\varepsilon_i + a_4\theta_{v_i} \quad (10)$$
$$y_{pb} = a_0 + a_1D_i + a_2K_{s_i} + a_3\varepsilon_i + a_4\theta_{v_i} \quad (11)$$
$$y_{cu} = a_0 + a_1D_i + a_2K_{s_i} + a_3\varepsilon_i + a_4\theta_{v_i} \quad (12)$$
$$y_{fe} = a_0 + a_1D_i + a_2K_{s_i} + a_3\varepsilon_i + a_4\theta_{v_i} \quad (13)$$

The constants ($a_0,\ a_1, a_2, a_3\ and\ a_4$) were determined using matrix triangulation (Gauss method).

2.9 Model validation

The zinc, lead, copper and iron concentrations at the three sample collection points at the dumpsite were used for the calibration of the leachate transport model. The predicted and observed concentrations of zinc, lead, copper and iron from these three collection points were plotted against the predicted concentrations. Also, statistical parameters such as R^2, adjusted R^2 and standard error of the estimate were calculated and used to further validate the transport models.

3. Results and discussion

3.1 Composition of solid waste

The percentage composition of the representative sample of the characterized solid waste from the dumpsite is presented in Table 1. The characterized solid waste at the dumpsite consists of 22.20% plastics which can release harmful chemicals into the surrounding soil and then seep into groundwater or other surrounding water sources. Chemicals such as bisphenol leach out of plastics and can disrupt the hormonal systems of vertebrates and invertebrates. The ferrous and non-ferrous metals comprised 5.30% and 9.10% of the characterised waste which make up the heavy metal composition of the dumpsite leachate. It was observed that the entire dumpsite was composed mainly of household wastes like food waste, general organics and textiles which gives a clue to the appropriate management system for the waste.

Table 1: Composition of solid waste

Waste constituent	Mass of segregated waste (kg)	Mass percentage (%)
Plastics	4.44	22.20
Ferrous metals	1.06	5.30
Food waste/organics	4.02	20.10
Textile and clothing	1.84	9.20
Paper	3.74	18.70
old cardboard	0.60	3
other	0.36	1.80
Non-ferrous metals	1.82	9.10
Glass	0.44	2.20
Construction and demolition	0.28	1.40
wood	1.4	7
Total	**20**	**100**

3.2 Characteristics of dumpsite leachate

Table 2 presents the characteristics of leachate collected from the dumpsite and the standard for land disposal. All chemical parameters of the leachate exceeded the specified permissible standards except for pH. The leachate contained different contaminants. During percolation through the soil, leachate undergoes various processes, such as physicochemical decomposition, ion exchange reactions, chemical alterations, oxidation, hydrolysis, etc., which alter the original properties of the soil. The relatively high values of total dissolved solid (TDS) in leachate indicate the presence of inorganic materials in the leachate. The high levels of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) could create potential pollution problems to water bodies since they contain organic compounds that will require a large quantity of oxygen for degradation. Nitrate is one of the most common groundwater contaminants, the excess levels can cause methemoglobinemia, or "blue baby" disease. The nitrate levels indicate the possible presence of other more serious residential or agricultural contaminants such as bacteria or pesticides. Though the pH level of the leachate sample was within the permissible level for land disposal, the acidic nature of the leachate makes it possible for inorganics compounds (heavy metals) to go into solution thereby increasing the transport potential of the heavy metal constituents.

Table 2: Characteristics of leachate samples from the dumpsite

Parameters	Unit	Concentration	Standards for land disposal
pH	–	5.47	5.5 to 9.0
TDS	mg/l	12164.15	2100
BOD	mg/l	1818.27	100
COD	mg/l	6668.42	-
Nitrate	mg/l	15.69	-
Ammonia	mg/l	121.24	-
Zinc	mg/l	119.43	0.001
Lead	mg/l	7.33	0.001
Copper	mg/l	24.01	0.001
Iron	mg/l	27.09	0.001

3.3 Characteristics of dumpsite soil

Table 3 shows the heavy metals concentrations in dumpsite soil and Table 4 displays the dumpsite soil transport properties. Table 3 indicates that parameters such as copper, iron, lead and zinc in the soil sample from the dumpsite are above the allowable concentration in uncontaminated soil. Among the heavy metals, zinc had the highest concentrations at all sampling points and depths. The location of the dumpsite is in a residential area with a number of small-scale businesses. The waste from these businesses can contribute a good amount of heavy metal concentration in the solid waste. The variation in concentration of each physicochemical parameter is visible with respect to the depth and distance. Table 3 gives an idea on the transport pattern of the pollutants in the soil. Generally, the heavy metals decreased with increasing depth in dumpsite soil. On the contrary, the dumpsite soil transport properties did not show any trend with sampling points and depths.

Table 3: Heavy metals concentrations in dumpsite soil

Parameters	Collection point 1				Collection point 2				Collection point 3			
	0.5m depth	1m depth	1.5m depth	2m depth	0.5m depth	1m depth	1.5m depth	2m depth	0.5m depth	1m depth	1.5m depth	2m depth
Lead (mg/kg)	6.33	5.08	4.97	2.25	5.95	4.72	3.36	2.98	4.99	4.27	3.01	2.55
Copper (mg/kg)	14.6	11.4	4.01	2.65	10.1	7.6	5.8	3.0	12.6	8.8	6.1	7.4
Iron (mg/kg)	17.09	14.39	11.14	7.98	15.02	12.67	9.31	5.11	13.88	10.96	8.37	5.66
Zinc (mg/kg)	109.43	46.18	32.02	25.56	98.82	70.05	30.66	15.44	111.27	82.50	63.41	30.79

Table 4: Transport properties of dumpsite soil

Parameters	Collection point 1				Collection point 2				Collection point 3			
	0.5m depth	1m depth	1.5m depth	2m depth	0.5m depth	1m depth	1.5m depth	2m depth	0.5m depth	1m depth	1.5m depth	2m depth
Hydraulic conductivity (m/s)	2.56×10^{-5}	2.68×10^{-5}	3.16×10^{-5}	2.36×10^{-5}	2.51×10^{-5}	2.66×10^{-5}	3.28×10^{-5}	2.57×10^{-5}	2.64×10^{-5}	2.72×10^{-5}	3.31×10^{-5}	2.40×10^{-5}
Soil organic matter (%)	5.44	5.17	4.83	5.01	9.88	6.17	7.33	4.59	7.22	6.85	5.03	4.35
Moisture content (%)	12.3	11.53	11.16	12.01	15.9	14.6	14.9	13.2	18.2	16.7	13.6	10.0
Porosity (%)	68.2	64.8	53.7	48.1	66	72.3	55.7	43.8	60	75	63	40

3.4 Model development

Mathematical models were developed to predict the leachate-constituent transport for different constituents of leachate. This was done by testing the redefined multiple linear regression model equations as shown in Equations (10) - (13). Tables 5 – 8 show the developmental processes of the leachate-constituent transport models. From the correlation matrix (Table 5), model predictors were selected using the dimension reduction technique. It was observed that the variable pairs (depth and pH) and (SOM and moisture content) have the highest positive correlations at 95.1% and 75.3% respectively, implying that the variables in each pair have similar effects on the dependent variable and that one variable can be used instead of the other, hence the elimination of the pH and SOM variables. Tables 6 – 8 present the summary on the development processes of the transport models. The multiple regression analysis used determined the relationship between the physicochemical properties of soil and the transport potential of the leachate constituents. The coefficients of the independent variables of the regression models quantified the proportional effects of the independent variables on the leachate constituents such that the negative coefficients implied that the leachate constituents (dependent variables) reduced with increasing trends in the independent variables, and positive coefficients implied that leachate-constituents concentrations reduced with reducing trends in the independent variables. Generally, the concentrations of leachate constituents in the soil reduced with increasing soil depth.

Table 5: Correlation matrix of the independent variables

Parameters	Depth	SOM	Hydraulic conductivity	Porosity	pH	Moisture content
Depth	1	-0.652	0.064	-0.791	0.951	-0.583
SOM	-0.652	1	-0.005	0.489	-0.720	0.753
Hydraulic conductivity	0.064	-0.005	1	0.159	0.037	0.092
Porosity	-0.791	0.489	0.159	1	-0.804	0.531
pH	0.951	-0.720	0.037	-0.804	1	-0.753
Moisture content	-0.583	0.753	0.092	0.531	-0.753	1

Table 6: Coefficients of the leachate-constituent transport models

Model	Zinc coeff.	Lead coeff.	Copper coeff.	Iron coeff.
Constant	119.954	10.201	28.958	25.050
depth	-47.988	-2.739	-7.331	-6.988
Hydraulic conductivity	-1175177.335	29077.480	-130073.183	16129.919
Porosity	0.064	-0.010	-0.051	0.026
Moisture content	2.056	-0.203	-0.391	-0.535

Table 7: Developed models for leachate-constituent transport in soil

Constituent	Developed model
Zinc	$y_{zn} = 119.954 - 47.988D_i - 1175177.335K_{s_i} + 0.064\varepsilon_i + 2.056\theta_{v_i}$
Lead	$y_{pb} = 10.201 - 2.739D_i + 29077.480K_{s_i} - 0.010\varepsilon_i - 0.203\theta_{v_i}$
Copper	$y_{cu} = 28.958 - 7.331D_i - 130073.183K_{s_i} - 0.051\varepsilon_i - 0.391\theta_{v_i}$
Iron	$y_{fe} = 25.050 - 6.988D_i + 16129.919K_{s_i} + 0.026\varepsilon_i - 0.535\theta_{v_i}$

Table 8: Statistical parameters of leachate-constituent transport model

Model	R	R^2	Adjusted R^2	Std. error of the estimate
Zinc	0.934[a]	0.872	0.799	15.46879
Lead	0.951[a]	0.904	0.849	0.52465
Copper	0.912[a]	0.831	0.735	1.96203
Iron	0.974[a]	0.950	0.921	1.06646

3.5 Model validation

Fig. 4 – 7 show the actual and predicted leachate-constituents' concentrations relative to soil depth. As shown in Table 8, the R^2 values obtained from the data analysis were 0.872, 0.904, 0.831 and 0.950 for zinc, lead, copper and iron respectively, indicating that the developed models can effectively predict the concentrations of the leachate-constituents in the soil. Among the developed models, the model for iron gave the highest R^2 value (0.950), implying that the model was an excellent fit. Following the iron model, is the lead model with an R^2 value of 0.904. However, the lower R^2 values for copper and zinc (0.831 and 0.872, respectively), indicate that the models have great fit but not as much as the iron and lead models.

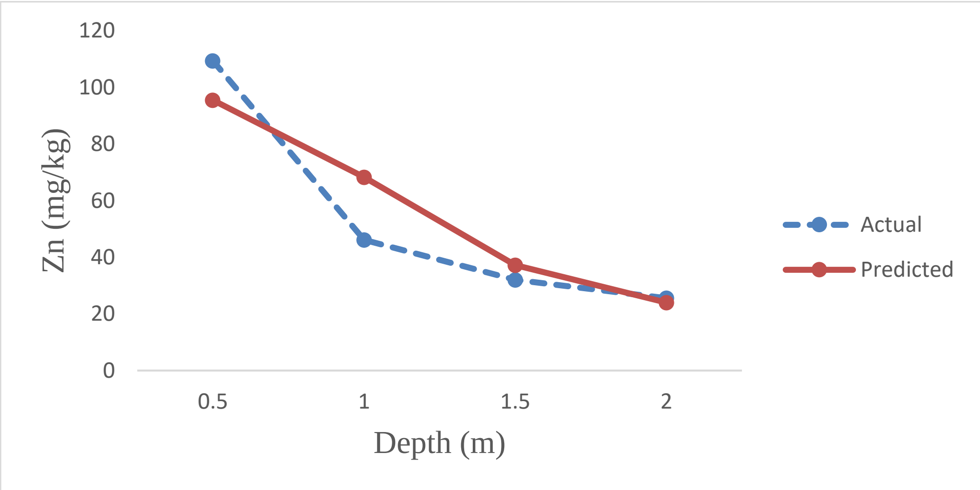

Fig. 4: Validation of the zinc model

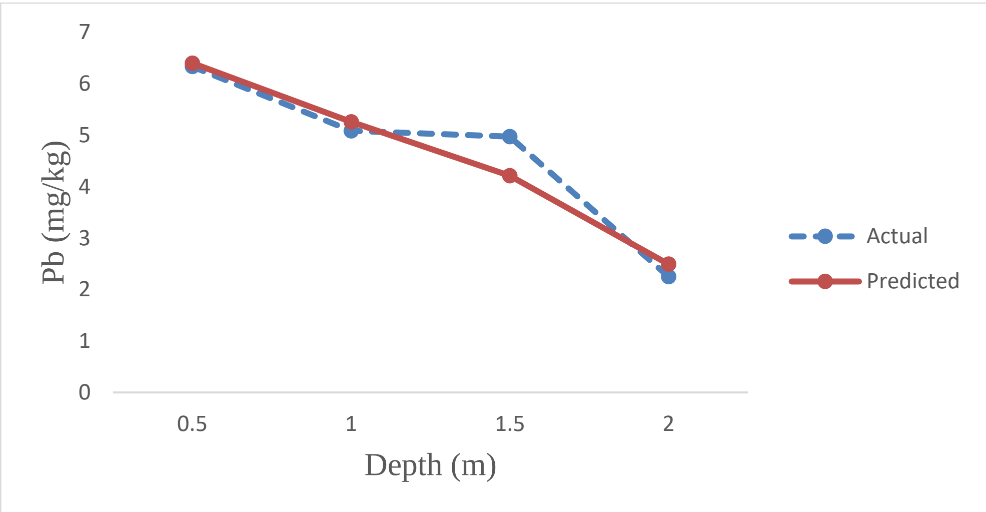

Fig. 5: Validation of the lead model

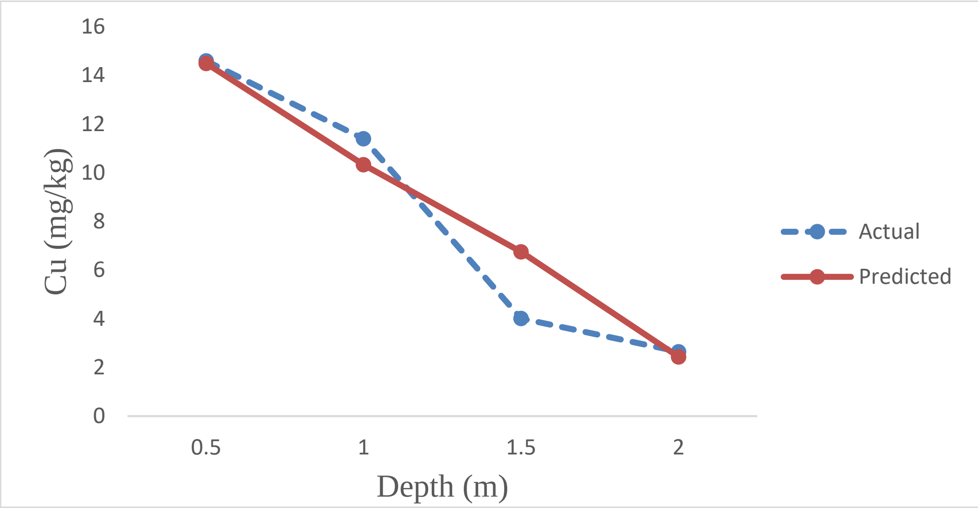

Fig. 6: Validation of the copper model

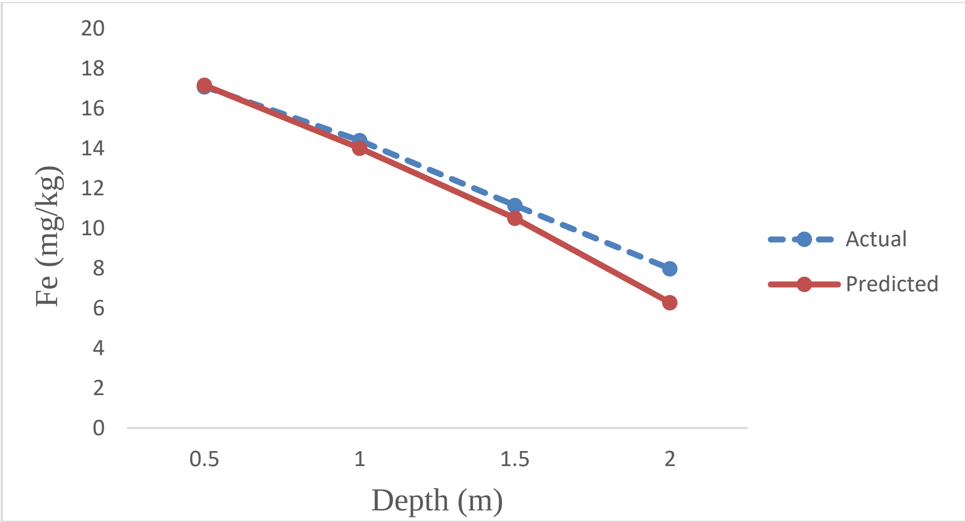

Figure 7: Validation of the iron model

4. Conclusion

The concentration of heavy metals in the soil due to dumpsite leachate and the transport regimes through the soil strata was investigated and modelled. The larger compositions of the solid waste were plastics (22.20%), biodegradable food waste (20.10%), paper (18.70%) and ferrous and nonferrous metals (5.30% and 9.10%). The ferrous and nonferrous metal composition of the solid waste reflected on the heavy metal constituents of the leachate. The concentration of each heavy metal in the soil varied inversely with the soil depth. The developed models have R^2 values of 0.872, 0.904, 0.831 and 0.950 for zinc, lead, copper and iron respectively, implying that the models can predict to a high degree of accuracy the extent of transport of the heavy metals in the soil beneath the dumpsite. Soil properties such as moisture content, hydraulic conductivity and depth play a major role on the transport regime of the heavy metals in the soil.

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