A case study of an empirical evaluation of the effect of landfill leachate on nearby soil

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Abstract – *Leachate and soil samples were taken for this study from the Davanagere city landfill site near Avaragolla. The purpose of the study is to evaluate the physical and chemical elements and the concentrations of heavy metals in the leachate and surrounding soil of the landfill site. The dump at Avaragolla Village is located in Davangere City, Karnataka, about 14 kilometers away. Standard techniques were used to test the physicochemical characteristics of the leachate sample on site, and heavy metals were evaluated using a Shimadzu AA7001 Atomic Absorption Spectrophotometer following nitric acid digestion. The majority of the determined heavy metal values were over the recommended limits. In the current study two soil types—silty sand and clayey sand—were selected. Soil Samples were collected at 4 different locations and depth in and around the landfill site. The results indicated that the heavy metals, namely Cu, Cr, Fe and Zn were significant concentrations in the soil within a radius of 1000m from the landfill. Zn > Fe > Cr > Cu was the order of the heavy metal concentration in the soil sample that was obtained. Leaching column studies were carried out to setup the development curve, which showed that heavy metals (Cu, Cr, Fe, and Zn) were retained in clayey and silty sand soils.*

Key Words: Municipal Solid waste, Landfill, Leachate, Heavy metals, Soil.

1. INTRODUCTION

The district of Davangere is located at the central part of the Karnataka, lodging an area of 5,924 km^2 and the current metro region population of Davangere in 2022 is 530,000, a 1.73% enhanced from 2021. The district produces very high municipal waste production 168.32 TPD of waste assessed to be around 1.2kg per person every day (Shravan and Nagarajappa, 2018). In addition to waste materials that enter landfills by percolation with ground-water internal flow or through penetration from rainfall, landfill locations are regarded as a major hazard to ground-water resources. (Clarke, et al., 2015).

The current work highlighting on these problems is rare, so in direction to take up adequate safety protection and upgraded standards. It is energetic that appraisal of the effects of polluted leachate on, physical - chemical characteristics of the natural soil in and around the Davangere city takes place. In this work, a detailed laboratory appraisal was assumed to appraise the effects of land-fill leachate pollution on the properties of natural soils of in and around dumping site of Davangere.

1.1 Objectives of Study

The chief objective of this work is to appraise the performance of the Avaragolla Village, with an opinion to aid future and construction of land-fills in Davangere. The objectives of the work are:

- To appraise the impact of leachate on properties of soils at solid waste dumping site of Davangere.
- To explore the fact of the leachate in different soil samples surrounding at the dump-site.
- Illustrate and distribution of trace metal elements in land-fill.

Fig -1.1: Avaragolla landfill site

2. CONTENTS AND METHODES

2.1 Soil Sampling

For this work, soil samples were taken from a landfill (Avaragolla Village, average area is 33 acres). As shown in Fig. -1.1, the land-fill site is located around 14 km south-west of Davangere city. The layer of the Avaragolla village are formed mostly by two types; Silty and Clayey sand soil samples of which were attained from earlier researchers (Jeragh 2009, 2012). In the village, a two square kilometer stretch of land has been adopted as a trash disposal site.

Soils sampling at three different seasons, depths, in-and around the land-fill included and contaminated parts of the site. The first was done on 12-13 December, 2021 during dry winter period. The second sampling was done on 14-15 May 2022 during top dry season. The final sets of samples were collected on 20-21 June 2022 during rainy period.

The aerial picture of Avaragolla Village, which is covered by the land-fill area and its surrounding region, four soil samples were taken at a depth of 10 cm below the surface of the ground. The values of sampling appraisal were adopted for the current study.

The second sampling was completed. The 2 soil samples were taken. Samples were collected at a below depth 10-20 cm at each point from random genuine grid on a circle with in successive radius of 500, 1000 and 1500 m away after the land-fill area.

2.2 Soil Analysis

Collected soil samples from Land-fill site, were dried and grinded soil pass through a 2mm stainless steel sieve to separates gravel and rock. For analysis, homogenized soil sample is collected. Physico-chemical variables were determined pH, EC (Conductivity meter), Organic Matter, Cation exchange capacity. For metal analysis soil was digested using nitric acid measured the trace metals (Fe, Zn, Cr and Cu) using Shimadzu AA7001 Atomic Absorption Spectrophotometer). Statistical analysis was performed using SPSS 10.0 for Windows to understand the significant relationship with in the variables. The correlations between soil variables and for metals were also evaluated. The soils adopted in the laboratory analysis were neutral soils collected from test pits of 0.6 to 3.0 m depth of the Averagolla land fill area. The collected samples from the selected location were clean and the soils were classed at the civil engineering laboratories of BIET in accordance with ASTM criteria.

Particle size was determined for three different soil samples using the method outlined in ASTM D422 (2007a), which was applied to laboratory testing using 750g of washed clayey soil and 350g of splashed silty sand. Nos. 4, 10, 100, and 200 of the ASTM standard sieve were used. According to the modified method (ASTM D1557 2012a), the soils' maximum dry compactness and ideal moisture percentage were assessed, and the field density of the soil samples was calculated (ASTM D1556, 2007b). The specific gravity (Gs) of the soil was evaluated using the moisture percentage of the soil, which was calculated and reported as a percentage using a frame of dry soil and water present (ASTM D2216, 2010b) (ASTM C128, 2012b). The chemical properties of the collected soils samples are measured for pH (Electrometric method BS 1377 part 1 (1990), organic matter (BS 1377 part 1 (1990).

2.3 Leachate analysis

The final sampling 2 soil locations significantly polluted by leachate was sample at few depths. This final sampling was planned to attain the results of contaminants. The soil samples were designated from significant content of the trace metals in the selected site. The chemical properties of the contaminated liquid waste appraised in this study. The heavy metals content was determined by using Shimadzu AA7001 Atomic Absorption Spectrophotometer.

Adsorption Isotherms study was conducted to estimate the communication between the leachate and soil (USEPA, 2010). The soils samples were air evaporated for 1 day, then crushed up adopting crusher then sieved using 2.0mm size. Each of the four heavy metal solutions (copper, iron, zinc, and chromium), weighing around 250 mL, was purchased. Five ratios of soil solution—1:5, 1:10, 1:30, 1:60, and 1:100—were made for each heavy metal liquid solution that was chosen and stored in polyethylene containers with closed lids. The maximum amount of heavy metals in the chosen leachate informed the choice of liquid solutions.

The hypothesis of the adsorption isotherms lines was applied using the linear Langmuir and Freundlich equation. According to the USEPA (2010), The linear Langmuir equation written as: $\frac{x}{m} = \left[\frac{K_L MC}{1+ K_L C}\right]$ where KL and M are coefficients calculated from the angle and equal linear balance. According to the USEPA (2010), the linear Freundlich balance can be written as: $\frac{x}{m} = K_f x C^{1/n}$ where x is amount of the solute adsorbed, m is the amount of adsorbent (oven-dried soil), C is amount of solute equilibrium (Kf), and 1/n = constants derived from the slope and equal linear equation.

The initial contents of the heavy metals and three chemical variables of the leachate collected from Avaragolla village landfill surroundings was appraised are given in (Table 2.1)

Sl No	Variables	Results		
		12-13 Dec 2021	14-15 May 2022	20-21 June 2022
1.	Ph	8.34	8.31	8.72

2.	EC	14.62 ms/cm	15.23 ms/cm	18.42 ms/cm
3.	TDS	11704 mg L	12894 mg/L	13456 mg/L
4.	Fe	4.38 mg/L	4.56 mg/L	5.01 mg/L
5.	Zn	13.56 mg/L	14.2 mg/L	15.21 mg/L
6.	Cr	0.32 mg/L	0.46 mg/L	0.56 mg/L
.	Cu	0.13 mg/L	0.16 mg/L	0.19 mg/L

Table-2.1. Chemical properties of Collected Leachate sample

The pH values of the collected soil samples are alkaline in nature which indicates presence of high calcium carbonate constituents (Ismael et al. 1986). The total organic concentrations of the soils are very less than1%. Caravaca and Albaldejo (1999) and Ismael et al. (1986) noted that the low precipitation and high temperatures in a semi-arid climate may be reducing the contribution of organic materials (Table 2.2).

Type of Soil	pH	Calcium Carbonate (%)	Organic Matter (%)
Silty sand Soil	8.51	8.20	0.028
Clayey sand Soil	9.24	7.14	0.041

Table-2.2. Average chemical properties of Avaragolla Village soil sample

The atomic absorption spectrophotometer, which was previously mentioned in this work, was used in the batch adsorption investigation to measure the amount of heavy metals adsorbed by soil for different soil solution ratios. To determine whether or not processes follow Langmuir/Freundlich isotherms, the adsorption data can be fitted using the adsorption equation Fig. 2.1 indicates the amount of metal adsorbed in the silty sand soil to the amount of metal present in liquid. According to Fig. 2.1, the amount of heavy metal adsorption increased as the amount of metal in the solution increased, as shown by the shadow parallel lines in the graph. At the beginning of the analysis at low metal levels in liquid, Cu adsorption is greater than that of other metals. Although Zn's adsorption is smaller than that of Cr, Cu and Fe's adsorption were negligible. The highest amount of Cr adsorption depends mostly on the soil pH level, and Cr liquefies well in both acidic and alkaline soil (Wyszkwska 2001).

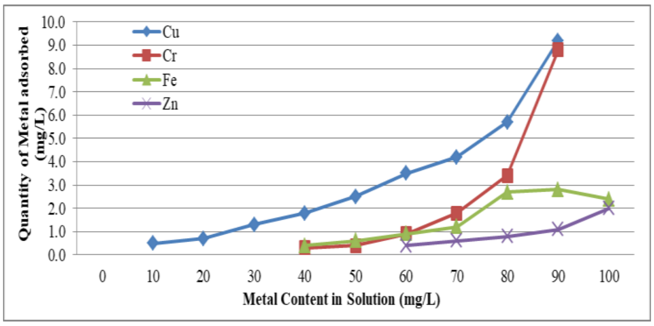

Fig - 2.1: Adsorption of heavy metals by silty sand soil

Figure 2.2 shows the amount of heavy metal adsorption in clayey soil. The amount of heavy metal adsorption increased as the liquid's metal content increased. In the original content, over 96% of the Cu and Cr in the liquid were adsorbed; however, only 65.85% of the Fe and Zn were individually adsorbed. Maximum levels of metal adsorption as related to the silty sand soil were shown by the clayey sand. It is predicted that all of the Cr and Cu will adsorb at low concentrations. This can be credited to the clay elements' tendency to scatter at lower concentrations due to the full expansion of diffuse double deposits, which improves the interaction between the superficial clay elements and the solution (Mohamed et al. 1992).

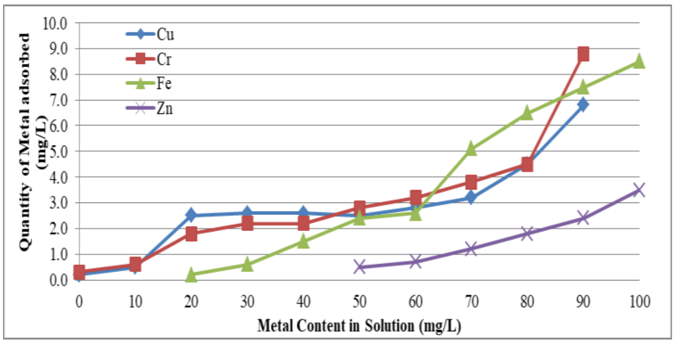

Fig -2.2: Adsorption of heavy metals by clayey sand soil

Adopting the Langmuir and Freundlich equations clarified the relationship between the liquid content and adsorption. The Langmuir isotherm was recognized as being dependent on thermodynamic equilibrium. It is extensively used because of its simplicity and capacity to use a variety of adsorption facts. Plotting the amount of soil adsorbed (x) and the amount of solute adsorbed (m) as an accumulation of the equilibrium solute content allows for the determination of the variables in Langmuir balance (C), The slope was used to get the variables for the Langmuir constants (b, K), where b represents the greater adsorption and K represents the relationship energy of the adsorbent's adsorption. The variables in Freundlich balance can be estimated by plotting log (x/m) against log (C).

The Freundlich constant variables (Kf, n) appraised from the slope and interrupt of the linear balance due to a deficiency and lack of self-regulating mark regarding the definite preservation apparatus (Bucher et al. 1989). However, the model introduces a number of conventions, such as comparable adsorption locations (which denotes that the adsorption locations are equivalent) and a mono-layer of adsorbents (the model proposes a highest of one layer of adsorption, but the in circumstance of clayey soil greater than one is probable). The linear degradation (R2) values are used as a measure of how well the adsorption facts close-fit. Fig-2.3 and 2.4 indicates the plot of the Langmuir and Freundlich graphs for a silty sand soil Fig-2.5 and 2.6 shows the analytical values for a sample of clayey sand soil.

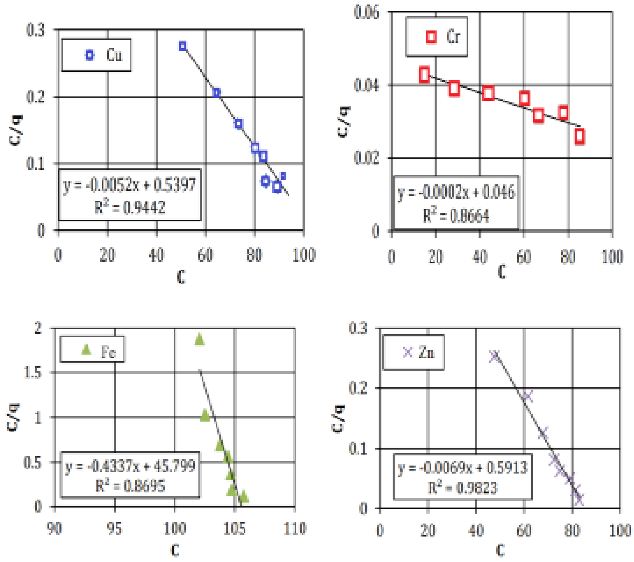

Fig-2.3 Langmuir graphs for a sample of silty sand soil

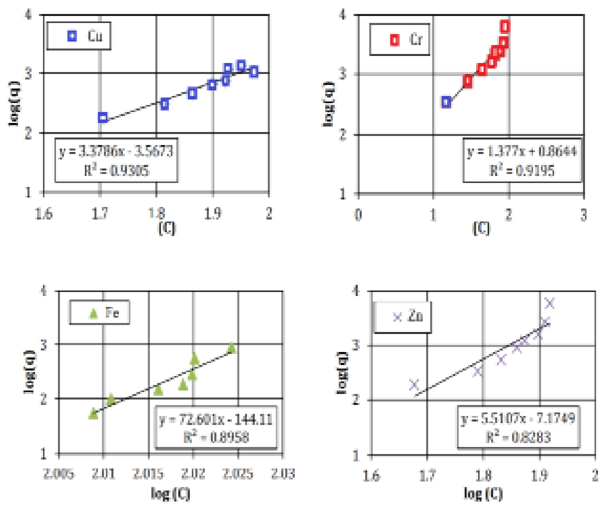

Fig-2.4 Freundlich graphs for a sample of silty sand soil

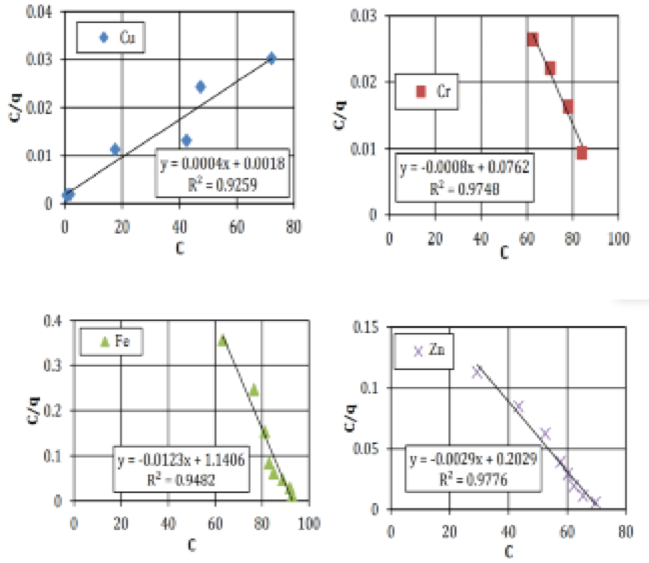

Fig-2.5 Langmuir graphs for a sample of clayey sand soil

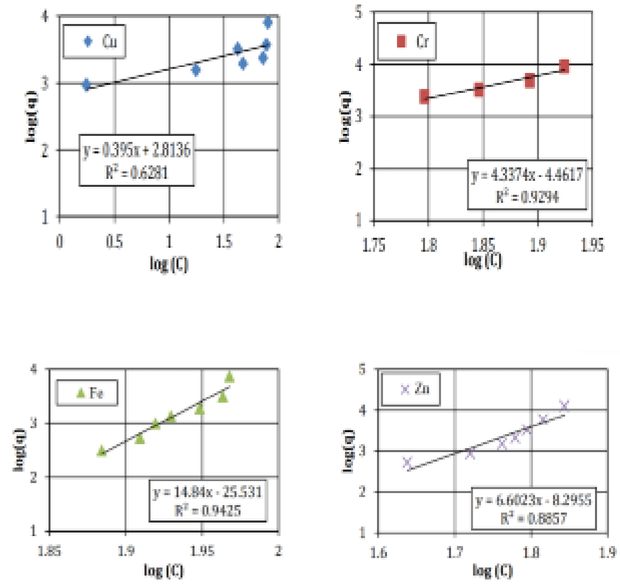

Fig-2.6 Freundlich graphs for a sample of clayey sand soil

Table 2.3 contains a prediction of the analytical results of the linear regression produced by the Freundlich and Langmuir model. For a few chosen soil samples, it can be stated that the linear regression findings from the Freundlich and Langmuir models are quite acceptable. . The R^2 numerical for all samples from 0.80 and 0.95, expect for the Cu for the clayey soil for Freundlich model, which is 0.61.

	Freundlich				Langmuir			
Samples	Cu	Cr	Fe	Zn	Cu	Cr	Fe	Zn
	R^2 Values							
Silty Soil	0.92	0.91	0.89	0.81	0.92	0.85	0.87	0.94
Clayey Soil	0.61	0.92	0.94	0.88	0.92	0.97	0.93	0.96

Table 2.3 The linear regression attained from Freundlich and Langmuir equation.

The findings for a selected soil samples show very little capacity to hold heavy metal. The Langmuir variables deliberate the highest adsorption (b) and the connection of energy adsorption. The fact that the elements in the silty sand keeps neutral electrical responsibility and have minimal cation-exchange capacity can be attributed to the fact that the silty sand soil sample exhibited insignificant adsorption and attachment energy for all tested metals. The soil samples from the clayey sand have high Cr and Cu adsorptions.

Samples	**Freundlich**				**Langmuir**			
	Silty		**Clayey**		**Silty**		**Clayey**	
Variable	**Kf**	**N**	**Kf**	**n**	**K**	**b**	**K**	**B**
Cu	-3.48	0.31	2.16	2.52	-0.001	-191	0.110	5001
Cr	0.88	0.72	-4.42	0.22	-0.105	-3323	0.003	1248
Fe	-143	-2.2	-24.50	0.07	-0.001	-2.20	-25.48	-81.20
Zn	-7.18	0.17	-8.20	0.15	-0.014	-142	-0.012	-342

Table 2.4 The variables of Freundlich and Langmuir for selected soil samples

3. CONCLUSION

The main goal of this research was to evaluate the effects of landfill leachate on the clean soil and the local ecological system in Avaragolla Village, Davangere. The analytical results foreseen in this study are evaluated in relation to the geoenvironmental characteristics of particular soils and the promotion of leachate. The research shed light on the land fill site in the village of Avaragolla and how the disposal of solid waste there contributes to the contamination of the groundwater and nearby clean soils. For the current study, two natural soil samples (clayey soil and silty soil) were selected since they both characterize the collective soils in the Avaragolla village and are commonly used to refer to them. The leachate was composed from the Avergolla village landfill site.

The basic physical characteristics of the selected soil samples were estimated by standard laboratory methods previous to the chief analytical program. According to reports, leachate has no effect on the silty sand soil that predominates in Avaragolla village.

To determine the collected soils' ability to adsorb heavy metals that will affect the soil layers, batch adsorption and column analysis were undertaken. The analytical values from the geo-environmental analysis are harmonious with the analytical values attained for the geo-technical characteristics of the silty sand soil. The occurrence of clay minerals shows a significant role in the clayey sand soil and indicates the significance of captions conversation in the soil characteristics. Good assessment was attained between the laboratory test results.

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