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Laterally and Vertically Distribution of Cadmium (CD) Heavy Metal, Case Study of Antang Landfill, Indonesia

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ABSTRACT

Antang landfill is situated in the center of Makassar City, South Sulawesi Province, Indonesia. In its operation, Antang landfill implements the Open Dumping method, potentially causing soil contamination. This study is conducted to identify the distribution of heavy cadmium metal in the soil around the Landfill. There are four sampling points in this study: (sample R, sample X, sample Y and sample Z) 0 m, 5 m, and 10 m laterally and a depth of 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm vertically. A total of 36 samples are analyzed for heavy metal content using the ICP-OES method. The result shows that cadmium (Cd) in this landfill has spread across the surface soil (topsoil) both vertically and laterally with varying intensities at each sample (sample R, sample X, sample Y and sample Z). The contamination level of cadmium in the soil around the landfill is considered low. Considering Makassar City in the future will still be faced with the problem of environmental pollution as a result of the development and increase of population, efforts to rehabilitate polluted soils should be concerned, such as the flushing method and phytoremediation.

1. INTRODUCTION

Makassar City has seen rapid development and an increase in population in the past few years, which inevitably leads to increased waste volume. Waste or garbage is a serious problem. For the Makassar City community, a landfill is a necessity to create environmental comfort in a big, bustling city. Even one day of garbage not being transferred to the landfill could cause massive nuisance and unpleasantness. Antang landfill located in Antang Urban-Village in Makassar City of South Sulawesi Indonesia. Antang landfill implements the Open Dumping method in its operation, potentially causing soil contamination [1]. Landfill and waste are piled up and left open daily on the soil [2]. Landfill is one place in urban areas that is at great risk of being contaminated with cadmium (Cd) due to ineffective waste management activities and poor

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handling of hazardous and Toxic Substances around the community and the landfill itself. Cadmium metal (Cd) is one of the heavy metals naturally occurring due to rock weathering and eruption or human activities, especially ones related to dry battery and agriculture industries [3].

Heavy metal cadmium (Cd) may be contained in the soil. Factors affecting the seepage of cadmium metal into the soil include soil organic matter content, soil acidity (pH), soil particle size, ion exchangeability, and soil temperature [3]. Cadmium can also be absorbed and accumulated by soil organisms that have developed resistance against it. Heavy metal Cadmium (Cd) contamination in the soil, while not caused large-scale deaths, may lead to health problems, even death, in humans. For this reason, a study on cadmium distribution around the soil of Antang landfill, both directly or indirectly, is essential to maintain public health, especially people who live around and close to the vicinity [1]. Based on the description above, this study raises the distribution of heavy metal cadmium in the soil and the contamination levels. Similar studies have also been done related to the behavior of several heavy metals and soil pollutants at the same landfill sites [4], [5], [6], [7].

2. METHODOLOGY

2.1. Study location

The study area is situated in Antang Urban Village, Manggala Sub-district, Makassar City, South Sulawesi Province, Indonesia. Geographically, the area was situated at coordinates 119° 29' 10" to 119° 29' 40" East Longitude and 5° 10' 20" to 5° 10' 40" South Latitude. Map and location of the landfill as well as laterally and vertically samples position are indicated in Figure 1.

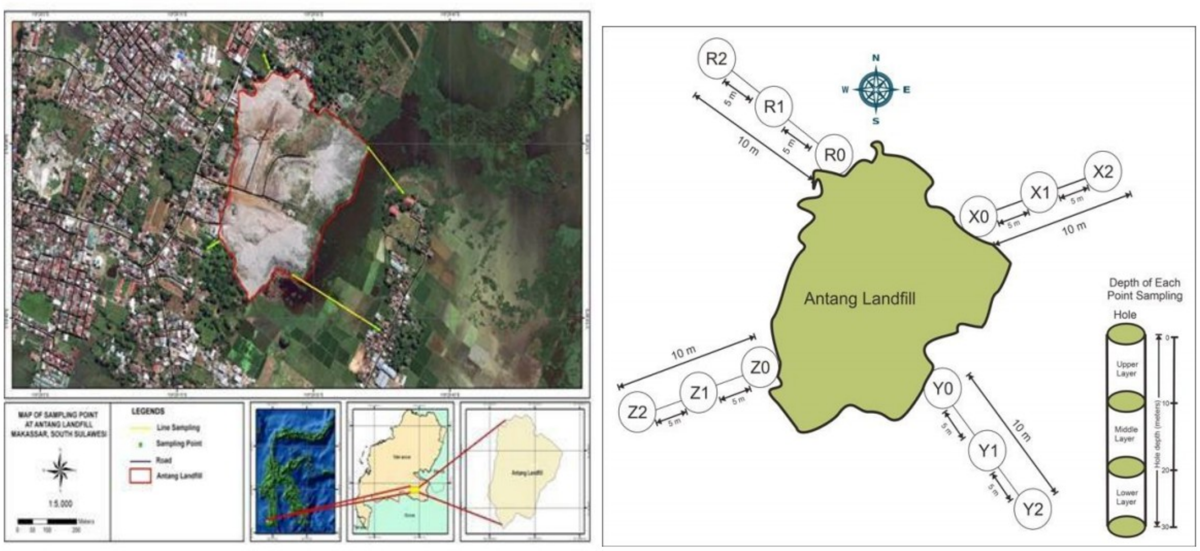

Figure 1. Map and location of the landfill laterally and vertically samples position for samples R, X, Y, and Z. Laterally distribution of sample (R) consist of (R0, R1, and R2), for sample (X) (X0, X1, and X2), for sample (Y) (Y0, Y1, and Y2), and for sample (Z) (Z0, Z1, and Z2).

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Vertically distribution of sample (R) consist of (R0) 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm; (R1) 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm; (R2) 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm). For sample X (X0) 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm; (X1) 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm, (X2) 0 to 10 cm, (X2) 10 to 20 cm, and 20 to 30 cm). Sample (Y): Y0 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm, (Y1) 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm, (Y2) 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm). For sample (Z) : (Z0) 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm, (Z1) 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm, (Z2) 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm).

2.2. Samples collection

Soil samples of Antang landfill were taken in four zones (Figure 1) where residential areas were close, and contamination had occurred on shallow groundwater [8], effectively affecting surrounding local wells situated 300-450 meters from the landfill [9].

Samples used in this study were the upper layer of soil (topsoil). The four sampling zones were (samples R, X, Y, and Z) with each sampling distance of 0 m, 5 m, and 10 m from garbage pile laterally and a thickness of soil sample of 0 to10 cm (upper layer), 10 to 20 cm (middle layer) and 20 to 30 cm (lower layer) from the surface of soil vertically. Soil samples were collected using hoes and soil rakes. At the same time, measurements were also made of soil environmental parameters, namely pH and soil moisture, using a soil tester and soil temperature using a mercury thermometer.

2.3. Preparation and Analysis

At the initial preparation stage, the soil sample was first put in the oven for 48 hours at 106^{o}C [10], [11] to facilitate the filtering process by making the soil particles detached from each other, crushed and grinded with a ceramic pestle [10], sifted using 2-mm stainless steel sieve [11], [12], [13] and stored in a desiccator before being tested [11]. Dry soil samples that have been prepared are then taken to the laboratory.

2.4. Data Analysis

The soil sample was analyzed in the soil laboratory of the Department of Agriculture of Universitas Muslim Indonesia to identify the soil textures with the 3-fraction method and the soil pH with calorimetry method or staining. The cadmium heavy metal content analysis was performed using the ICP-OES method to detect cadmium heavy metal concentration in the topsoil of the study area.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Vertically distribution of heavy cadmium metal

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A total of 37 soil samples were analyzed for determining cadmium heavy metal concentration using the ICP- OES method for soil samples of R, X, Y, and Z with each thickness of 0 to 10 cm (upper layer), 10 to 20 cm (middle layer), and 20 to 30 cm (lower layer) vertically, as well as for samples R (R0, R1, R2), X (X0, X1, X2), Y (Y0, Y1, Y2), and Z (Z0, Z1, Z2) with each distance of 0 m, 5 m, and 10 from garbage pile laterally. The vertical concentration of heavy cadmium metal in the study area for samples R0, X0, Y0 and Z0 are shown in

(Figure 2).

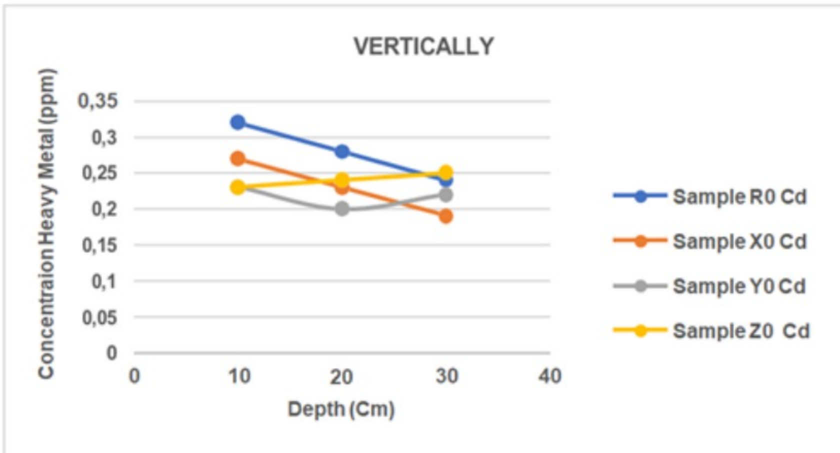

Figure 2. The vertical concentration of heavy cadmium metal in the study area for samples R0, X0, Y0 and Z0.

Figure 2 shows the concentrations of cadmium in the sample of R0, X0 and Y0 decreased at each layer (0 to 10, 10 to 20 and 20 to 30 cm), while the cadmium concentration of Z0 sample increased at each layers by (0.23, 0.24, and 0.25) ppm. The results of cadmium analysis vertically in the samples of R1, X1, Y1, and Z1 at the upper, middle, and lower layer (with each thickness of 10 cm) at the study area, Makassar City, Indonesia, are illustrated in Figure 3.

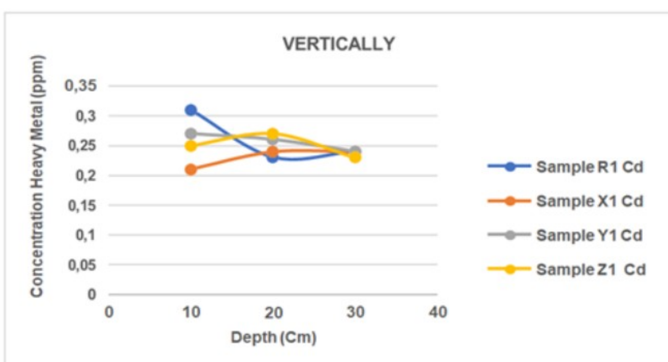

Figure 3. The results of cadmium analysis vertically in the samples of R1, X1, Y1, and Z1 at the upper, middle, and lower layer (with each thickness of 10 cm) at the study area.

Figure 3 reveal that the cadmium concentrations of the sample of R1 and Y1 decreased at each layer (upper layer, 0 to10; the middle layer, 10 to 20 middle; and lower layer 20 to 30 cm), and the cadmium concentration of X1 sample increased at each layer by (0.21, 0.24 and 0.24) ppm, while the sample of Z1 showed irregular cadmium concentrations at each layer by (0.25, 0.27 and 0.23) ppm. The graphic of the results of cadmium analysis vertically in the sample of R2, X2, Y2 and Z2 at the upper, middle, and lower layer (with each thickness of 10 cm) at the study area, Makassar City, Indonesia, are expressed in (Figure 4).

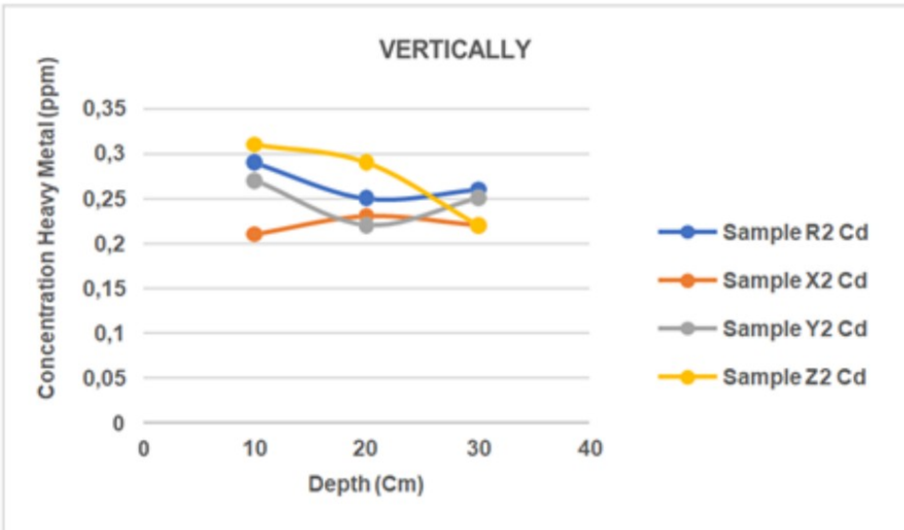

Figure 4. Vertically Cadmium concentration in the samples of R2, X2, Y2 and Z2 at the upper, middle, and lower layers (with each thickness of 10 cm) at the study area.

The Figure 4 describe irregular cadmium concentrations (0.29; 0.25 and 0.26) ppm; (0.21, 0.23 and 0.22) ppm; and (0.27, 0.22 and 0.25) ppm, respectively, at each layer in the samples of R2, X2, and Y2, while the cadmium concentration of Z2 sample decreased at each layer by (0.31, 0.29 and 0.22) ppm.

3.1.2. Laterally distribution of heavy cadmium metal.

The graphic of the results of cadmium analysis laterally in the sample of R0, R1 and R2, with each distance of 0 m, 5 m, and 10 m from the garbage pile laterally at the study area, are explained in (Figure 5).

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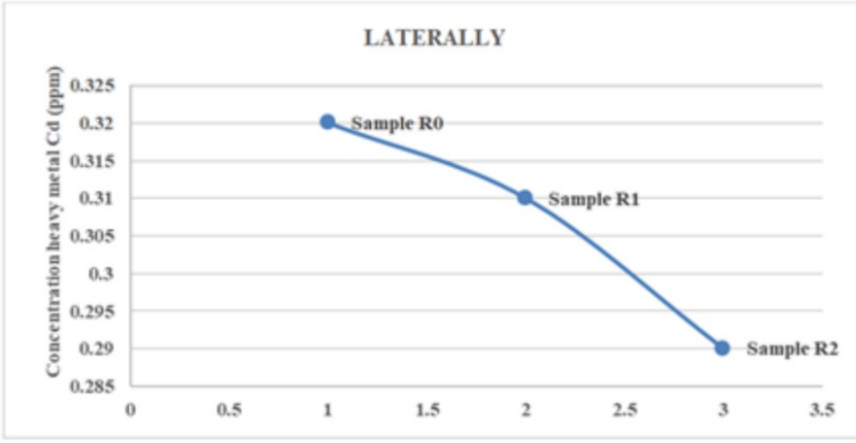

Figure 5. The graphic of the results of cadmium analysis laterally in the samples of R0, R1 and R2, with each distance of 0 m, 5 m, and 10 m from the garbage pile laterally at the study area.

Figure 5 shows the cadmium concentrations of the R0, R1, and R2 decreased at each sample, with a concentration value of 0.32, 0.31, and 0.29 ppm, respectively. It means that the cadmium concentration decreases from the source of the garbage pile to the outer direction of landfill (from inside to outside of landfill). Laterally cadmium concentrations in the samples of X0, X1 and X2, with each distance of 5 m from the garbage pile, are illustrated in Figure 6.

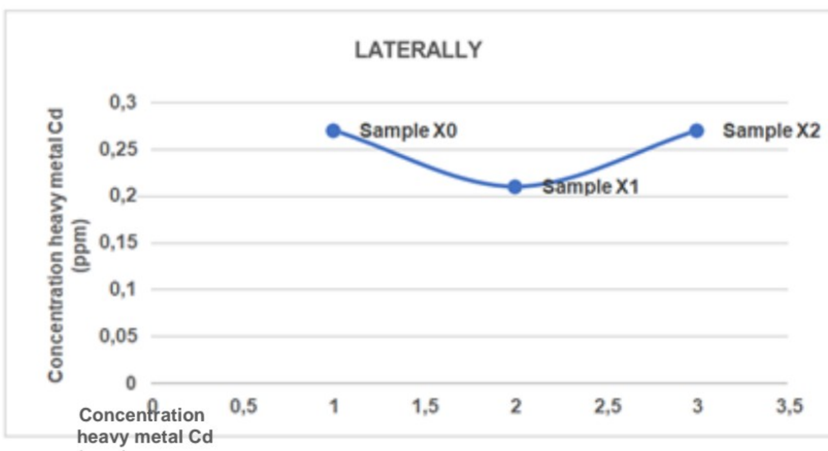

Figure 6. Laterally cadmium concentration in the samples of X0, X1, and X2, with each distance of 5 m (0, 5, and 10 m) from the garbage pile at the sampling area.

Figure 6 illustrates laterally cadmium concentration of X0, X1, X2 samples with a value of each sample (X0 = 0.27; X1 = 0.23, and X2 = 0.27 ppm). The value of cadmium concentration shows irregular variation from the position of 0, 5, and 10m (from the garbage pile to the direction of the outer of landfill).

The graphic of the results of cadmium analysis laterally in the samples of Y0, Y1, and Y2, with an interval of 5 meters from every sampling point at the site of landfill are indicated in (Figure 7).

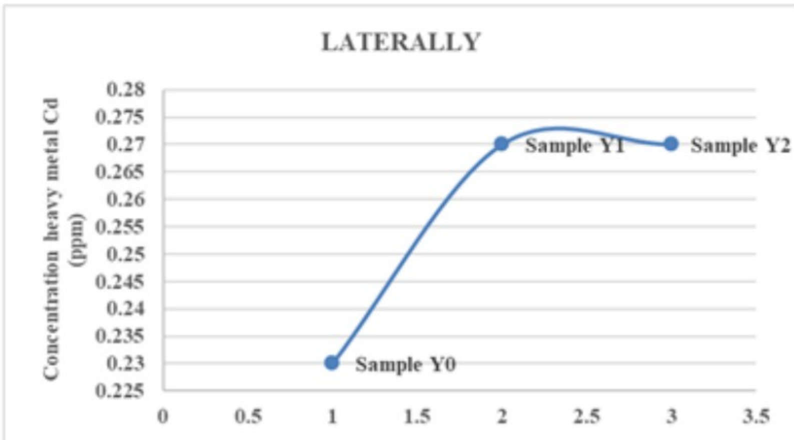

Figure 7. Laterally cadmium concentration in the samples of Y0, Y1 and Y2, with an interval of 5 m from every sampling point at the sampling area.

Figure 7 depicted the cadmium concentration of the samples of Y0, Y1, and Y2 laterally. The concentration of cadmium tends to be increased from Y0 to Y1 and stagnant at the Y2 (0.23, 0.27, and 0.27 ppm). The graphic of the results of cadmium analysis laterally in the samples of Z0, Z1 and Z2, with a distance of 0m, 5m, and 10m around the site of the study area, Makassar City, Indonesia, are depicted in (Figure 8).

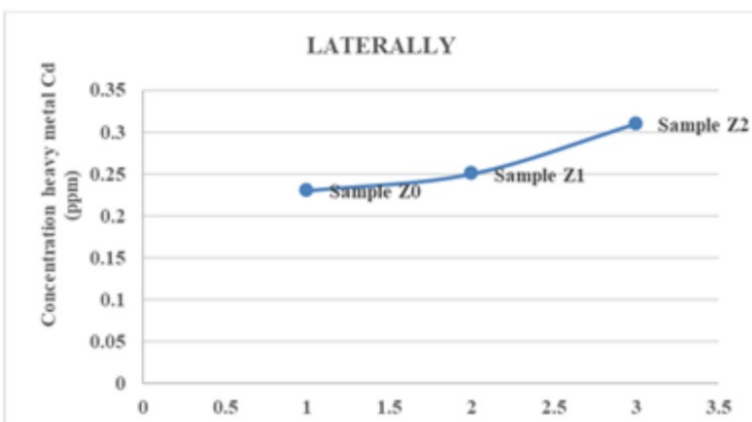

Figure 8. Graphic of cadmium concentration laterally in the samples of Z0, Z1, and Z2 at the landfill site.

Figure 8 shows that the cadmium concentrations of samples Z0, Z1, and Z2 laterally increase regularly from the point of the garbage pile to the outside of the landfill. Cadmium concentrations vary from 0.23, 0.25, and 0.31 ppm). This phenomenon shows the difference in

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the concentrations of the samples R0, R1, and R2, as shown in Figure 5.

3.2. Discussion

The result showed that cadmium (Cd) concentration in Antang landfill had spread across the surface soil (topsoil) both vertically and laterally with varying intensities at each sample (sample R, sample X, sample Y and sample Z). The contamination level of cadmium was still below the average threshold expected by the soil environment. The maximum tolerable threshold was five ppm [14]. Whether the heavy metal measured in the soil was harmful to the environment could not be determined because Indonesia does not yet have regulations regarding the maximum tolerable concentration of heavy metals in soils. There had been several studies on heavy metals on soils in Indonesia, but they still adopted the critical threshold of other countries for comparison. Cadmium (Cd) Heavy metal had spread above the surface (topsoil) both vertically and laterally on (sample R, sample X, sample Y and sample Z). That is because waste management was still actively carried out at those locations, thereby constantly receiving waste and garbage such as dry batteries, electronics, and PVC, that were suspected to contain cadmium.

The distribution of cadmium (Cd) heavy metals in the soil could not be separated from environmental factors affecting the absorption of heavy metals into the soil. These factors were pH and soil organic matter. The distribution of cadmium (Cd) heavy metal in soils with low pH tended to be lower when compared to soils with high pH. In soils with low pH, elements of cadmium (Cd) heavy metal would dissolve in groundwater, making them washed down more easily to the ground's lower layers during rain or absorbed by plant roots during the process of nutrient absorption [15]. In soils with high pH, cadmium would be bound by soil colloids and organic matter or deposited in the form of hydroxide, thus avoiding the process of washing and absorption by plant roots [15]. Soil organic matter also played a role in affecting cadmium content on soils. Organic matter would bind to heavy metals, forming chelates. Organic matter chelates could help regulate metal presence in the ground [16].

Other factors that might affect cadmium (Cd) distribution in the soil were waste input continuity, cadmium contamination resulting from fossil fuel emissions of motor vehicles, and cadmium bioaccumulation in animals and plants. Regular waste input meant higher risk of waste containing hazardous and toxic waste entering into the landfill, potentially causing increased cadmium content in the soil. Fossil fuel emissions of motor vehicles might originate from waste management activities such as transportation, disposal and dumping. Bioaccumulation in animals and plants might decrease the distribution of cadmium in the soil. Some animals and plants that could accumulate heavy metals in their tissues and organs included earthworms, cows and grass [16], [17]. Other factors contributing to the presence of heavy metals such as cadmium (Cd) in the soil include: characteristics of waste, volume, season, temperature, rainfall, soil pores, conductivity, groundwater flow, topography, and sampling time. Land cover of final waste disposal that blanketed waste was mud with high porosity and permeability. Mud possessed good infiltration and percolation features that could carry away pollution by groundwater movement faster than clay. Soil types might vary at each depth due to the characteristics of the waste dumped into the landfill.

The content of heavy metal cadmium (Cd) elements on the top soil surface around the landfill at (sample R, sample X, sample Y and sample Z) was fairly high. Low acidity of soil could raise the accumulation of organic acids in the soil. Low storage or soil binding potency against cadmium (Cd) at (sample R, sample X, sample Y and sample Z) was thought to be due to low clay content. This was in line with [25], the argument stating that clay fraction was the most critical soil characteristic of absorbing the ions of heavy metals. Heavy metals would be carried by leachate, deposited underground and keep accumulating. The heavy metals would affect the quality of the soil and groundwater environment around the landfill. When continuous and robust rainfall occurs, it might cause see page into lower layar and seepage water would flow into the river. This was highly detrimental to the community's life around the landfill since the majority of people around it still relied on wells as a source of water needs for households. Acidic pH was very harmful to agriculture because vegetation took and accumulated heavy metals from polluted soil.

High mobility of cadmium at (sample R, sample X, sample Y and sample Z), was presumably due to low soil pH (acidic). Their compound surge and acid concentration-organic acid generated. The cadmium was present significantly [26]. Cadmium was affected by humic acid and the availability of organic material because all heavy metals, including cadmium, strongly absorbed organic matter in the soil. Cadmium was able to bind organic components. Cadmium contents at (sample R, sample X, sample Y and sample Z) below the average threshold were likely due to these points. Decomposition of was and a large volume of was dumped without being sorted. Some inorganic waste was still decomposing on the ground surface.

The soil in the Antang landfill was Ultisol soil (reddish soil that contained a lot of clay). Thus, it displayed plasticity, promoted flooding and surface water pollution. The color was caused by metal contents, mainly oxidized iron and aluminium (weathered soil). The average pH of the soil of the Antang landfill analyzed was 4.84 with average temperature between 25^{o}C and 31^{o}C [26]. Acidity (pH) played a significant role the bioavailability of heavy metals and soil toxicity to the surrounding area. The concentration of pH influenced the mobility of metals in the soil [23]; [27]. At low pH, or acidic pH, it contributed to the availability, mobility and redistribution of cadmium [10], [13]. Relatively acidic soil displayed increased solubility and micronutrient mobility, causing the soil's concentration to increase [10], [28]. When the soil became too acidic, plants could not utilize N, P, K, and other necessary nutrients. In acidic soil (low pH), Al, Fe and Mn ions dominated. These ions bound nutrients that were essential to plants, particularly elements P, K, S, Mg, making it hard for them to absorb nutrients properly even though they were abundantly available in the soil [29].

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Heavy metal cadmium possessed a unique effect on children in that it promoted their brain development. On the other hand, however, it had adverse effects on adults in that it increased breast cancer risk, cardiovascular and pulmonary diseases. Other effects demonstrating the destructive impact of cadmium were renal failure, arthritis formation, and bone depreciation. Cadmium would undergo biotransformation and bioaccumulation processes in living organisms (plants, animals and humans).

4. CONCLUSIONS

The results of the study show that cadmium (Cd) heavy metal concentration in the study area has spread on the topsoil from the surface of soil with a deep of 30 cm (vertically) and from the point of garbage pile to the outer direction of landfill with a distance of 0 to 10 meter (laterally). The level of cadmium contamination around the landfill site is low or mild, which is favourable to the soil environment.

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