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Behaviour of Mercury Around the Landfill of Tamangapa Antang, Makassar City, Indonesia

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Abstract. Study of mercury behaviour has been conducted to know the spread of mercury (Hg) vertically and laterally around the Tamangapa Antang Landfill, Makassar City, Indonesia. Thirty-six samples (top soil) were collected in the area of Antang Landfill. The samples were devided into four lines, namely lines A, B, C, and D. Every line consist of three holes (line A: hole A1, A2, A3); (line B: hole B1, B2, B3); (line C: hole C1, C2, C3) and (line D: hole D1, D2, D3). Every hole was devided into three layers (Upper, Middle and Lower layer) with a thickness of layer 10 cm respectively. Furhermore all samples (top soil) were analyzed by means of cold vapour Atomic Absorption Spectrophotometer method (mercury determinition). The result of the study shows that the mercury in the study area has spread vertically and laterally around the Antang Landfill. The concentration of mercury in vertikal and lateral profile vary from 0.02 to 0.07 ppm. Eight top soil samples (A1-upper, A1-middle, A2-upper, A3-upper, A3-middle, D3- upper, D3-middle and D3-lower) were identified above the threshold level (according to State Minister for the Environment of Indonesia, number 51 2004 with threshold limit 0.05 ppm). Otherwise twenty-eight samples were found at the normal limit (less than 0.05 ppm). pH value in the studied area varies from 4.82 to 6 and it is shows an acidic condition. Soil pH significantly affects solubility and mobility of metals, since most metals dissolve in acid soils. So that proper remediation or precautions are needed to prevent risks to humans and the environment.

1. Introduction

Landfill of Tamangapa Antang uses Open Dumping method in its operation, where garbage or trash is heaped up and exposed to open air [1]. Garbage accumulation method in landfill can degrade environmental quality, such as air pollution as the result of solid waste burning, groundwater contamination as the result of leaching, and increased number of disease vectors that is harmful to the health of garbage collectors and communities around the landfill.

Soil is part of the cycle of heavy metal waste disposal, if the soil exceeds the ability to digest waste, this will result in soil pollution. The types of waste that have the potential to damage the environment are wastes that are included in Hazardous Toxic Substances (B3) which contain heavy metals [2], like the mercury (Hg). Heavy metal is one of the natural components of the earth that cannot be degraded or destroyed. In small concentrations, heavy metals can enter the body through food, drinks and air. According to [3], within the body of living things, heavy metals are trace minerals that are very small in number.

Landfill of Tamangapa Antang, is the only landfill located in Makassar that began operations in 1993. The Tamangapa Antang landfill which was originally designed for 10 years needs, but the fact is that until now the landfill is still being used, which means it is over from 20 years. By looking at this reality, it is known that it is probable that in the Tamangapa Antang landfill area, environmental pollution has occurred which can have an effect on environmental sanitation in this area. Along with its operation for decades, the Tamangapa Antang Landfill has been deemed inadequate and its capacity has been insufficient to accommodate the volume of waste in the next few years, not to mention the location that is very close to settlements which is very disturbing to the surrounding community. With a local population of around 1.5 million, Makassar City produces around 70 thousand tons per day or 1.4 million kilos per day of urban waste every day. In general, most of the waste produced is organic waste (wet waste), which covers 60-70% of the total volume of organic waste 86.4% and organic waste 13.6%. Most of the waste comes from population activities such as markets, trade centers, restaurants, and hotels [4],

Therefore, it can be assumed that the area of Landfill of Tamangapa Antang, in Makassar has been contaminated, namely soil, groundwater pollution which can be harmful to environmental sanitation and air pollution. This has a major impact on the quality of shallow ground water. Pollution of shallow ground water caused by the permeation of liquid waste from the landfill can also pollute the surrounding residential wells.

This study aims to analyze the mercury behavior around the Landfill of Tamangapa Antang in Makassar, Indonesia. The study focused on how the impacts that can be caused by the spread of mercury (Hg) around the landfill of Tamangapa Antang in Makassar, Indonesia. The samples were devided into four lines, namely lines A, B, C, and D. Every line consis of three holes for laterally (line A: hole A1, A2, A3); (line B: hole B1, B2, B3); (line C: hole C1, C2, C3) and (line D: hole D1, D2, D3). vertically for line A (0 to10 cm, 10 to 20 cm and 20 to 30 cm), for (line B: 0 to 10 cm, 10 to 20 cm and 20 to 30 cm), for (line C: 0 to 10 cm, 10 to 20 cm and 20 to 30 cm), and for (line D: 0 to 10 cm, 10 to 20 cm and 20 to 30 cm).

2. Research method

2.1. Research Area

Administratively, the study area situated in Bangkala, Manggala District, Makassar City, Indonesia. The map of the sampling points are shown in Figure 1.

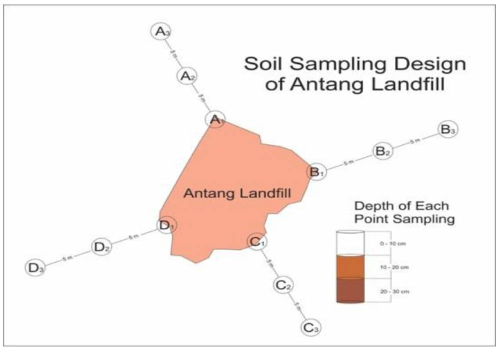

Figure 1. Location of Sampling Points, for line A, line B, line C and line D, lateral for lines A (hole A1, hole A2 and hole A3), for (line B: hole B1, hole B2 and hole B3), for (line C: hole C1, hole C2 and hole C3), and for (line D: hole D1, hole D2 and hole D3), and vertically for (line A: 0 to 10 cm, 10 to 20 cm and 20 to 30 cm), for (line B: 0 to 10 cm, 10 to 20 cm and 20 to 30 cm), for (line C: 0 to 10 cm, 10 to 20 cm and 20 to 30 cm), and for (line D: 0 to 10 cm, 10 to 20 cm and 20 to 30 cm).

2.2. Soil Sampling

The sample used in this study was topsoil collected from the Landfill of Tamangapa Antang in Makassar City, Indonesia. Determination of soil sampling points by dividing four lines. Laterally for Line A (hole A1, hole A2 and hole A3), for Line B (hole B1, hole B2 and hole B3), for Line C (hole C1, hole C2 and hole C3), and for Line D (hole D1, hole D2 and hole D3). Vertically for Line A with

IOP Conf. Series: Earth and Environmental Science **279** (2019) 012020 doi:10.1088/1755-1315/279/1/012020

depth (0 to 10 cm, 10 to 20 cm and 20 to 30 cm), for Line B with depth (0 to 10 cm, 10 to 20 cm and 20 to 30 cm), for Line C with depth (0 to 10 cm, 10 to 20 cm and 20 to 30 cm), and for Line D with depth (0 to 10 cm, 10 to 20 cm and 20 to 30 cm).

2.3. Soil Sample Analysis
Soil samples was roasted in the oven for 48 hours with a temperature of 106ºC ,[5], samples were then crushed with ceramic pestle and then sieved by passing a 2 mm filter [5]. Soil samples are then stored in desiccator and then the soil sample is taken to the laboratory for analysis [6].

2.4. Sample preparation and heavy metal analysis
A total of 5 grams of soil sample is put into a 300 ml polypropylene tube, then 200 ml of distilled water is added. It is then acidified with 10 ml HF solution, added with 5 ml $HClO_4$, 2.5 ml HCl and 2.5 ml HNO_3, then homogenized for 16 hours, with a speed of 200-220 RPM, filtered using whatman filter paper (No. 42), stored in a bottle of acid, and ready to be analyzed by atomic absorption spectrophotometer [7].

3. Results and discussion
3.1. Results
The analysis Result of mercury heavy metal concentration (Hg) using the Atomic Absorption Spectrophotometer method for Line A, Line B, Line C and Line D, Laterally for Line A (hole A1, hole A2 and hole A3), for Line B (hole B1, hole B2 and hole B3), for Line C (hole C1, hole C2 and hole C3), and for Line D (hole D1, hole D2 and hole D3). Vertically for Line A with depth (0 to 10 cm, 10 to 20 cm and 20 to 30 cm), for Line B with depth (0 to 10 cm, 10 to 20 cm and 20 to 30 cm), for Line C with depth (0 to 10 cm, 10 to 20 cm and 20 to 30 cm), and for Line D with depth (0 to 10 cm, 10 to 20 cm and 20 to 30 cm). A graph of the results of analysis of mercury (Hg) vertically in holes A1, B1, C1 and D1 with the depths of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm, around the area of Tamangapa Antang Landfill are shown in Figure 2.

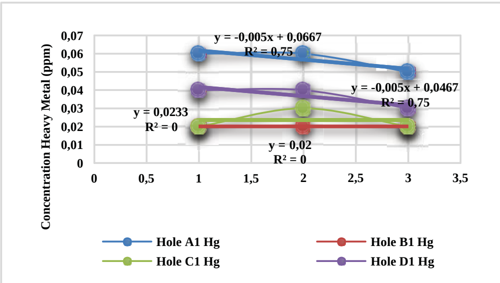

Figure 2. The graph of the results of analysis of mercury (Hg) vertically in holes A1, B1, C1 and D1, for at the depth of 0 to 10 cm (upper), 10 to 20 cm (middle) and 20 to 30 cm (lower) around Tamangapa Antang Landfill, Makassar City, Indonesia.

Figure 2 show that A1 hole at the depth of (0 to 10 cm) and (10 to 20 cm), the content of mercury is constant which value about 0.06 ppm, which has exceeded the threshold. While at a depth of 20 to 30 cm, the content of mercury decreases to 0.05 ppm, which is still in the normal range. B1 hole at a depth of 0-10 cm, 10 to 20 cm and 20 to 30 cm has constant content of around 0.02 ppm, which is still below the normal limit. The content in C1 hole at a depth of 0 to 10 cm ranged from0.02 ppm, at a depth of 10 to 20 cm the content of mercury increased to 0.03 ppm, while at a depth of 20 to 30 cm the content decreased to 0.02 ppm which is still below the normal limit. The content of mercury in D1 hole at the depth of 0 to 10 cm and 10 to 20 cm is constant that is around 0.04 ppm. While at a depth of 20 to 30 cm the content decreased to 0.03 ppm, which is still below the normal limit. A graph of the results of analysis of mercury (Hg) vertically in holes A2, B2, C2 and D2 with the depths of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm, around of area of Tamangapa Antang Landfill are shown in Figure 3.

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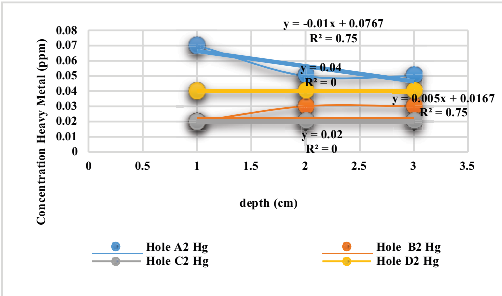

Figure 3. The graph of the results of analysis of mercury (Hg) vertically in holes A2, B2, C2 and D2, for the depth of 0 to 10 cm (upper), 10 to 20 cm (middle) and 20 to 30 cm (lower) around Tamangapa Antang Landfill, Makassar City, Indonesia.

A2 hole at a depth of 0 to 10 cm has a content of about 0.07 ppm, which is the concentration still at the normal limit (the value is illustrated in Figure 3). While at the position of 10 to 20 cm and 20 to 30 cm, the content decreased to 0.05 ppm which is still below normal limits. In B2 hole at the position of 0 to 10 cm, the content is about 0.02 ppm, while at the position of 10 to 20 cm and 20 to 30 cm the content is increasing to 0.03 ppm. The content of merkury in this hole is still below the normal limit (see Table 1 and Figure 3). C2 hole at the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm have a constant content with a value of 0.02 ppm, which is still below the normal limit. Similar to C2 hole, D2 hole at the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm have a constant content, and the value are 0.04 ppm respectively, which is still below the normal limit.

A graph of the results of mercury (Hg) heavy metal vertical analysis on holes A3, B3, C3 and D3 with the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm, around Tamangapa Antang Landfill Site are shown in Figure 4.

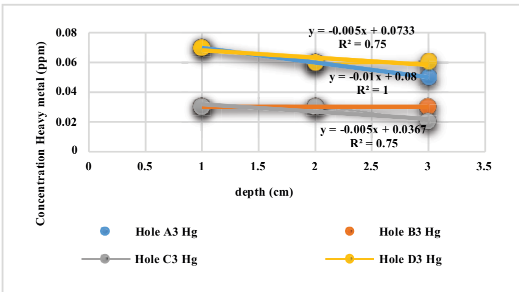

Figure 4. The graph of the results of analysis of mercury (Hg) vertically in holes A3, B3, C3 and D3, for at the depth of 0 to 10 cm (upper), 10 to 20 cm (middle) and 20 to 30 cm (lower) around Tamangapa Antang Landfill, Makassar City, Indonesia.

From Figure 4 it can be seen that the A3 hole at 0 to 10 cm depth have concentrations 0.07 ppm, at the position of 10 to 20 cm the content decreases to 0.06 ppm, which has exceeded the normal threshold. While at the position of 20 to 30 cm the content decreases again to 0.05 ppm, which is still within the normal range. B3 hole at the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm has a constant content of about 0.03 ppm, which is still below the normal limit. C3 hole at the position of 0 to 10 cm and 10 to 20 cm have content ranging from 0.03 ppm and at the position of 20 to 30 cm the content decreases to 0.02 ppm, which is still below the normal limit. D3 hole at the position of 0 to 10 cm have content ranging from 0.07 ppm, while at the position of 10 to 20 cm and 20 to 30 cm the content decreases to 0.06 ppm, which has exceeded the normal threshold.

Graph of the results of laterally analysis of mercury (Hg) heavy metal in holes A1, A2 dan A3 (line A), with the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm, around Tamangapa Antang Landfill is shown in Figure 5.

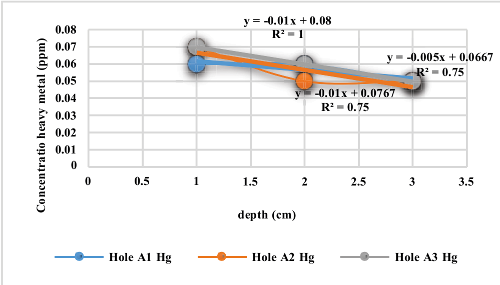

Figure 5. The graph of results of mercury (Hg) heavy metal laterally analysis in holes A1, A2, and A3, for the depth of 0 to 10 cm (upper), 10 to 20 cm (middle) and 20 to 30 cm (lower) around Tamangapa Antang Landfill, Makassar City, Indonesia.

From Figure 5 it can be seen that the A1 hole at the position of 0 to 10 cm and 10 to 20 cm have content ranging from 0.06 ppm, which has exceeded the average threshold. While at the position of 20 - 30 cm the content decreases to 0.05 ppm, which is still within the normal threshold. The A2 hole at the position of 0 to 10 cm has the content ranging from 0.07 ppm, which has exceeded the average threshold. While at the position of 10 to 20 cm and 20 to 30 cm the content decreased to 0.05 ppm, which is still at the normal limit. A3 Hole at the position of 0 to 10 cm and 10 to 20 cm has content ranging from 0.07 ppm and 0.06 ppm, which has exceeded the average threshold. While at position of 20 to 30 cm the content is about 0.05 ppm, which is still at the normal limit.

Graph of the results of lateral analysis of mercury (Hg) heavy metal in holes B1, B2 and B3 (line B), with the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm, around Tamangapa Antang Landfill is shown in Figure 6.

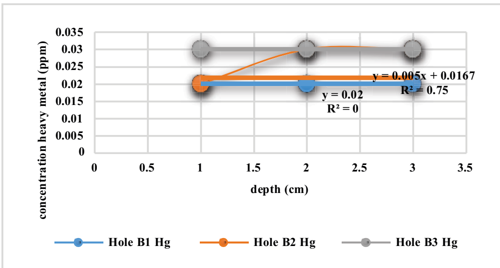

Figure 6. The graph of the results of analysis of mercury (Hg) laterally in holes B1, B2 dan B3 for at the position of 0 to 10 cm (upper), 10 to 20 cm (middle) and 20 to 30 cm (lower) around Tamangapa Antang Landfill, Makassar City, Indonesia.

From Figure 6 it can be seen that B1 hole at the position of 0 to 10 cm have content ranging from 0.02 ppm, at the position of 10 to 20 cm the content increases to 0.03 ppm, while at the position of 20 to 30 cm the content decreases to 0.02 ppm, which is still below the limit. B2 hole at the position of 0 to 10 cm has content ranging from 0.02 ppm. While at the position of 10 to 20 cm and 20 to 30 cm the content increased to 0.03 ppm, which is still below normal limit. Hole B3 at the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm has a constant content of about 0.03 ppm, which is still below the normal limit. A graph of the result of lateral analysis of mercury (Hg) heavy metal in holes C1, C2 and C3 (line C), with the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm, around Tamangapa Antang Landfill is shwon in Figure 7.

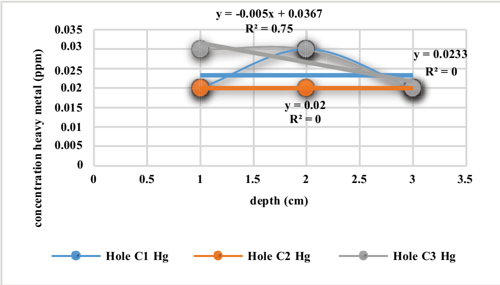

Figure 7. The graph of the results of analysis of mercury (Hg) laterally in holes C1, C2 dan C3 for at the position of 0 to 10 cm (upper), 10 to 20 cm (middle) and 20 to 30 cm (lower) around Tamangapa Antang Landfill, Makassar City, Indonesia.

From Figure 7 The data shows that C1 hole at the position of 0 to 10 cm have content ranging from 0.02 ppm, at the position of 10 to 20 cm the content increases to 0.03 ppm while at the position of 20 to 30 cm the content decreases to 0.02 ppm, which is still within normal limit. C2 hole at the position of 0 to 10 cm, 10 to 20 cm and 20-30 cm have a constant content of about 0.02 ppm, which is still below the normal limit. C3 hole at the position of 0 to 10 cm and 10 to 20 cm have a constant content of about 0.03 ppm, while at the position of 20 to 30 cm the content decreases to 0.02 ppm, which is still below normal limit.

A graph of the results of lateral analysis of mercury (Hg) heavy metal in holes D1, D2 and D3 (line D), with the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm, around Tamangapa Antang Landfill is shown in Figure 8.

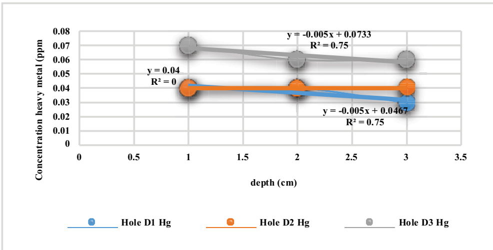

Figure 8. The graph of the results of analysis of mercury (Hg) laterally in holes D1, D2, and D3, for at the depth of 0 to 10 cm (upper), 10 to 20 cm (middle) and 20 to 30 cm (lower) around Tamangapa Antang landfill, Makassar City, Indonesia.

Figure 8 shows that D1 hole at the positiion of 0 to 10 cm and 10 to 20 cm have content ranging from 0.04 ppm, while at the position of 20 to 30 cm the content decreases to 0.03 ppm, which is still below the normal limit. D2 hole at the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm has a constant content of about 0.04 ppm, which is still below the normal limit. D3 hole at the position of 0 to 10 cm have content ranging from 0.07 ppm, while at the position of 10 to 20 cm and 20 to 30 cm the content decreases to 0.06 ppm, which has exceeded the threshold.

3.2. Discussion

The distribution and abundance of heavy metals in the study site contained a lot of metallic mercury (Hg) which far exceeded the threshold set by [8]. The results of the analysis indicated that the total content of mercury (Hg) in Tamangapa Antang Landfill, Makassar City, has spread both vertically and laterally with a very varied amount at each distance and depth on the soil surface (topsoil), with the level of enrichment exceeding the threshold of the expected limit of the soil environment.

Enrichment of mercury (Hg) heavy metal element content on the surface of the topsoil around the Antang Landfill is still high. This is caused by anthropogenic influences, leachate, soil characteristics, the amount of organic waste and inorganic wastes that are discharged to the Tamangapa Antang Landfill in Makassar [9], [10]. exacerbated by very acidic pH, which ranges from 4.82 to 6, in acidic pH heavy metal in the soil are relatively high.

Low soil acidity can increase the accumulation of organic acids in the soil. The low retention or binding capacity of the soil against mercury (Hg) on line A, line B, line C and Line D is expected due to the low clay content. Heavy metal is carried by leachate and will settle in the soil, so that heavy metals such as mercury (Hg) will continue to accumulate in the soil [11]. The heavy metal will affect the environmental quality of the soil and groundwater around the landfill. This has a great impact on the lives of the communities around Tamangapa Antang landfill, because most of the people around the study area are still using dug wells as a source of drinking water [12]. Acidic pH is very dangerous for agricultural purposes, because plants take and accumulate heavy metals from contaminated soil [13]. Metal pollution in the soil can make organic complex reactions that dissolve at normal pH and then infiltrate with runoff into deeper soil layers.

The high mobility of mercury (Hg) on line A and line D is thought to be due to low soil pH (acid). This results in an increase in soil reduction due to the addition of organic matter, as well as an increase in the content of organic acids produced by organic matter. Mercury (Hg) in this study is mostly contained in the soil surface (topsoil). The mobility of metal mercury (Hg) in the soil depends on humus acid and the availability of organic matter because all heavy metals such as mercury (Hg) are very strong at absorbing organic matter on the soil. Mercury (Hg) can bind organic components, such as on line A and line D which contains a lot of mercury (Hg) above the average threshold is most likely because line A and line D are still actively receiving waste. When decomposing waste/garbage is still in process, a lot of waste/garbage is disposed of in the landfill without being sorted. Some an-organic waste is still in the process of decomposition on the soil surface compared to line B and Line C which is no longer actively receiving waste.

The Tamangapa Antang Landfill Site has ultisol soil (reddish soil that contains lots of clay layers), thus showing plasticity, encouraging flooding and surface water pollution [14]. The average soil pH in the analyzed Tamangapa Antang Landfill ranged from 4.82 to 6, acidic with an average value of 4.84, the average temperature ranged between 25°C to 31°C. pH affects metal mobility in the soil [5]. Low pH or acidic pH will help the availability of mobility and redistribution of heavy metal mercury (Hg) in various fractions due to an increase in ion solubility in acidic soil environments [5]. Relatively acidic soil has increased solubility and micronutrient mobility so that the concentration of heavy metals in the soil increases [14], [5].

Mercury (Hg) is a metal that is very toxic to organisms. In certain uses or activities mercury (Hg) will be distributed to the environment in the form of agriculture, medicine, paint, paper, mining and industrial waste. All forms of mercury (Hg), damage to hair and teeth, loss of memory and disruption of the nervous system. This is very dangerous for the health of the population [7], especially the people who live around the landfill environment.

4. Conclusion

The results showed that the soil around the Antang Landfill Site, Makassar City, Indonesia was contaminated by mercury heavy metals (Hg), with concentrations exceeding the threshold of each depth both vertically and laterally. Line A for A1-hole at 0 to 10 cm and 10 to 20 cm depth shows a concentration with a value of 0.06 ppm, has exceeded the threshold. At the position of 20 to 30 cm indicate a concentration with a value of 0.05 ppm. A2 hole at the position of 0 to10 cm the content of Hg show 0.07 ppm, has already exceeded the threshold. While at the position of 10 to 20 cm and 20 to 30 cm the conten of mercury shows a value of 0.05 ppm. A3 hole at the position of 0 to 10 cm and 10 to 20 cm, the mercury content is 0.05 ppm. B1 hole at the position of 0 to 10 cm 10 to 20 cm and 20 to 30 cm, the content shows a value of 0.02 ppm respectively. B2 hole at the position of 0 to 10 cm the content show 0.02 ppm, while at the position of 10 to 20 cm and 20 to 30 cm the content of mercury show a value of 0.03 ppm. B3 hole at the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm the content is 0.03 ppm. C1 hole at the position of 0 to 10 cm and 10 to 20 cm the value show a content of 0.02 ppm. While at the position of 10 to 20 cm it ranges from 0.03 ppm. C2 hole at the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm the value is 0.03 ppm. C3 hole at the position of 0 to 10 cm and 10 to 20 cm the content of mercury is 0.03 ppm. While at the position of 20 to 30 cm the content is 0.02 ppm. Line D for the D1 hole at the position of 0 to 10 cm and 10 to 20 cm shows a content value of 0.04 ppm. While at the position of 20 to 30 cm shows a mercury content value of ppm. D2 hole at the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm the content value is ppm respectively. D3 hole at the position of 0 to 10 cm the content of mercury is 0.07 ppm, while at the position of 10 to 20 cm and 20 to 30 cm the content is 0.06. In general the content of metal mercury is still below of treshold (A1 hole at the position of 20 to 30 cm; A2 hole at the position of 10 to 20 cm and 20 to 30 cm; A3 hole at the position of 0 to 10 cm and 10 to 20 cm; B3 hole at the position of 0 to 10 cm, 10 to 20 cm and 20 to 30 cm; C3 hole at the position of 0 to 10 cm and 10 to 20 cm; C3 hole at the position of 20 to 30 cm; D1 hole at the position of 0 to 10 cm and 10 to 20 cm. D1 hole at the position of 20 to 30 cm. The pH of the soil is acidic which ranges from 4.82 to 6.0 and is one of the main factors that can affect the mobility of metal mercury (Hg), in the soil environment. Metal mercury (Hg) from landfills, can be damage to the environmental and health of human being due to its toxicity in the organism. Soil is very important for humans, because it can produce nutrients for plantations. Soil has the potential, to withstand additional heavy metal loads further under acidic pH conditions.

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