The concentration of heavy metals zinc and lead in the soil around the Putri Cempo landfill, Indonesia

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Abstract. Improper disposal of municipal waste is a serious threat to the environment and a challenge to climate which results in the land, water, and air pollution. Through decomposition processes and life cycle activities, landfill contributes to more than 5% of greenhouse gas emissions that cause climate change. This study aims to determine the concentration of selected heavy metals around the Putri Cempo landfill. Soil samples were taken in the depth of 0-30 cm. Characterization of soil parameters included soil pH, organic matter (OM), zinc (Zn), and lead (Pb). The result showed soil pH value ranging from 6.07 to 6.85 which is slightly acid, organic matter ranged from 0.95% to 5.87%, while Zinc and lead concentration ranged from 49.2μg/g to 224.7μg/g and 4.3μg/g to 82.4 μg/g respectively and were below the permissible limits of heavy metals in soil recommended by World Health Organization (WHO). The mean concentration of both metals was detected low far from the landfill and high closer to the landfill, which proves that there had been the anthropogenic contribution of heavy metals pollution in the soil through the disposal of wastes. In conclusion, this study serves as a starting point for future environmental studies.

1. Introduction
Improper disposal of municipal waste is a serious threat to the environment resulting in various forms of pollution such as land, water, and air pollution [1]. Due to uncontrolled population growth, industrialization, urbanization, and rapid technological developments, the amount and variety of waste produced have increased significantly [2], [3], [4]. This results in landfill overloading and rise landfill gas generation like CH4 and CO2, as a result of physical, chemical and microbial processes that occur in solid waste [5]. Through decomposition processes and life cycle activities, landfill contributes to more than 5% of greenhouse gas emissions in the global anthropogenic GHG budget which results in global warming and climate change [6].

Despite the negative impact, landfill is still quite a common method for waste handling in developing countries where Indonesia is not an exception with 90% of waste disposed of in this way. Out of the 46 cities in Indonesia, 33 still use the open disposal system for waste management, including Surakarta. Putri Cempo is the only landfill that serves and accommodates all the wastes of Surakarta city. Due to the excessive amount of waste that has entered the landfill, Putri Cempo is overloaded and has been reported to be disqualified [7]. As result, this caused the degradation and pollution of the surrounding environment by various pollutants. Due to improper leachate management, uncontrolled leachate flows
and diffuses enter groundwater thereby introducing heavy metals into the surrounding environment [7], [8].

Heavy metals are long-lasting and undecomposed pollutants that emerge in the environment as a result of natural and anthropogenic activities. They enter the body through food, air, and water thereby affect human health [9]. The most known heavy metals are copper (Cu), nickel (Ni), chromium (Cr), lead (Pb), cadmium (Cd), mercury (Hg), zinc (Zn), and iron (Fe). Some of them are essential for the survival of all life forms at low concentrations. However, lead (Pb), cadmium (Cd), and mercury (Hg) are toxic to living organisms even in low concentrations, and they cause anomalies in the metabolic functions of the organism especially when are in high quantities [10].

Landfills have been reported to be responsible for introducing heavy metals that have biological toxicity into the environment [11]. Soil polluted by heavy metals is difficult to manage and often associated with insufficient nutrients, degradation of soil and water quality, and ultimately irreparable damage to soil biota [12]. Besides, heavy metals assimilation by plants and the successive crowding along the food chain is a critical threat to animal and human health [13]. There is no doubt that Putri Cempo landfills lead to soil and water pollution, as much waste is dumped recklessly regardless of the environmental implications. This can affect human health, as landfill is closer to the community, some soils are used for agricultural purposes, and over 1000 cows grow in landfills and over 200 scavengers work there.

Since heavy metals results in all forms of pollution, the emergence Investigation and continuous monitoring of these pollutants are essential since slight changes in their concentration whether due to natural or anthropogenic factors, result in serious environmental and subsequent health problems. This study aimed to determine the concentration of zinc and lead around the Putri Cempo landfill. Even if various studies have been carried out in the same study area, none of them studied the concentration of heavy metals in the soil around this particular landfill.

2. Material and methods

2.1. Site description
Surakarta is a city in Central Java, Indonesia geographically situated between 110°45'15" - 110°45'35' East longitude and 7°36'00" - 7°56'00" South of latitude. Putri Cempo landfill is about 5 km from the center of Surakarta, in the northern part of Surakarta in Mojosongo village. The area comprises 17 hectares of which 13 hectares are used for landfill purposes. The landfill was designed with a capacity to accommodate waste for only 20 years but it has operated for over 30 years.

2.2. Soil sampling
A transect line method was conducted and 8 soil samples were taken along the transect line in the depth of 0-30 cm. Samples were taken from geographically dispersed locations (North, South, East, and West) at a target interval considered as near and away from landfills. The 4 composite samples were taken near the landfill at 100m and 4 others away from the landfill at 500m. Samples were properly packed, appropriately labeled, and then transported to the laboratory for analysis.

2.3. Soil analysis
The samples were air-dried and solid particles like debris, gravel, and large chunks were carefully removed. The soil samples were grounded using porcelain mortar and sieved through a 2mm sieve after which were later subjected to analyses. Soil pH was determined by electrode glass method[14], soil OM by Walkley & Black method [15], and Zn and Pb by atomic absorption spectrophotometer (AAS) [16].

2.4 Data analysis
Data were analyzed using Microsoft Excel 2013 to calculate the mean, maximum and minimum and to make graphs and tables.
3. Results and discussion
The results of soil physical-chemical properties and heavy metal concentration are presented in Table 1. WHO recommendations for maximum permissible limits of toxic metals in the soil were also provided for comparison.

Table 1. Physical-chemical and heavy metals concentration.

| Distance From Landfill | Sample code | OM in% | pH | Threshold value |
|------------------------|-------------|--------|----|-----------------|
|                        |             |        |    | Zn in μg/g | Pb in μg/g |
|                        |             |        |    | 300 | 100 |
| 100m                   | NNL         | 5.3    | 6.3| 224.7 | 82.4 |
|                        | SNL         | 1.19   | 6.46| 62.3 | 12.0 |
|                        | WNL         | 2.91   | 6.79| 92.4 | 6.6 |
|                        | ENL         | 5.87   | 6.85| 208.6 | 65.7 |
| 500m                   | NAL         | 1.54   | 6.45| 52.1 | 10.4 |
|                        | SAL         | 1.93   | 6.78| 73.2 | 21.2 |
|                        | WAL         | 2.68   | 6.07| 49.2 | 4.3 |
|                        | EAL         | 0.95   | 6.18| 52.1 | 8.6 |
| Mean                   |             | 3.8175 | 6.6 | 147 | 41.675 |
| Max                    |             | 5.87   | 6.85| 224.7 | 82.4 |
| Min                    |             | 0.95   | 6.07| 49.2 | 4.3 |

*: Average at 100 m, : Average at 500m, NNL: North Near Landfill, SNL: South Near Landfill, WNL: West Near landfill; ENL: East Near landfill, NAL: North Away from Landfill; SAL: South Away from Landfill, WAL: West Away from Landfill, EAL: East Away from Landfill.

Table 1 shows the OM content ranged from 0.95% detected in East-away from landfill to 5.87% detected in East-near landfill. The average OM was 3.8175% close to landfill and 1.775% far from landfill. OM content of the soil sample is given in Figure 1.

Figure 1. Organic matter content

Figure 1 revealed higher OM at 100 m than at 500m with a downward trend. At every 1 m away from the landfill, OM reduced by 0.0051. This means the more closely to landfill the high OM detected and vice-versa. High OM close to landfill resulted from the decomposition and composting processes of the organic wastes that occupied over 62.87% of waste disposed at Putri Cempo. In addition, due to the continuous decomposition of organic waste in the landfill, a lot of gas also can be produced especially CH4 which has a significant impact on the climate change [5]. Odoemelam and Ajunwa [17], reported OM content of < 2.0 % as low; 2.1- 3.0 % medium and >3.1% as high [17]. By following this soil categorization, OM of the study area is classified as low (1.775%) away from the landfill and high (3.8175%) near the landfill. The higher OM content near against far from landfill is similar to OM reported by [18].
The soil pH was slightly acid and ranged from 6.07 detected West away from landfill to 6.85 detected East near the landfill. The average pH was 6.6 near landfill and 6.37 away from landfill (Table 1) and is within range for optimal growth of a wide variety of plants. The results of pH are presented in figure 2.

![Soil pH graph](image1)

**Figure 2.** Soil pH.

Figure 2 showed higher soil pH at 100 m than at 500 m with a downward trend. An increase in every 1 m away from the landfill reduced soil pH level by 0.0006. This implied that the more distant to the landfill the more soil pH reduced and vice-versa. The observation of the highest pH at dumpsite corroborated with [18], [19], and [20]. Prechthai et al [19] reported that most soils within the pH range of 6.0-9.0 have metals that are not always in the free form, hence not likely to be bioavailable [19]. The pH of investigated soil is within this range therefore, the metals investigated in this study possibly may not be bioavailable to the plant until when favorable conditions like acidic precipitation prevailed on the soil.

Zinc is a phytotoxic heavy metal that can directly affect soil fertility. The result from Table 1, declared Zn concentration ranged from 49.2 µg/g detected West-away from landfill and 224.7 µg/g detected North-near the landfill. The mean concentration of Zn was detected low (56.65 µg/g) at 500 m and high (147 µg/g) at 100 m. The concentrations of Zn in investigated soil are presented in Figure 3.

![Zinc concentration graph](image2)

**Figure 3.** Zinc concentration.

Figure 3 showed the higher concentration of Zn close to the dumpsite than far from the dumpsite with the downward trend from 100 m to 500 m. An increase of every 1 m away from landfill reduced Zn concentration by 0.2259, this means that there is a gradual decrease in the concentration of Zn as moves several meters away from the dumpsite. A similar observation has been reported by Okeke et al studied the concentration of heavy metals in Enugu metropolis, Nigeria. The author concluded that the higher concentration of Zn at the landfill is due to the activities within the dumpsites such as mechanic workshops and residential [1]. As well as the waste disposed of in landfills which may be composed of fertilizers and soil amendments like manure, compost, ammonium nitrate, and so forth. However, the concentration of Zn in various locations of Putri Cempo either close or far from the landfill were under the desirable limit recommended by WHO (Table 1).

Lead (Pb) is a toxic heavy metal that affects humans when ingested into the body. At higher concentrations, Pb interrupts water balance, enzyme activity, and mineral nutrition[20]. The result from Table 1, revealed Pb concentration ranged from 4.3 µg/g detected West-away from landfill and 82.4
µg/g detected North- near the landfill. The mean concentration of Pb was detected low (11.125 µg/g) at 500m and high (41.675 µg/g) at 100 m. The concentration of Pb is presented in Figure 4.

![Figure 4. Lead concentration.](image)

Figure 4 showed the higher concentration of Pb close to the dumpsite than far from the dumpsite with the downward trend from 100 m to 500 m. An increase of every 1m away from landfill reduced Pb concentration by 0.0764. This means, there is a gradual decrease in the Pb concentration as moves several meters away from the landfill. The concentration of Pb reduced with the increase in distance from landfill. The higher concentration of Pb at the landfill is similar to the observation by Amerh et al. [20] in the study on Municipal Dumpsite in Sunyani, Ghana. The same observation also goes to [21]. The author concluded that the higher concentration of Pb close to the landfill can be associated with industrial/chemical waste disposed of in the landfill [21] or waste products containing batteries, food packaging materials, PVC materials, and insecticides [20]. However, the concentration of Pb in various locations of Putri Cempo either close or far from the landfill was below the standard limit provided by WHO (Table 1).

4. Conclusion
The literature has undoubtedly proven that increased waste generation and disposal has a significant impact on climate change and soil contamination by heavy metals. This study showed an increase in heavy metal pollution as getting closer to the landfill. The northern and eastern parts of Putri Cempo are the most polluted by heavy metals. The concentrations of Zn and Pb either close or far from the landfill are below the permitted limits given by WHO and their sequence concentrations in the soil follow Zn > Pb. Although studied soil was found to be safe for now, there are concerns for the gradual and continuous buildup of pollutants which has started as indicated in the obvious difference of metals concentration close and far from landfill. Therefore, the continuous cultivation of consumable plants around Putri Cempo is very risky for humans. Environmental pollution by landfill due to dissolving heavy metals requires long-term monitoring, therefore, future studies with sufficient sample size are highly recommended in this area.

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