Magnetic Properties of Soils from Sarimukti Landfill as Proxy Indicators of Pollution (Case Study: Desa Sarimukti, Kabupaten Bandung Barat)

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Abstract. Leachate is the liquid arises from waste disposal. It contains heavy metals and magnetic minerals. Leachate could penetrate into sub surface that cause soil contamination. We have studied magnetic properties of soils from three zones in the Sarimukti landfill. We measured magnetic susceptibility in dual frequency and temperature dependent of susceptibility. The results showed that magnetic susceptibility at low frequency ($\chi_{LF}$) of soil samples have the value ranging from 50-1400 ($10^{-8}$ m$^3$/kg). It infers that the samples were dominated by ferrimagnetic minerals. The relative difference of magnetic susceptibility measured at two frequency ($\chi_{FD}(\%)$) are less than 4%. It indicates that magnetic minerals probably derived from anthropogenic sources. There is negative correlation between $\chi_{LF}$ and $\chi_{FD}(\%)$. It supports the analysis that the source of magnetic minerals is anthropogenic. The results of the temperature dependent magnetic susceptibility measurements showed that the peak of magnetic susceptibility in heating curve occurs at the temperature about 200°C and 500°C. After 500°C, heating curve rapidly decreases. It can be inferred that the dominant type of magnetic minerals in the samples is titanomagnetite.

1. Introduction
Leachate is a liquid derived from waste which has yellow, brown or black colour [1]. Leachate is produced when water in the form of rainfall or groundwater percolate into the waste [2]. Leachate will be found around landfills. The large volume of incoming waste and heavy rainfall in the landfill area is potentially generating leachate in large numbers.

Leachate can penetrate into subsurface and this can contaminate soil and groundwater. Leachate of the landfill contains heavy metals, magnetic minerals, hazardous chemicals, bacteria, and viruses. Therefore, it is necessary to identify the contamination of the soil to provide a solution to the problem of soil contamination caused by leachate.

In this research, we identified of magnetic properties on soil samples taken from the Sarimukti landfill, Kabupaten Bandung Barat. Magnetic measurements performed in this study are the measurement of the frequency dependent magnetic susceptibility and temperature dependent magnetic susceptibility. The aim of the study is to identify the magnetic properties of the soil in the Sarimukti landfill and surrounding area as an indicator of soil contamination.
2. Methods

We have collected soil samples from three zones of Sarimukti landfill, namely zone 1, zone 2, and zone 3. Zone 1 and zone 2 are inactive zones, while zone 3 is an active zone. Inactive zone is a zone that is no longer used as landfill, otherwise active zone is a zone that is still active as a landfill and produce landfill leachate. The three zones have different topography as shown in Figure 1.

![Topographic map of Sarimukti landfill](image)

**Figure 1.** Topographic map of Sarimukti landfill. The arrows show the ground water flows around the target area [3] and the picture show the boundary between the zones.

Soil samples were obtained from surface to a certain depth. The samples were then placed into 10 cm$^3$ sample holder. In total, we have 25 samples. All samples were subjected to magnetic susceptibility measurement by using Bartington Magnetic Susceptibility system with sensor B (Bartington MS2B). MS2B operates at low frequency (470 Hz) and high frequency (4700 Hz). The relative difference of magnetic susceptibility values in these frequencies is known as frequency-dependent susceptibility, $\chi_{FD}$ (%). We also measured temperature-dependent susceptibility for some selected samples using Bartington MS2 with sensor W.

3. Results and Discussion

In zone 1, we have samples from 0-60 cm depth. Magnetic susceptibility value at low frequency ($\chi_{LF}$) ranges from 1150-1400 ($\times$ 10$^{-8}$ m$^3$/kg). The highest value of $\chi_{LF}$ is at depth of 30-40 cm. Soil samples from zone 2, taken from 0-50 cm depth, has $\chi_{LF}$ ranging from 800-1000 ($\times$ 10$^{-8}$ m$^3$/kg) with the highest value is at depth of 20-30 cm. In zone 1 and zone 2, there is similar pattern of variation in magnetic susceptibility with depth.

Soil samples from zone 3 has lower values of $\chi_{LF}$ than those of zone 1 and zone 2. In zone 3, the $\chi_{LF}$ varies from 50-550 ($\times$ 10$^{-8}$ m$^3$/kg). The highest value of $\chi_{LF}$ is at topsoil. Plot of variation of magnetic susceptibility values with depth is shown in Figure 2.
Samples of rocks and soils, that dominated by silty clay [3] showing purely paramagnetic behaviour rarely show $\chi_{LF}$ values exceeding $10 \times 10^{-8}$ m$^3$/kg. Therefore, as a rule-of-thumb, the $\chi_{LF}$ of any sample with a value less than this is probably controlled by the concentration of paramagnetic minerals and for values greater than this by ferrimagnetic minerals [4]. Based on $\chi_{LF}$ value; it can be deduced that magnetic minerals contained in the samples are dominated by ferrimagnetic minerals.

The presence of magnetic minerals can occur due to soil formation process (pedogenic) or also due to other sources, such as human activities (anthropogenic). Anthropogenic sources can be industrial activities, household or vehicle derived particulates.

The pattern that high magnetic susceptibility values decrease from the surface to a certain depth indicates a large contribution of anthropogenic related ferrimagnetic minerals [5]. This pattern occur in zone 3. It indicated that magnetic minerals in this zone derived from anthropogenic sources.

The $\chi_{FD}$ (%) values of the samples in landfill area are less than 4%. Low values of $\chi_{FD}$ (%) (1-4%) are commonly found in contaminated soils. Magnetic minerals in soils derived from pedogenic process has a higher value (~10%) [6]. It infers that the magnetic minerals from study area are derived from anthropogenic sources.

Statistical analysis of $\chi_{LF}$ and $\chi_{FD}$ (%) shows negative correlations. The existence of negative correlations. The existence of negative correlation between $\chi_{LF}$ and $\chi_{FD}$ (%) indicate that the magnetic minerals are from anthropogenic sources. It supports the analysis that the source of magnetic minerals is anthropogenic. Plot $\chi_{FD}$ (%) vs $\chi_{LF}$ is presented Figure 3.
Temperature-dependent susceptibility analysis is widely used for determining the Curie point [7] at which ferrimagnetic or ferromagnetic mineral becomes paramagnetic during heating. Temperature-dependent susceptibility measurements were performed by heating the samples to 700 °C and cooling it to room temperature. Cooling process is often used as an indicator to identify mineralogical phase changes. In this study, we selected one sample in each zone to be subjected to temperature-dependent susceptibility measurement.

Sample from zone 1 showed an increase in magnetic susceptibility as temperature increase with the peak at about 200-300 °C. Heating curve rapidly decrease after 500°C, as shown in figure 4.
Peak increases in magnetic susceptibility from zone 2 at about 200-300 °C. After the 500°C heating curve is rapidly declining. Plot of temperature on the magnetic susceptibility for zones 2 are presented in Figure 5.

![Figure 5](image)

**Figure 5.** Temperature vs Magnetic Susceptibility Plot for Zone 2

Based on plot of temperature with magnetic susceptibility values from zone 3, magnetic susceptibility increases at 200-300 °C when the sample was heated. As same as previous samples, after 500°C heating curve is rapidly declining, as shown in figure 6.

![Figure 6](image)

**Figure 6.** Temperature vs Magnetic Susceptibility Plot for Zone 3.
The presence of magnetite phase is at a temperature of about 580°C. This shows that the Curie point of magnetite to be around 580°C or more precisely ranged from 575-585 °C. All samples has heating that curve decreases after 500°C. It indicates the occurrence of phase transitions. Based on these results, three samples have similar mineralogical phase with the mineral magnetite. In addition, the peak increase in any samples taken from each zone occurs at about 200°C and 500°C. Therefore, the dominant type of magnetic minerals in the sample is titanomagnetite.

4. Conclusions
1. Based on magnetic susceptibility value, magnetic minerals in the samples are dominated by ferrimagnetic.
2. Source of magnetic minerals are anthropogenic.
3. According to temperature dependent susceptibility measurement, the dominant type of magnetic minerals is titanomagnetite.

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