Magnetic morphology and mineralogy in urban soil of
Bandung City, Indonesia

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Abstract. High numbers of vehicles and its activity in Bandung City resulting in levels of pollution caused by their particulates on the top soils. Since the urban topsoil containing particulates are harmful, thus its mineralogy and morphology need to identified. The samples of topsoil were taken in several locations around Bandung City. Afterwards, the topsoil samples were extracted for mineralogy and morphology analysis using X-Ray Diffractometer (XRD), Scanning Electron Microscope (SEM) and Energy Dispersive X-ray (EDX) tests. The result of XRD measurement shows that the magnetic mineral dominated by magnetite. The magnetite is iron rich mineral that could be changed in morphology by the oxidation during environmental changing. Furthermore, the morphology of the magnetic mineral by SEM analysis exhibit the shapes of octahedron and spherules. The octahedron shape represents of paedogenic magnetic mineral carrier while the spherule indicate the presence of anthropogenic mineral. EDX analysis show the evidence of heavy metal elements on the magnetic mineral with spherule shape that caused by vehicles particulates.

1. Introduction
Vehicle activity is one of the main causes of air pollution. The pollution caused by vehicles, especially in developing countries, is very sharp in line with the increase the number of vehicles. The fuel that used by vehicles contains lead as a heavy metal which acts as a pollutant that affects air quality and health [1].

Bandung is one of the cities with a fairly crowded vehicle activity. Meanwhile, vehicle smog pollution detection tools known as Air Monitoring Quality System (AQMS) are available in several places in Bandung. This measuring tool can be used to determine the levels of pollutants produced by vehicle fumes which are then informed to the public through the Air Pollution Standard Index (APSI) board, but in the past few years it has been known that only two of AQMS are active. So, there is no monitoring of the level of pollutants in several areas in Bandung. Thus, as not all air quality monitoring stations are active and the APSI board is not functioning properly, an alternative method that is fast, easy and inexpensive is needed to determine the level of this pollution.
In the past decade, identification of magnetic morphology and mineralogy methods have been widely used to detect levels of pollution or environmental pollution, for instance, Yunginger et al (2018) identified lithogenic and anthropogenic components in the sediments of Lake Limboto [2], and Kirana et al (2014) analysed the magnetic characterization of the Citarum River sediments [3]. In addition to sediment, this method can also characterize soil samples in the area to be studied for pollution levels [4]. This study aims to identify magnetic minerals in pollutants and relate them to the source of the pollution. In general, magnetic minerals are naturally present in rocks, soil, sedimentary deposits and even particles in the air, although quantitatively the percentage is quite small, about 0.1% of the total mass of rock or sediment [5].

Some studies have shown a link between the abundance of magnetic minerals and the soil that is suspected of being exposed to pollutants. Lu and Bai (2006) conducted a study on the correlation between magnetic properties and heavy metal concentrations in urban Hangzhou China [6]. Marie et al. (2010) examined emissions and pollution from motorized vehicles on high way in Argentina [7]. Venuti et al. (2016) discussed anthropogenic pollutants on surface soils along the Salaria road, Italy [8].

This research was conducted to identify the magnetic properties of surface soils that are suspected of being exposed to pollutants in several areas in Bandung City. The use of the magnetic method is based on the abundance of magnetic minerals contained in pollutants either derived from vehicles or other human activities. Vehicle fumes that generate magnetic abundance will be distributed above the urban topsoil. Measurements of contaminated soil samples are carried out to determine the morphology (shape and size of grains) and mineralogy contained in soil samples so that the dominant magnetic minerals contained in these pollutants and environmental changes will be known.

2. Material and Methodology

Urban surface soil samples were taken to identify morphology and magnetic mineralogy at four locations in Bandung, namely Moh. Toha (MTH), Gede Bage (GDBG), Pasir Koja (PSKJ) and Gasibu (GSB). Furthermore, the preparation and extraction of the surface soil samples that have been taken are carried out. Sample preparation was carried out using a sieve with a mesh size of 120 to obtain a homogeneous grain with a size of less than 200 μm.

Then, the extraction process (Figure 2) is carried out by dissolving 5 grams of the soil sample that has been prepared previously into 50 mL of aquabides according to the method used by Novala et al. (2019) [9]. The extraction process is carried out using a magnetic stirrer.

After the preparation and extraction of the sample process, the morphological measurements of the magnetic minerals were taken with a Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray (EDX) using JEOL JSM-6510A. Before carrying out the SEM-EDX test, conducting glue is attached to the sample to be analysed, then the coating process measured by JEOL-GC-32010CC Carbon Coater instrument. Mineralogical analysis of magnetic minerals was performed by measuring X-Ray Diffractometer (XRD) using the Rigaku SmartLab X-Ray Diffractometer instrument.
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Figure 1. Map of Bandung City, bordered with green line. The red dots show sampling points of urban soil around Bandung City.

Figure 2. The extraction process of the sample using magnetic stirrer, including (a) stirring the sample using magnetic bar, (b) taking the magnetic bar with magnetic stick and (c) extracted sample.

3. Result and Discussion
The results of element mapping in MTH samples with SEM-EDS analysis are shown in Figure 3. This element mapping aims to find the distribution of dominant heavy metals in the sample. The brighter colour indicates the amount of certain elements in the sample. Based on Figure 3, there are elements of Fe and O that dominate as a sign that there are magnetic grains. Similarly, the mapping results of the GDBG (Figure 4) and PSKJ (Figure 5) sample elements showed high levels of Fe and O and low levels of Ti. In addition, there are also heavy metal content in the samples i.e. C, Mg, Al, Si, Ca, V, Cr, Mn, Co, Ni, Cu, Zn, Cd, Hg, and Pb.
Figure 3. Mapping results of MTH sample elements. The colours in the left side of each elements show the index for low contain (dark colour) to the high contain (light colour) of the element in the sample. This index also applies to Figure 4 and Figure 5.

Figure 4. Results of mapping the GDBG sample elements
According to Lu and Bai (2006), the presence of Cu, Zn, Cd, V and Pb elements indicates contaminants from the combustion process (exhaust) of vehicles [6]. In addition, Cu can be derived from brake pads also [10], while Cr is produced from tires and brake linings and Ni is one of the heavy metals produced in the oil combustion process [11]. Moreover, the main source of Pb is the use of brake and wheel weights loss which can affect the urban environment [12], while Zn comes from tires which are recognized as the source of particulate matter in urban environments [11]. The heavy metal content (mass fraction) in each sample is shown in Table 1.

Table 1. EDX analysis of magnetic mineral samples of GDBG, MTH and PSKJ

| Element | % Mass of GDBG | % Mass of MTH | % Mass of PSKJ |
|---------|----------------|---------------|----------------|
| C       | 2.44 (Spherule) 65.07 (Octahedral) 7.01 (mapping) | 9.65 (Spherule) 8.8 (Octahedral) 30.78 (mapping) | 5.16 (Spherule) 10.26 (Octahedral) 50.95 (mapping) |
| O       | 39.31 (Spherule) 9.05 (Octahedral) 34.96 (mapping) | 37.7 (Spherule) 35.39 (Octahedral) 31.75 (mapping) | 2.95 (Spherule) 30.99 (Octahedral) 26.26 (mapping) |
| Mg      | - 0.41 (Octahedral) 1.2 (mapping) | - 0.02 (Octahedral) 1.03 (mapping) | - 0.19 (Octahedral) 1.36 (mapping) |
| Al      | 0.21 (Spherule) 0.71 (Octahedral) 3.48 (mapping) | 0.16 (Spherule) 0.91 (Octahedral) 1.85 (mapping) | 1.39 (Spherule) 1.98 (Octahedral) 0.69 (mapping) |
| Si      | 0.24 (Spherule) 0.3 (Octahedral) 4.65 (mapping) | - (Spherule) - (Octahedral) 4.03 (mapping) | 0.95 (Spherule) 1.79 (Octahedral) 0.70 (mapping) |
| Ca      | 0.06 (Spherule) 0.03 (Octahedral) 1.38 (mapping) | - (Spherule) 0.06 (Octahedral) 2.03 (mapping) | 0.24 (Spherule) 0.23 (Octahedral) 0.10 (mapping) |
| Ti      | 0.4 (Spherule) 1.95 (Octahedral) 4.71 (mapping) | 0.12 (Spherule) 10.05 (Octahedral) 1.7 (mapping) | 1.63 (Spherule) 3.49 (Octahedral) 2.03 (mapping) |
| V       | - (Spherule) 0.12 (Octahedral) 0.32 (mapping) | - (Spherule) 0.5 (Octahedral) 0.1 (mapping) | 0.41 (Spherule) 0.31 (Octahedral) 0.16 (mapping) |
| Cr      | 0.45 (Spherule) 0.02 (Octahedral) 0.45 (mapping) | - (Spherule) 0.03 (Octahedral) 0.02 (mapping) | 0.31 (Spherule) 0.4 (Octahedral) 0.08 (mapping) |
| Mn      | 0.68 (Spherule) 0.22 (Octahedral) 0.3 (mapping) | 0.27 (Spherule) 2.37 (Octahedral) 0.21 (mapping) | 0.81 (Spherule) 0.35 (Octahedral) 0.13 (mapping) |
| Fe      | 55.79 (Spherule) 21.71 (Octahedral) 40.06 (mapping) | 51.24 (Spherule) 40.75 (Octahedral) 25.76 (mapping) | 82.29 (Spherule) 48.03 (Octahedral) 17.55 (mapping) |
| Co      | 0.43 (Spherule) 0.05 (Octahedral) 0.11 (mapping) | 0.1 (Spherule) 0.47 (Octahedral) 0.05 (mapping) | - (Spherule) 0.08 (Octahedral) 0.03 (mapping) |
| Ni      | - (Spherule) - (Octahedral) - (mapping) | 0.47 (Spherule) 0.01 (Octahedral) 0.41 (mapping) | - (Spherule) 0.01 (Octahedral) 0.04 (mapping) |
| Cu      | - 0.24 (Spherule) 0.38 (Octahedral) 0.26 (mapping) | 0.14 (Spherule) 0.28 (Octahedral) 1.27 (mapping) | 0.4 (Spherule) 0.46 (Octahedral) 0.46 (mapping) |
| Element | % Mass of GDBG | % Mass of MTH | % Mass of PSKJ |
|---------|----------------|--------------|---------------|
|         | Spherule       | Octahedral   | Spherule      | Octahedral   | Spherule | Octahedral |
| Zn      | -              | 0.11         | 0.18          | 0.27         | 0.2      | 1.91       | 0.24       | 0.48       |
| Cd      | -              | -            | 0.26          | -            | 0.17     | 0.14       | 0.17       | 0.01       | 0.04       |
| Hg      | -              | -            | 0.15          | -            | -        | 0.02       | 0.13       | 0.05       | 0.02       |
| Pb      | -              | 0.01         | 0.12          | 0.1          | 0.08     | 0.04       | 0.19       | 0.01       | 0.03       |
| Total   | 100            | 100          | 100           | 100          | 100      | 100        | 100        | 100        | 100        |

SEM measurements on the sample will produce a morphological image of the magnetic mineral of the sample which can be known by identifying each magnetic grain that has been seen previously through mapping. Figures 6 and 7 show the morphology of magnetic grains in the MTH and GDBG samples, while Figures 8 and 9 are the morphological images of the magnetic grains in the PSKJ and GSB samples.

**Figure 6.** SEM image and EDX analysis of MTH magnetic minerals

**Figure 7.** SEM image and EDX analysis of GDBG magnetic minerals

**Figure 8.** SEM image and EDX analysis of PSKJ magnetic minerals
Figure 9. SEM image and EDX analysis of GDBG magnetic minerals

The identified magnetic mineral morphology is focused on two forms of magnetic minerals, i.e. magnetic mineral in shapes of octahedral and spherules. The morphology of magnetic minerals in the form of octahedral or tetrahedral dipyramid is known as titanomagnetite or magnetite [13]. The SEM image in Figure 6-9 shows the presence of grains in the form of magnetite with an octahedral shape and a sharp tip originating from the weathering of igneous rocks in volcanic areas (paedogenic process) and having a surface that tends to be rough, while the SEM image results are spherule grains derived from anthropogenic material. The shape of the spherule grains in the SEM measurement results has a diameter smaller than 40 µm. According to Gautam et al. (2004), grain spherules with a diameter of 2-40 µm are indicated as an abundance of magnetic minerals originating from road traffic [14]. This change in the shape of the ferrimagnetic mineral grains in the form of magnetite from an octahedral to a spherule occurs due to the effect of oxidation originating from anthropogenic sources (vehicle activity). According to El Baghdadi et al. (2011) magnetic minerals in the form of spherules are often generated from pollution in vehicle fuel combustion [15]. Spherule-shaped grains that come from roadside pollution are also found in various areas including Nepal [14], Greece [11], Morocco [15], Italy [8] and China [16].

Figure 10. The diffractogram of the MTH surface soil sample where M is the magnetite mineral and A is the albite mineral
XRD measurements are carried out as supporting data to determine the type of magnetic minerals present in the sample. Based on the measurement results, it was found that the dominance of magnetic minerals contained in the sample was magnetite ($\text{Fe}_3\text{O}_4$) and albite in the MTH sample (Figure 10).

![Figure 10. Diffractogram of the sample with peaks indicating magnetite (M), albite (A), and quartz (Q) minerals.](image_url)

The XRD test results showed that the PSKJ sample (Figure 11) had a mineral content of magnetite with a higher diffractogram peak than the other three samples. This proves that the PSKJ sample is dominated by ferrimagnetic minerals in the form of very strong magnetite. The difference in XRD measurement results between the MTH and PSKJ samples is the presence of quartz ($\text{SiO}_2$) minerals which are minerals that form igneous rocks. Based on the SEM-EDX and XRD image analysis, it can be said that by knowing the dominance of the magnetite mineral in urban soil samples in Bandung City, it can be analysed the grain shape originating from the pedogenic process as well as from the anthropogenic process.

4. Conclusion
The morphology of magnetic minerals in the urban surface soil samples in Bandung has an octahedral and spherule shapes. Magnetic minerals in the form of octahedra are derived from pedogenic processes, while magnetic minerals in the form of spherules are derived from anthropogenic processes. One of the sources of anthropogenic processes comes from vehicle particulates. This is consistent with the analysis of heavy metal content in the sample. Meanwhile, the XRD test results showed that the sample was dominated by the mineral magnetite. Therefore, based on the data obtained, it can be said that there is exposure of vehicle particulates on the urban surface soil in the Bandung City area and further monitoring is necessary to determine how much particulate exposure on the urban surface soil.

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