Mapping leachate distribution based on the self-potential method in Manggar Landfill, Balikpapan Indonesia

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Abstract. TPA Manggar is a landfill in Balikpapan City. During the rainy season, the leachate discharge entering the processing plant is so large that the collection tub will not be able to withstand the leachate flow rate. To find out the direction of the distribution of leachate waste and the extent to which it has spread and to map the areas at high risk of being contaminated, measurements were taken using the Geophysical method, namely the Self Potential Method (SP). The SP method is based on measuring the self-potential of rocks in the earth's crust without having to inject an electric current into the soil. Based on this, research will be carried out to determine the mapping of the distribution of leachate flow in the TPA Manggar area. The results of measurement and processing of self-potential data can be showing beneath the surface in the form of leachate distribution in the study area based on isopotential contour. Based on the results of contour and isopotential map data processing. The highest potential value of this study was 60 mV, while the lowest potential value of this study was -40 mV.

1. Introduction
Garbage is the residue of daily human activities or natural processes in solid form. The increase in the population increased human activity, and changes to a more modern lifestyle have increased the amount of waste produced. It results in the accumulation of waste that cannot be decomposed by nature, causing pollution. Based on this, we need a waste management system in an area. One of them is the Balikpapan City area, as the population increases, the waste produced will also increase. The high population activity in Balikpapan City will indirectly affect the amount of waste generated every day. To anticipate the problem of waste problems, the Balikpapan city government made a waste management site, namely the UPTD Manggar Balikpapan Final Disposal Site (TPA). UPTD TPA Manggar Balikpapan also provides benefits as a means of education for both students and students about the importance of waste and creating jobs for the surrounding community [1].

The leachate treatment system at TPA Manggar uses the sanitary landfill method. During the rainy season, the leachate discharge entering the treatment plant is so large that the collection tub may not be able to withstand the leachate flow rate. As a result, the leachate that enters will overflow and spill onto the ground so that the percolation of rainwater and the infiltration process causes leachate to seep into the soil. Leachate can seep through the soil and cause groundwater pollution in the landfill site. This seepage depends on the physical properties of the landfill, such as permeability, porosity, and piezometric pressure [2]. Leachate is the liquid waste that is produced when rainwater falls, flows, and seeps into the garbage. This wastewater carries dissolved material obtained from the waste it passes through. In general, leachate is acidic, rich in acidic organic matter, contains sulfate ions, and has a high metal concentration. Leachate has a distinctive odor when seeps into the soil and pollutes the soil and groundwater [3]. In order to know the direction of the distribution of leachate waste and the extent to
which it has spread and to map the areas at high risk of being contaminated, measurements were taken using the self-potential (SP) method [2] [4].

The (SP) method is a very simple and inexpensive geophysical method. The SP method measures the potential of rocks in the earth's crust without having to inject an electric current into the soil [5][6]. Self-potential is a natural statistical potential that arises due to mechanical and electrochemical processes under the surface [7]. The SP method is mostly used in Engineering Geology (such as determining the depth of bedrock), searching for water reservoirs, supporting methods in geothermal searches, and for identifying the distribution of waste below the surface [8]. The spread of waste can be done in various ways. Leachate is a fluid generally flows due to the influence of gravity. The land surface elevation above the mean sea level is the main factor causing the spread of leachate. However, capillary processes, osmosis, and electrokinetic phenomena are also factors that can influence the spread of this waste[4]. Based on the above, this study aims to map the distribution of leachate in Manggar landfill using the self-potential method and determine the direction of its distribution.

2. Materials and methods

2.1 Self-Potential (SP) measurement

The SP method has been used since 1920 as an alternative tool for metal exploration, more specifically, to detect the presence of large quantities of iron ore [7]. In recent years, the SP method is widely used for subsurface water and geothermal investigations, and can also be used for mapping purposes. The SP method is very cheap to use for geophysical exploration, both from the equipment required and from simple field operations [5][7]. The SP method is a passive method, where the difference in soil potential is naturally measured between two points on the surface. The measured potential difference values can be less than millivolts to one volt, and the sign (negative or positive) of the potential value is an important factor for the interpretation of SP anomalies [9]. Electrokinetic potential (Ek) (streaming potential) is formed as a result of electrolyte flowing through capillaries or porous media, where its potential is measured at the capillary end. The potentials arising from this process are alternatively as electrofiltration, electromechanical, or streaming potential. According to Helmholtz's law, the flow of electric current is linked to a hydraulic gradient and a quantity known as the coefficient coupling electrofiltration, to account for the physical and electrical properties of the electrolyte and tissue through the medium through which the electrolyte has passed. It is also important that water flows in parallel either to the geological boundary or to its free surface (eg water level). The following is the electrokinetic potential equation:

\[ E_k = \frac{\varepsilon \mu C_E \delta P}{4\pi \eta} \]  

Where \( E_k \) is electrokinetic potential, \( \varepsilon \) is the dielectric constant, \( \mu \) is the resistivity of the electrolyte, \( \eta \) is the dynamic viscosity of the electrolyte, \( \delta P \) is the hydrostatic pressure difference, \( C_E \) is the coefficient of the electroporation pair. Based on the equation above, the fluid flow will then be in the direction of electrical current.

Self-potential occurs because of the potential generated by several natural sources themselves without injection to the subsurface of the earth, even though the complete cause of the physical process is not widely known [10]. The natural potential of land consists of two components, one of which is constant and the other changes with time. Constant components are due to electrochemical processes, as well as components that change due to variations in the potential range variation of alternating current (AC) induction by electric storms and variations in the earth's magnetic field, which is also built up by rainfall. In mineral exploration, each component of SP is called mineral potential and background potential (Table 1)[7].
Table 1. Types of SP anomalies and their geological sources[6]

| Source                          | Anomalies type            |
|---------------------------------|---------------------------|
| Sulphide                        | Negative ≈ 100 mV         |
| Graphite                        |                           |
| Magnetise, coal                 |                           |
| Quartz veins                    | Positive ≈ 10 mV          |
| Pegmatites                      |                           |
| Fluid Streaming, Geochemical Reaction | Positive +/- negative ≤ 100 mV |
| Bioelectric                     | Negative, ≤ 300 mV        |
| Topography                      | Negative up to 2 V        |

2.2 Data acquisition

This research was conducted at Manggar Landfill in Balikpapan, which is located approximately 15 km from Balikpapan City, East Kalimantan of Indonesia can be seen in Figure 1. The stage before the first data acquisition that was carried out was the survey design map creation. Making the survey design map aims to determine the boundaries of the surveyed area and the measurement targets can be met. In making the survey design map, a geological map and topographic map are needed to describe the conditions of the area. Before doing research, it is necessary first to calibrate the tool. The calibrated tool is the porous pot electrode. The way to do the calibration is by sticking 2 porous pot electrodes into the soil that has been perforated at a predetermined distance. In this situation, the potential difference is measured with the result that must be less than or equal to 2 millivolts [5]. There are several possibilities if the value obtained is more than 2 millivolts such as leaking solution, porous pot electrodes that are not suitable for placement on the ground. If the measured potential value is too large, both electrode porous pot must be cleaned first and then refilled with new CuSO₄ solution.

Figure 1. Map of research location
The data collection method used is the fixed base technique. The measurement scheme using this method can be seen in Figure 2. Based on Figure 2, one porous pot electrode remains at the reference point, while the other porous pot electrode moves every certain interval according to the direction of the path. The advantage of this method is the potential that is measured continuously against a fixed point so that zero error (zero error) between the two porous pot electrodes does not arise. While the disadvantage of this method is that the cable used is relatively long [5]. The data acquisition process of the self-potential method is carried out in two ways, namely as a function of time (base) and a function of distance (rover), measurement as a function of time (base) aims to measure the daily variation and the results of this basic measurement are used to correct data [8].

![Image](image1.png)

**Figure 2.** The technique of data acquisition of fixed base configuration [5]

### 2.3 Data processing

The data obtained from the acquisition process is a potential value between two porous pot electrodes read in a digital voltmeter. These potential data have not shown the true potential self-value, since there are differences in values at a measuring point if the measurements are repeated at different times. Furthermore, the potential data of the measurement result must be corrected [8][11]. Corrections made in this study include diurnal correction and reference correction. Corrected potential data is assumed as potential data from anomaly causing objects, in which the fluid flow is targeted. Corrected SP data are interpreted qualitatively by using Surfer software to obtain isopotential contour maps. Based on this isopotential map, it can be interpreted as the fluid flow direction (Leachate) of the research area.

### 3. Results and Discussion

Measurement of the SP method was conducted at the Manggar Balikpapan TPA. This study will focus on analyzing the direction in which leachate is distributed in the research. Using Surfer software, the potential data collected are used to make a contour map by entering the coordinates (latitude and longitude) and potential data.

![Image](image2.png)

**Figure 3.** Show Isopotential contour map represents the distribution of potential values, the line for slicing (A’-A) and line for slicing (B’-B)
Self-potential measurement resulted in data in the form of electric potential in mV units. In this survey, data collection was carried out by a fixed base. The amount of data is 65 data with a spacing of 5 meters. Correction result data is Self Potential data. Data generally have small SP values, ranging from 60 mV to -40 mV. These results are used in the potential value of the leachate from Rosid's (2011) study that the leachate conductivity is 2.68 mS (1 mS = 1 milli Siemens = 1 mV) [4]. The data was made isopotential contour map (Figure 3) using Surfer Software. Based on the results of data processing in the study area using Surfer software, the anomaly distribution pattern indicated as leachate accumulation can be seen from the isopotential contour distribution pattern which is blue to purple which has a lower SP value than the surrounding area.

3.1 Slicing on isopotential contour maps

On the isopotential contour map that has been processed further, a cross-section is selected for slicing. The criteria for selecting the contour area to be sliced are indicated that some low potential anomalies and locations have closed closures [2]. The result of truncating potential anomaly value data to the distance of each electrode. The potential data anomaly and the distance are presented in the form of a profile curve, namely the potential anomaly curve concerning distance (Figure 4). The interpretation of SP anomaly source and the subsurface material indication is carried out based on the profile shape, amplitude, polarity (positive or negative) anomaly value, and contour pattern. After determining the incision line that has been sliced, 2 incision paths were selected. The first is for the incision path from east to west with the path name (A-A'). The second is for the incision path from east to west with the path name (B-B').

![Figure 4. Profile cross-sectional curve (a) A-A’, (b) B-B’](image)

On the contour map that has been sliced, Figure 4 (a) obtains the cross-sectional profile curve (A-A’). The potential anomaly curve can be observed with the distance between the electrodes. At a distance of 0 meters to 53 meters, the curve looks sloping and wide based on the electrokinetic potential in Figure 3. The results of the profile curve in Figure 4 (a) A-A’ can be seen from the self-potential values ranging from -32 mV to 56 mV, According to the theory, the profile curve from the minimum potential position tends to be vertical to asymmetrical with a steep slope and a positive curve tail, which can lead to complications when two or more geological structures give an increase to the SP anomaly that is obtained [6]. The results of the B-B profile curve in Figure 4 (b) can be seen from the self-potential values ranging from -14 mV to 12.3 mV with a distance of 0 meters to 55 meters. The incision on the B-B line was chosen because it has many closed cabinets and has a low anomaly value of -25 mV and a high anomaly value of 10 mV. it is possible to spread leachate to low potential anomalies.
4. Conclusion
Based on the results of contour and isopotential map data processing, the research area is a conductive zone than can be seen from the low measured potential value. The highest potential value of this study was 60 mV, while the lowest potential value of this study was -40 mV. The anomaly distribution pattern indicated as leachate buildup can be seen from the isopotential contour distribution pattern, which is blue to purple and has a lower SP value than the surrounding area.

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