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Mapping Leachate Contamination Using Resistivity Geoelectric Method at TPA Kebon Kongok, West Lombok Regency, West Nusa Tenggara Province

Muhammad Hisyam Ramadhan[1] , Mochamad Arief Budihardjo[2*] , Kasiyati[3*]

[1] *Master of Environmental Sciences, Postgraduate School, Diponegoro University, Semarang*

[2] *Department of Environmental Engineering, Diponegoro University, Semarang*

[3] *Department of Biology, Faculty of Sciences and Mathematics, Diponegoro University, Semarang*

Corresponding Authors E-mail: m.budihardjo@ft.undip.ac.id, atie_bd@yahoo.co.id

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Abstract

TPA Kebon Kongok is one of the Final Processing Sites in Indonesia that uses a sanitary landfill system. The limited availability of land and the increasing height of the waste pile that has been dumped during the TPA operation period and the discovery of leachate puddles at several points in the TPA area are problems that need to be addressed immediately so as not to disturb the environmental ecosystem and society. The purpose of this research is to determine the depth of leachate pollution in the subsurface and map the leachate distribution pattern around the TPA Kebon Kongok area. This research was conducted using the resistivity geoelectric method with a 2-D Wenner configuration in 10 lines and the Self Potential (SP) method with an area 132,732 m² and 138 data point. Based on data analysis, it is found that the layer indicated as leachate has a resistivity value of 0.143-4.71 Ωm. Based on the results of the SP analysis, it is known that the accumulated leachate streams are interpreted to have relatively lower self-potential values with anomalous values of -100 mV to -40 mV. Low potential values were found in the northwest to southeast of the study site, while relatively high potential values were found in the southern part of the study site. The direction of leachate distribution in various directions is due to the fact that the study area has different elevations and the subsurface layer is composed of layers that easily drain liquids, which are indicated as sand layers. This research is expected to be a consideration for the management of TPA Kebon Kongok in taking mitigation steps from leachate pollution.

Introduction

Waste is one of the environmental problems that is very close to everyday life, both in developed and developing countries. Waste is considered a complex and serious problem [1]. Waste is all the remains of human activities or activities that are no longer needed in the form of solids, liquids, and gases [2]. Waste management in Indonesia faces various complex challenges, including increasing waste volumes, limited infrastructure, and low public awareness of the importance of good waste management. Waste in developing countries, especially in Indonesia, is collected at a disposal site called a Final Processing Site (TPA). TPA is a place for collecting, moving or transporting, processing, and disposing of waste [3].

Lombok Island has a landfill located in Suka Makmur Village, Gerung District, West Lombok Regency, West Nusa Tenggara Province, Kebon Kongok Landfill is one example of a landfill that applies a sanitary landfill system. One of the problems that often occurs in landfill areas that use a sanitary landfill system is seepage from leachate. Leachate is a highly concentrated liquid that forms when rainwater and other liquids percolate through solid waste in landfills and contains large amounts of organic matter, ammonia-nitrogen, toxic chemicals, and organic and inorganic chlorinated salts, which can pose serious environmental risks if not managed properly [4].

Leachate can seep through the soil and cause pollution of the soil and groundwater at the landfill site. This seepage depends on the physical properties of the landfill subgrade such as permeability, porosity and piezometric pressure. Leachate seepage through the soil occurs slowly and if there is a watercourse under the landfill site, the leachate will contaminate the stream with substances that are quite harmful to the environment [5]. One parameter that can be used to determine the distribution of leachate contamination in the subsurface is the electrical conductivity parameter [6]. This parameter is one of the indicators used to determine the type of pollution that occurs according to the resistivity value obtained [7]. The conductivity value is inversely proportional to the resistivity, so when the conductivity is low (high resistivity), the solute concentration also decreases [8].

Previous research on the distribution of leachate contamination has been conducted by [9] using the resistivity geoelectric method with a dipole-dipole configuration at TPA Kebon Kongok, Gerung District. The results obtained from the study were that leachate contamination was found to a depth of 13.9 meters with a resistivity value of 23.6 Ωm. However, the previous research only focused on the area around the leachate processing area, even though TPA Kebon Kongok now has a new landfill and leachate processing site. This study aims to determine the direction of leachate distribution in TPA Kebon Kongok, which is thought to originate from the first landfill and the second landfill.

One geophysical method that is good enough to map subsurface conditions to determine the distribution of leachate contamination is the resistivity geoelectric method with the Wenner configuration and the Self Potential (SP) method. The geoelectric method aims to study the variation of rock resistivity below the earth's surface, thus obtaining a 2-dimensional profile of the subsurface resistivity model and is used to describe variations in the multi-layered subsurface resistivity structure [10]. Meanwhile, the Self Potential method aims to study the direction of distribution of leachate contamination by looking at the potential difference value at the measurement point [11]. This research is expected to model the 2-dimensional distribution of leachate contamination with data processing using RES2DINV Software, because the advantages of the software can process data quickly and automatically produce a subsurface resistivity cross section model, and it is easy to understand the results of the cross section model [12].

Referring to the above, it is necessary to investigate the distribution of leachate seepage in the Kebon Kongok landfill area located in West Lombok Regency. The research was conducted using geophysical methods, namely geoelectricity, so as to obtain the condition of the subsurface structure of the research area in 2-D form and the distribution of anomalies.

Method

The reference study was conducted by studying previous research on leachate seepage that had occurred. This included the location of the study, geological structures, topography, and others. The stages carried out in this research are data acquisition, 2D modeling, and anomaly distribution modeling**.**

a. Resistivity Geoelectric Data Acquisition

The geoelectric method is one of the most widely used geophysical methods for estimating subsurface conditions by passing an electric current into the earth through two current electrodes and then measuring the potential difference using two other electrodes [13]. In the case of two electric current sources, field measurements are used using two current electrodes (C_1 and C_2) and two potential electrodes (P_1 and P_2) [14]. One of the uses of geoelectric methods with two sources is to use the Wenner configuration. This configuration is often used in geoelectric exploration with an equally spaced arrangement. The distance between the current electrodes (C_1 and C_2) is three times the potential electrode distance, the potential distance to the sounding point is a/2, then the distance between each current electrode and the sounding point is 3a/2. The target depth that can be achieved in this method is a/2. The distance between the current electrode and the potential electrode in the Wenner Configuration is the same ($C_1 P_1 = C_2 P_2$ = na and the distance $C_1 P_2 = C_2 P_1$ = 2na) as shown in Figure 1[15].

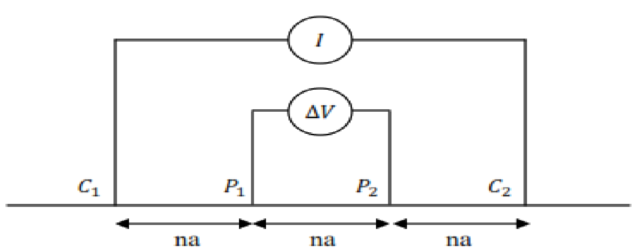

Figure 1. Current and potential electrodes in the Wenner configuration [16].

The data from the resistivity geoelectric research with the Wenner configuration was entered into Microsoft Excel, and then the average current (I) and potential difference (ΔV) values were sought. After that, the geometric factor (K) is calculated using equation 1 and the apparent resistivity value (ρ_a) using equation 2 [17].

$$K = 2\pi na \quad (1)$$

$$\rho_a = 2\pi na \frac{\Delta V}{I} \quad (2)$$

The data that has been processed is then inverted to display the image of the subsurface distribution of the study area using RES2DINV software [18].

b. Self-potential Geoelectric Data Acquisition

The self-potential (SP) method is a geophysical technique used to identify and map leachate distribution in landfill areas by measuring the natural electrical potential difference in the soil without injecting external current. It is one of the passive geophysical methods. It is often applied to fluid flow mapping beneath the Earth's surface. The types of configurations used in SP research include leap-frog and fixed-base [19].

The fixed base configuration uses a porouspot placed outside the measurement area (base) and another porouspot moving along a predetermined measurement point (rover). The potential difference read on the multimeter is the potential difference between the rover and base electrodes. The advantage of this method is that the error value is small because the measurement is carried out continuously, while the disadvantage is that it requires a very long cable, and the measurement time is longer because you have to keep pulling the cable and waiting for the voltage value to stabilize [20].

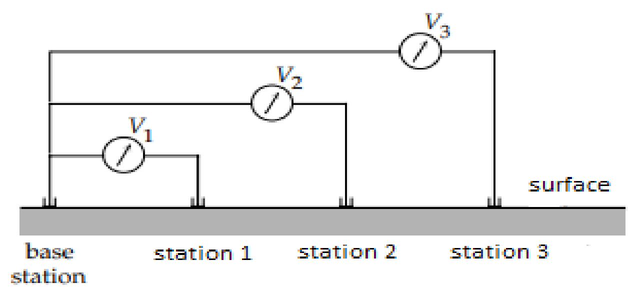

Figure 2. Fixed base configuration [14].

Research data using the SP method needs to be corrected daily first using Microsoft Excel software. This aims to get the actual anomaly value. Then, if the anomalous value has been obtained, a distribution map is made based on the anomaly value using Surfer software [21]. The data that has been processed is then interpreted by looking at the inversion results of the distribution of resistivity values described through dark blue to light blue color variations in 2D cross sections, which are indicated as layers that have been contaminated by leachate [22]. For the resistivity geoelectric data, qualitative analysis is carried out based on zones with high contrast resistivity values, either very high or very low, and also quantitative analysis based on the resistivity value shown by the processed cross section and the rock resistivity value [23]. The rock resistivity values can be seen in Table 1.

Table 1. Rock resistivity values [24]

Materials	Resistivity (Ωm)
Groundwater	0.5-300
Clay	1-100
Sand	1-1,000
Aluvium	10-800

To determine the direction of leachate distribution, the interpretation technique used was to observe the distribution of potential difference values on the isopotential contour map and then analyze the direction of leachate distribution. For the results of SP data processing, qualitative analysis was carried out based on zones with potential difference values that have low to high contrast and also quantitative analysis based on the potential difference values shown by the contour map.

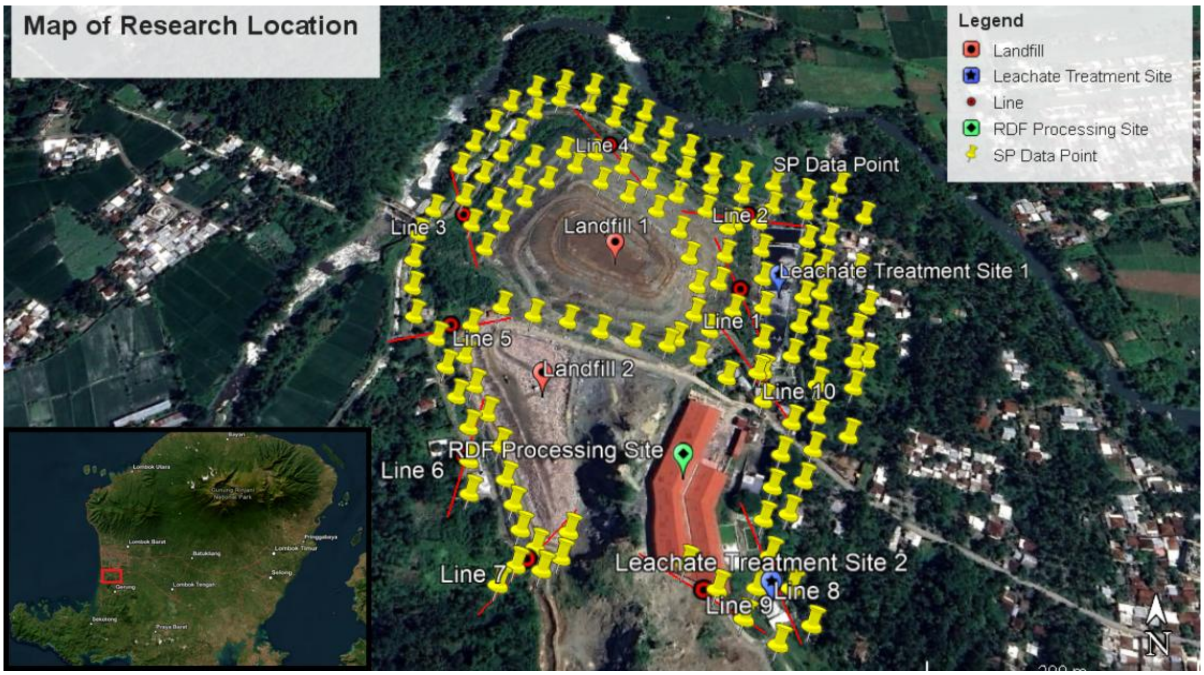

Figure 3. Map of the research location

The resistivity geoelectric method was carried out using 10 measurement lines around the landfill area because there were indications of leachate seepage that could pollute the surrounding environment. Each track has a different length, namely 115m, 92m, 69m, and 46m. The difference in the length of some of these lines is due to field conditions that do not allow for surveying with a predetermined line, which is 115m long. The selection of different track lengths follows the spacing of each electrode and the number of electrodes. The spacing used on each track is 5m, 4m, 3m, and 2m, and for the SP method, using 138 measurement points with a measurement area of 132,732 m^2. The research location map can be seen in Figure 3. The selection of lines is based on locations that have high leachate seepage potential, such as around the landfill area, around the leachate management area, and the border between the landfill and residential areas. The position of the lines has different directions, because it follows the conditions in the field. Measurements were taken from areas with high elevation values to areas with low elevation values. This was done to see how far leachate seepage occurred, because the nature of liquid objects (leachate) is to flow from high areas to lower areas [25]. The topographic map of the research location can be seen in Figure 4.

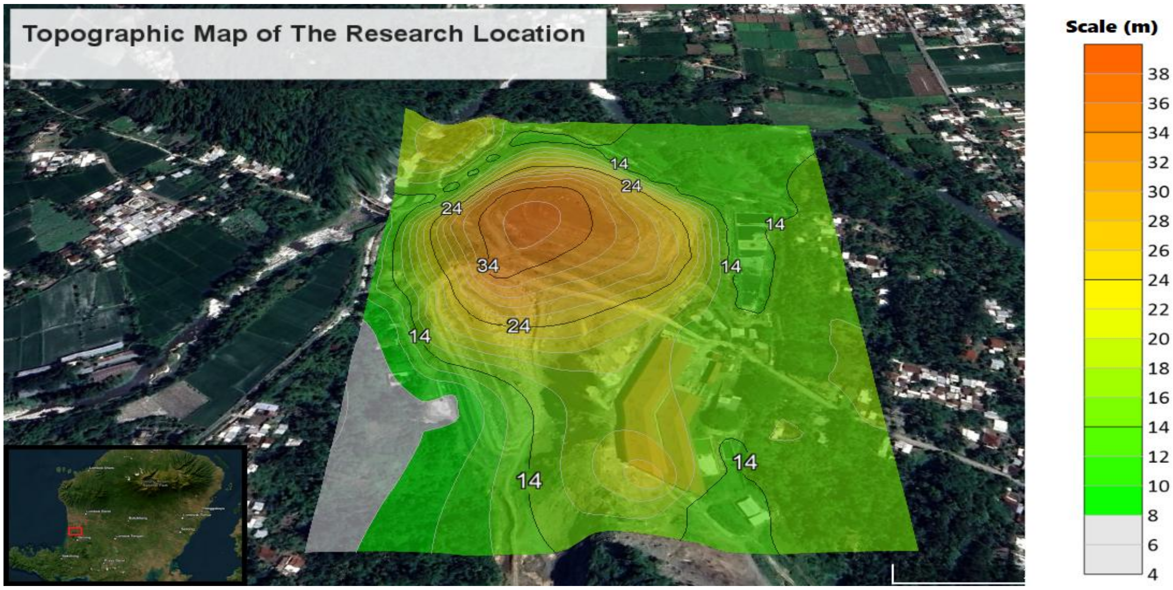

Figure 4. Topographic Map of the research location

Result and Discussion

The inversion results obtained from data processing through RES2DINV software are in the form of 2D cross sections, which are then further interpreted to determine the resistivity value of the layer indicated as leachate in the research area. The determination of the leachate resistivity value is based on previous research [9] and rock resistivity table [24] adjusting the geological conditions of rocks in the research area. Based on previous research [26], it is known that the subsurface rock lithology conditions of the research area consist of sand, silty sand, clay, and alluvium. The following is an analysis of subsurface cross-sectional images in the research area from the results of resistivity geoelectric data processing, which can be seen in Figures 5 and 6.

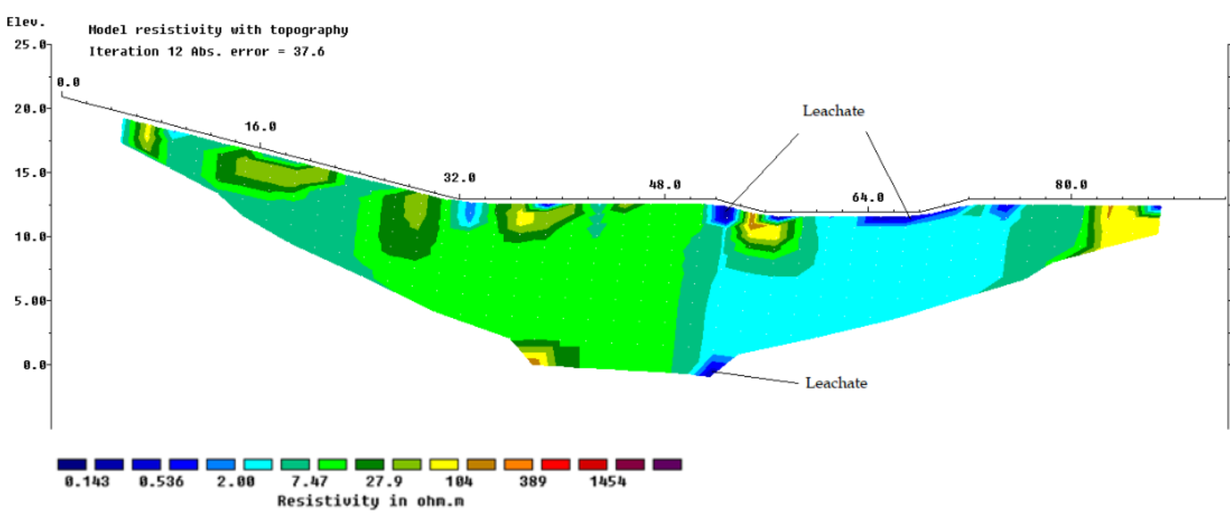

Figure 5. Subsurface Cross Section of Line 2

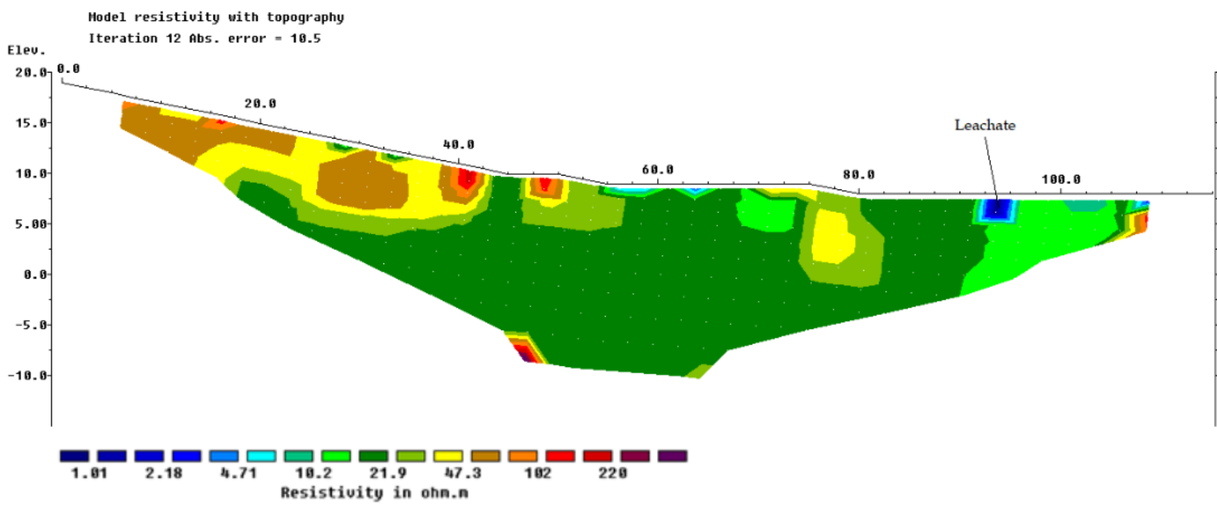

Figure 6. Subsurface Cross Section of Line 6

Areas that have a high potential for leachate seepage are located on lines 2 and 6. This is because the position of these lines passes through the landfill area. Line 2 is in an old landfill that no longer functions as a landfill, while Line 6 is in a new landfill that is still functioning today. The soil types found in both lines 2 and lines 6 are dominated by clay, silty sand, sand, and alluvium. The soil types found in track 2 and track 6 are dominated by clay, silty sand, sand, and alluvium. Based on the interpretation results carried out in the research area, it is found that clay has a resistivity value between 7.47-27.9 Ωm, silty sand has a resistivity value between 4.71-7.46 Ωm, sand has a resistivity value between 0.143-4.7 Ωm, and alluvium has a resistivity value between 28-220 Ωm. Based on Figures 5 and 6, marked in blue is leachate, because it has a low resistivity value between 0.143-4.71 Ωm. This is corroborated by the discovery of leachate seepage on the surface at the measurement point on both lines, which can be seen in Figure 7. The difference in resistivity values obtained with previous research could be influenced by the age of the landfill and the season, because the composition of leachate undergoes significant changes due to degraded waste, and is mixed with rainwater [27]. Leachate seepage found in line 2 during the rainy season can overflow and flood the surrounding area. Villagers complain about this because it causes itching on the parts of the body that are exposed to leachate. Leachate seepage in line 6 occurred after the new landfill was built, because previously the area was a storage pond, but after the landfill was built, the pond was polluted by leachate, so the management built a barrier wall so that the leachate would not spread to the villagers' plantations. This condition needs to be considered by the local government because if left without special handling, leachate pollution will become more widespread. The results of this study provide information to the local government and the community to find out the subsurface conditions at TPA Kebon Kongok and the distribution of leachate, so that pollution caused by leachate seepage can be minimized.

(a) (b)

Figure 7. Leachate seepage occurring at (a) lines 2; (b) lines 6

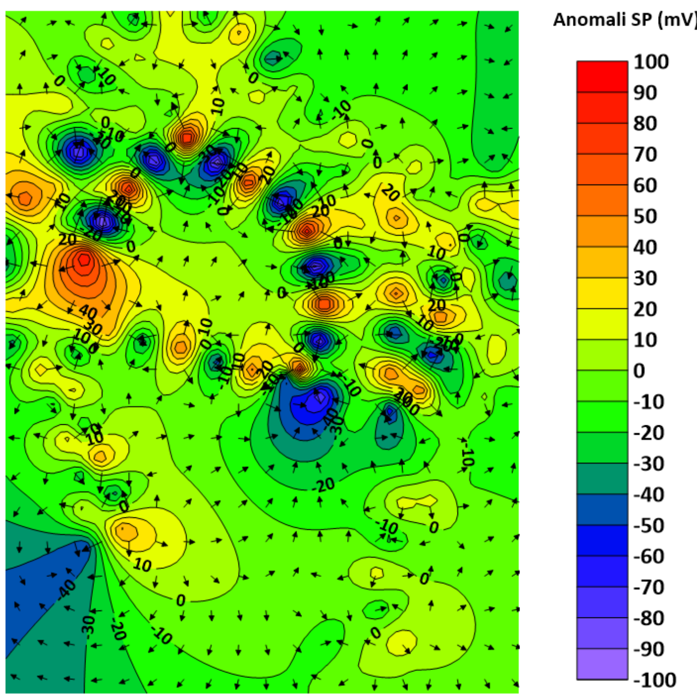

Figure 8. Contour Map of SP Data Processing Results

Measurement of the natural potential difference using the fixed base technique SP method, which can be seen in Figure 8, obtained potential difference values ranging from -100 mV to 100 mV. The blue potential value distribution pattern is a small anomaly value due to the accumulation of fluid flow or leachate, while the red potential value is a large anomaly value and is identified as alluvium. The leachate identified in the study area has a potential difference value of -100 mV to -40 mV. This is in accordance with the conditions in the field, which can be seen in Figure 8, where leachate seepage is in locations marked in blue.

Based on Figure 8, it is found that in the SP anomaly there are many small blue closures in the first landfill area. This is due to the presence of leachate puddles on the surface during SP measurements. This leachate puddle is found on the road that was previously used as access to the landfill by waste transportation vehicles which can be seen in Figure 9.

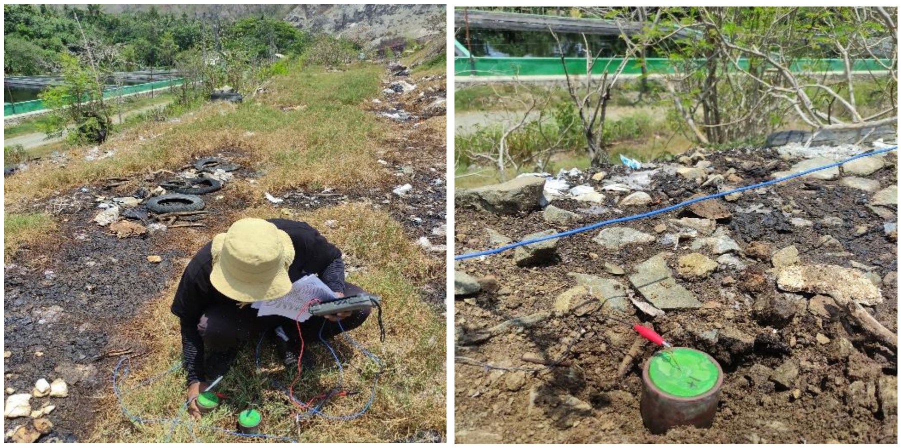

Figure 9. Leachate puddle conditions when taking SP measurements

The anomaly value identified as the leachate layer has a lower potential value than the unpolluted area and is found in areas that have low topography. This is due to the gravitational force, so that the fluid flow will flows from higher to lower places [28]. This pattern suggests that the leachate follows the natural slope of the subsurface layer, which may act as a leachate migration pathway [29]. Blue to purple anomalous distribution patterns with values of -40 mV to -100 mV indicate low potential values due to the accumulation of fluid flow or leachate in the subsurface. Meanwhile, anomaly distribution patterns that show green to red with values of -30 mV to 100 mV are anomaly values that have not been polluted by leachate. Based on the distribution of natural potential values, leachate accumulation is interpreted to have low potential values in the northwest to southeast of the study site, while relatively high potential values are in the southern part of the study site. This is because the northwest-to-southeast part is close to the waste pile from the first landfill.

Conclusion

Based on the results of data interpretation, it is found that the layer indicated as leachate has a resistivity value of 0.026-6.17 Ωm. The accumulated leachate flow is interpreted to have relatively lower self-potential values with anomalous values of -100 mV to -40 mV. Low potential values were found in the northwest to southeast of the study site, while relatively high potential values were found in the southern part of the study site. The direction of leachate distribution in various directions is due to the fact that the study area has different heights and the subsurface layer is composed of a layer that easily drains liquid, which is indicated as a sand layer. Further research needs to be conducted on soil sampling for laboratory tests in areas where leachate seepage is indicated.

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