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Identification of Pesticide-Saturated Soil Using Near-Surface Geophysics Method

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ABSTRACT. *Harmful substances deposited in the soil can disrupt soil functions, leading to environmental pollution and harm. Pesticides are one example of these harmful substances. Absorption of pesticides into the soil can lead to infertility and negatively impact overall soil health. Therefore, a study was conducted to identify pesticide-saturated soil near the surface and map the soil health conditions around Situ Cisanti. The research utilized geoelectric methods and collected soil and water samples from the inlet (a) and outlet (b) areas of Situ Cisanti. After conducting measurements around Situ Cisanti, the data collected include soil resistivity, ranging from 0.483 to 2.04 Ωm (a) and 658 to 2787 Ωm (b). Soil pH levels were 8.9 - 9.0 (a) and 8.9 (b). Soil Electrical Conductivity (EC) and Total Dissolved Solids (TDS) measured 250 - 280 µs and 194 - 207 ppm (a), and 240 µs and 178 ppm (b). Water pH was 7.7 (a) and 8.7 - 9.1 (b). Water EC and TDS were 100 µs and 83 ppm (a), and 80 - 180 µs and 65 - 94 ppm (b). The results indicated higher pesticide contamination in the outlet compared to the inlet, signifying potential risks to soil health.*

1. Introduction

Pesticide-saturated soil refers to soil that has become highly impregnated or saturated with pesticides. Pesticides are chemical substances used to protect crops and livestock from various pests, diseases, competition from weeds and parasites, thus contributing to increased agricultural production (Popp et al, 2013). When these chemicals are applied to agricultural fields, gardens, or other areas, they can interact with the soil. The saturation of soil with pesticides can occur when these chemicals are applied in excessive amounts or with high frequency, without proper consideration of recommended doses or timing. Overuse or improper application can lead to the accumulation of pesticides in the soil, which can have various environmental and agricultural consequences. The phenomenon of pesticide-saturated soil raises multifaceted concerns. Firstly, there is the potential for these chemicals to leach into groundwater, posing a threat to water quality and aquatic ecosystems. Contaminated water sources can have cascading effects on biodiversity, impacting both flora and fauna. Moreover, the persistence of pesticides in the soil can disrupt the delicate balance of microbial communities, affecting nutrient cycling, and soil fertility.

Situ Cisanti is located at the base of Mount Wayang, an active volcano in the Bandung region at arboretum point 73. Mount Wayang, with an elevation of 2,181 meters above sea level (masl), is a twin volcano with Mount Windu and falls into the category of type B volcanoes or volcanoes with fumarole/solfatara activity, which has not experienced magma eruptions since 1600 (Bronto, Koswara & Lumbanbatu, 2006). Administratively, Situ Cisanti is recognized as one of the lakes located in Tarumajaya Village, Kertasari Subdistrict, Bandung Regency, West Java. It is an artificial lake that collects water from seven main springs of the Citarum River. These springs are Pangsiraman, Cikolebere, Cikawadukan, Cikahuripan, Cisadana, Cihaniwung, and Cisanti (Silitonga, 1973). Situ Cisanti, located in the protected forest of Mount Wayang, serves as a watershed area for sustaining the flow of the seven springs that are dammed into the lake. As a reservoir for these springs, Situ Cisanti plays an indispensable role in preserving both the quality and quantity of water resources.

Soil is the layers of generally loose mineral and/or organic material that are affected by physical, chemical, and/or biological processes at or near the planetary surface and usually hold liquids, gases, and biota and support plants (Van Es, 2017). Soil plays a vital role in sustaining life on this planet. Soil is a critical component of nearly every ecosystem and can be thought of as the ecosystem foundation, as soil productivity determines what an ecosystem will look like in terms of the plant and animal life it can support. For example, in cultivated fields, soil quality plays a significant role in crop productivity since soil nutrients and soil physical properties can directly impact yields (Schoonover et al, 2015). However, over time, harmful substances that accumulate in the soil can reduce the effectiveness of soil functions and cause pollution, potentially harming the ecosystem. These substances can take the form of waste, fertilizers, or pesticides. `Farmers in the village of Tarumajaya mostly still use additives such as fertilizers and pesticides, and excessive use of these additives can adversely affect soil structure. This condition poses a threat to soil fertility, impedes the absorption of certain nutrients, and impacts soil microorganisms. Under severe circumstances, the excessive application of pesticides indicates the potential for land degradation (Joko et al, 2017).

One commonly used method in soil pollution studies is the geoelectric method, as described by Ngadimin & Handayani (2001). This method involves the measurement of potential, current, and electromagnetic fields that occur naturally or as a result of current injection. The principle of the geoelectric method involves injecting an electric current into the soil surface through a pair of electrodes and measuring the potential difference with another pair of electrodes. When an electric current is injected into a medium and its potential difference (voltage) is measured, the resistance value of that medium can be estimated. The geoelectric method is widely used and provides satisfactory results in obtaining an understanding into the layers of soil beneath the surface. The interpretation of geoelectric data is based on the principle that different materials will have different resistivities when subjected to electrical current. One commonly used geoelectric method for measuring electrical flow and studying subsurface conditions is the resistivity method (Soininen, 1985).

The purpose of this research is to identify pesticide-saturated soil around Situ Cisanti using near-surface geophysics methods, specifically the geoelectric method, supported by soil and water sampling data collection in the inlet and outlet areas of Situ Cisanti. The goal is to map the soil health conditions of Situ Cisanti to determine whether the soil is affected by environmental pollutants or not.

2. Research Methodology

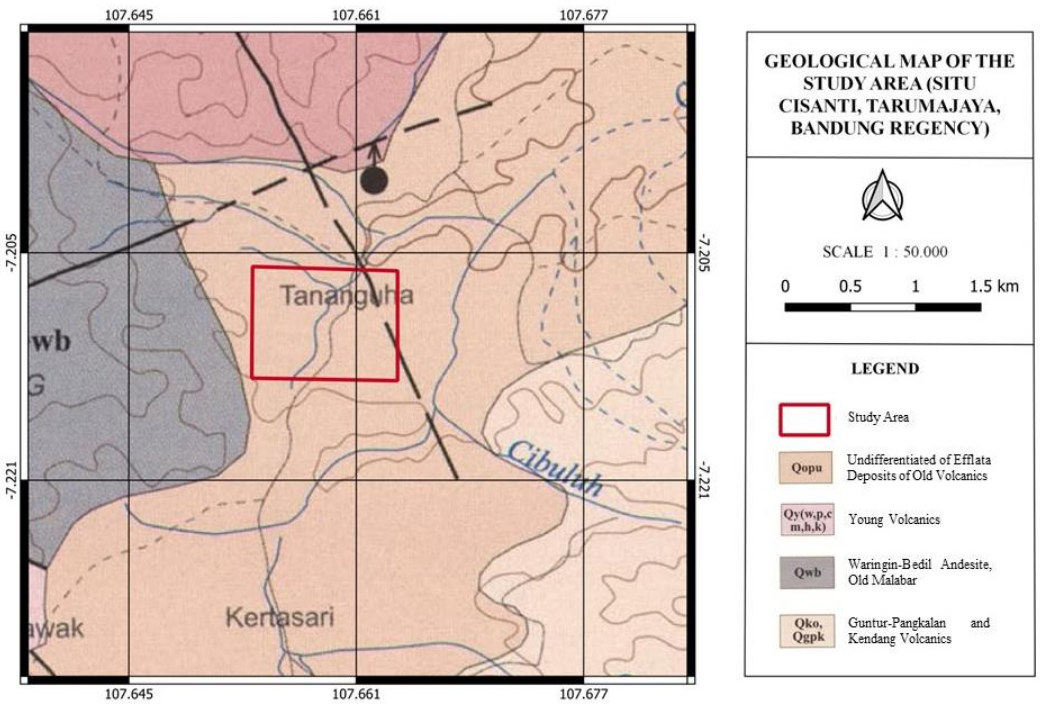

Figure 1. Geological Map of Situ Cisanti (modified from Alzwar et al., 1992)

The measurements were conducted at Situ Cisanti, located in Pangalengan, Tarumajaya Village, Kertasari Subdistrict, Bandung Regency. Situ Cisanti is a lake that serves as the headwaters of the Citarum River, the longest river in West Java, with a length of approximately 300 km. This area is characterized by the Undifferentiated Efflata Deposits of Old Volcanics (Qopu), consisting of fine to coarse dacitic crystalline tuff, tuffaceous breccia containing pumices, and old andesitic-basaltic laharic deposits. The springs in this area are formed due to the contact between impermeable rocks of the Waringin-Bedil Andesite, Old Malabar (Qwb) formation, and the Undifferentiated Efflata Deposits of Old Volcanics (Qopu). Soil and water samples were collected and surface soil measurements were taken using the geoelectric method, specifically the resistivity method.

The measurements were conducted around the designated inlet and outlet areas of the spring to determine the subsurface resistivity differences. This process was undertaken with the specific purpose of acquiring a comprehensive model representation of the subsurface conditions prevailing in the designated region. Resistivity measurements were performed using the dipole-dipole configuration, employing the RMSS-D (Resistivity Meter Small Scale-Digital) Marcapada instrument. Each measurement line was 25 meters long with a 0.5-meter electrode spacing. Additionally, physical and chemical parameter measurements for water and surface soil samples were conducted using the Hanna Combometer. The obtained results, including EC, TDS, pH, and temperature values, served as supporting data for the resistivity model values obtained through the geoelectric method. The research methodology is illustrated in the following flowchart:

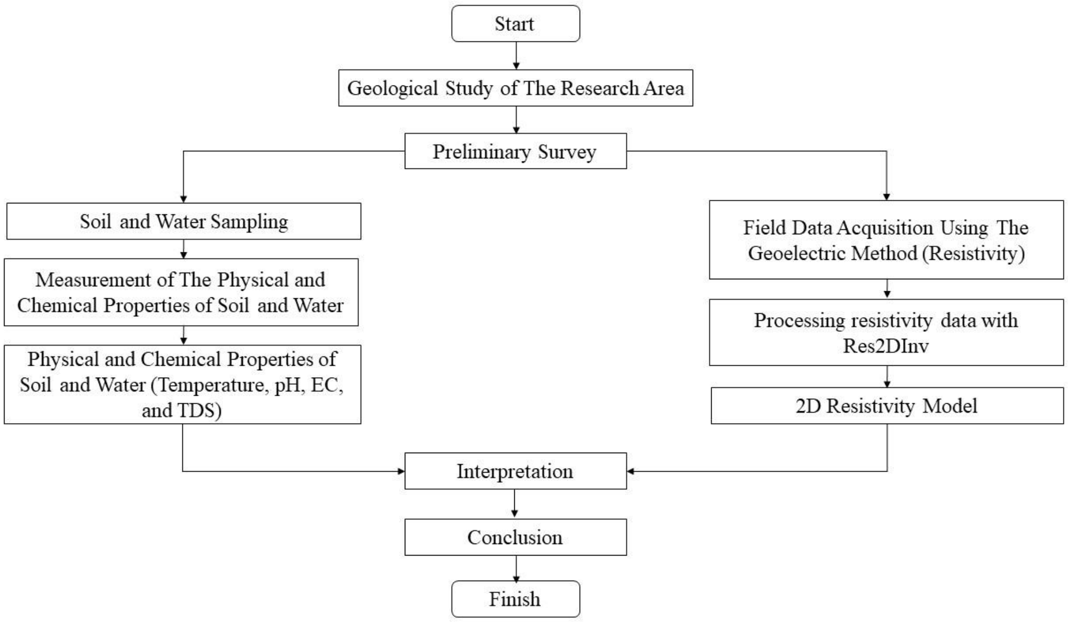

Figure 2. Flowchart of Research Methodology

3. Results and Discussion

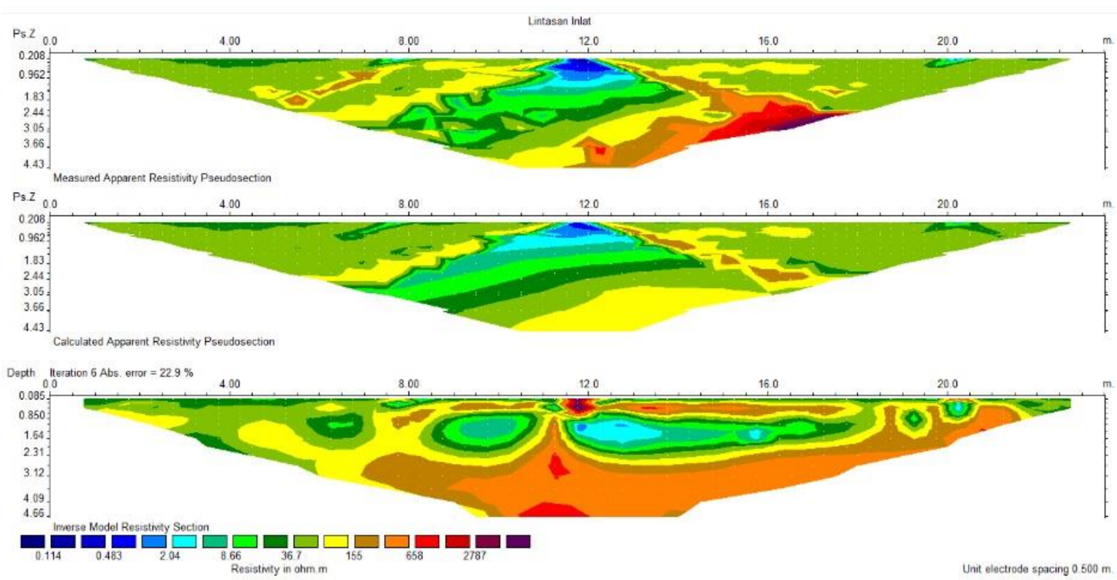

Figure 3. 2D Resistivity Model of The Inlet Area

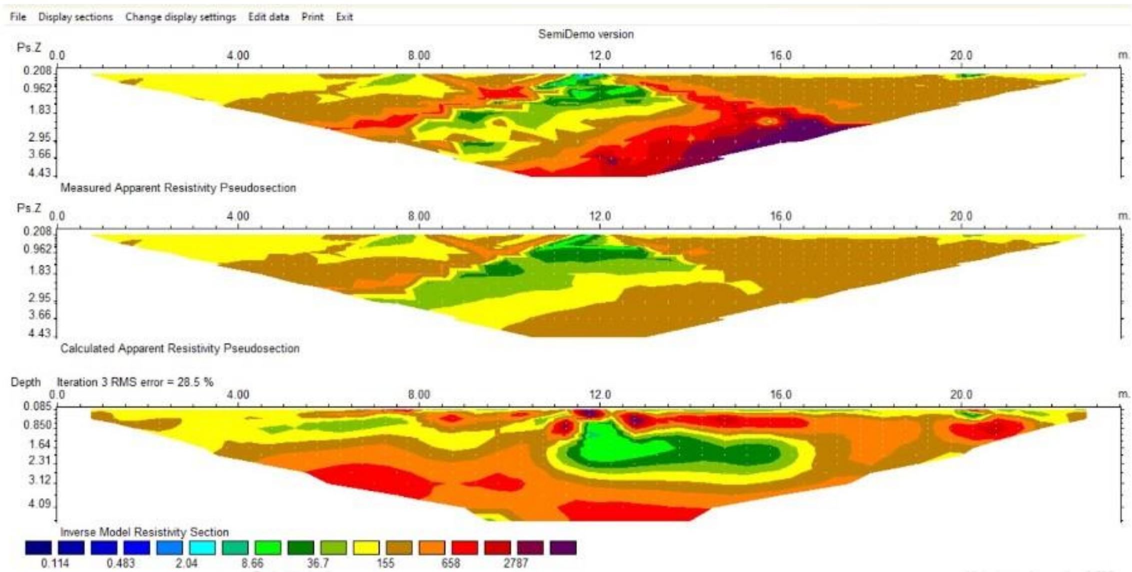

Figure 4. 2D Resistivity Model of The Outlet Area

Based on the field data acquisition results, data processing was carried out using the RES2DINV software, yielding resistivity models for the inlet and outlet as depicted in Figures 3 and 4 above. The first 2D resistivity model (Fig. 3) representing the inlet area with a track distance of 25 m and a depth penetration of 4.66 m, reveals geoelectric measurement results with resistivity values that tend to be low, approximately ranging from 0.483 to 2.04 Ωm, indicated by the color blue. These low resistivity values indicate a higher water content in the inlet area, rendering it more conductive. This observation also confirms the presence of an aquifer layer at a depth of 0.850 to 1.64 m.

The resistivity values in the inlet area exhibit a distribution of lower resistivity compared to the outlet area. This is apparent in the predominant color scale, where the inlet area is primarily characterized by shades of green to yellow, with a resistivity range spanning from 8.66 to 166 Ωm. In contrast, the outlet region is dominated by brown to red hues. This distinction indicates a lower level of soil contamination and the absence of pesticides in the inlet area. With these indications, the surroundings of the inlet are considered clean, particularly due to the proximity to seven springs, including Cikahuripan and Citarum, with the latter being the "Sirah Cai" or the first water source.

In the second 2D resistivity model (Fig. 4), representing the outlet area with a track distance of 25 m and a depth penetration of 4.09 m, there is a notable difference compared to the inlet area. The outlet area exhibits a widespread of high resistivity values, indicated by orange to red colors, with resistivity ranging from 658 to 2787 Ωm. Consequently, it can be indicated that the layers in the outlet area are resistive. The overall resistivity values in the outlet area are higher compared to those in the inlet area, suggesting an indication that the zone in the outlet area has experienced soil contamination, although at a level considered relatively mild.

Figure 5. The Comparative Results of the Physical and Chemical Parameter Tests (temperature, pH, EC, and TDS) on the Soil and Water of Situ Cisanti

The data obtained from resistivity models indicate that the outlet area is more resistive compared to the inlet area, indicating soil contamination in the outlet area due to the presence of pesticide content. This assumption is supported by measurements of soil and water samples, as illustrated in Figure 5 using a combometer. The combometer is a tool used to measure pH, EC, and TDS. The EC value is utilized to assess the nutrient solution quality in the soil. From the measurement results, it can be observed that the EC in the inlet area is greater than in the outlet area. Thus, the inlet area is considered conductive due to its higher EC value, leading to lower resistivity, as conductive properties facilitate the flow of electric current (Rahma & Zulfian, 2020). This affirms that the results from the sampling measurements align with the previously obtained resistivity data.

4. Conclusion

Based on the results, the inlet zone exhibits a range of resistivity values from 0.483 to 2.04 Ωm. These values indicate a higher water content in the inlet area, suggesting the presence of an aquifer layer at a depth of 0.850 to 1.64 m. The resistivity values in the inlet are lower compared to the resistivity values in the outlet zone, which range from 658 to 2787 Ωm. Consequently, the inlet zone is considered cleaner than the outlet zone, which is categorized as experiencing mild contamination. The outlet zone shows soil contamination due to the presence of pesticide content. This is supported by the measurements of soil and water samples at Situ Cisanti using a combometer. The measurement results indicate a higher EC value in the inlet than in the outlet, indicating that the inlet zone is more conductive than the outlet zone. Therefore, the assumption is that the outlet zone is more contaminated than the inlet zone.

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Involvement of the Author

EA and AS provide the main ideas for the research. BAP and FTD conduct data acquisition. EE and NR process the acquired data. ASNP and CAP perform data analysis.

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