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# Application of Eletrical Resistivity in the Assessment of Mining Waste Contamination in Brumadinho-MG

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## Abstract

The tragedy involving the dam failure, as well as the soil and river contamination in the city of Brumadinho, in the state of Minas Gerais (MG), highlights the importance of the safety of these structures and how geophysical techniques and methods can play a crucial role from project planning to the monitoring of tailings dams. Geophysical methods are used in research to characterize and study the geology of the area where the dam will be implemented, providing valuable information for assessing the feasibility of construction. This study focuses on the application of geophysics, specifically using the electrical resistivity method with the electrical profiling technique, applied in a mining waste disposal area. This geophysical method is easy to acquire and can provide highly relevant information about soil contamination levels through electrical resistivity maps of the studied area. The results obtained from this study are expected to contribute to a better interpretation of the contamination level of tailings in the Brumadinho region, providing necessary information for environmental monitoring and safety management of such structures.

## Introduction

The extraction of minerals has been essential to human development since prehistoric times and has only grown in importance over the centuries. In Brazil, mining plays a fundamental role in the economy, boosting the export of mineral resources and supplying key sectors such as steel, construction, and technology. The growth of this sector has significantly contributed to the development of several mining regions, promoting economic and structural advancements. However, mining activities also generate significant environmental and social impacts, making the pursuit of sustainable development essential. Increased demand for minerals and the need for higher productivity pose challenges such as tailings management and dam safety. The implementation of rigorous planning and the adoption of more effective environmental regulations are fundamental to avoiding environmental disasters like the dam failures recorded in Brazil in recent years. Furthermore, the application of new technologies and sustainable practices can reduce operational risks and minimize the socio-environmental impacts of mining.

Given the severity and impact of dam failures in environmental, economic, and social contexts, ensuring the safety of these structures has become increasingly essential. Continuous monitoring is indispensable. Geophysics has been widely used in dam monitoring in various countries, and with technological advancement, it has significantly contributed to the analysis and interpretation of data obtained through different methods. Among these techniques, electrical resistivity stands out for its ability to detect subsurface saturation, enabling detailed analysis of field resistivity profiles, which helps prevent structural failures. Tailings dams are structures designed to contain and store liquids or mixtures of liquids and solids resulting from mineral processing (DNPM, 2017).When proper inspection or effective safety measures are lacking, these structures can fail, resulting in catastrophic breakages. The collapse of these dams causes drastic changes in land cover (Aires et al., 2018) and results in severe impacts, such as hydrological disturbances, environmental contamination, human losses, and harm to the health and well-being of affected populations (Foley et al., 2005; Dias et al., 2018; Carvalho et al., 2017; Queiroz et al., 2018; Magris et al., 2019; Neves et al., 2018).

On January 25, 2019, just over three years after the tailings dam failure in Mariana, Minas Gerais, a new disaster occurred in Brumadinho, MG. The collapse of the Córrego do Feijão dam resulted in severe environmental impacts, affecting not only the soil but also water resources and local biodiversity. Additionally, the disaster had devastating social and economic consequences, destroying communities, compromising the supply of drinking water, and harming economic activities dependent on the region's natural resources.

Both dams used the upstream raising method (G1, 2019), a technique considered more structurally vulnerable due to its construction over previously deposited tailings. The waste from Dam I, associated with the Córrego do Feijão mine, overflowed into two other dams and spread over a large area of Brumadinho municipality until it reached the Paraopeba River (Figure 1).


**Figure 1 –** Schematic location of the Córrego do Feijão mine and areas affected by the collapse (Source: Adapted by the author from the G1 news portal, 2019).

These events highlight the urgency of improving environmental control and inspection mechanisms, as well as investing in alternative solutions for tailings management in mining. Technologies such as real-time monitoring systems and the replacement of conventional dams with safer methods, such as dry stacking, are essential measures to prevent new tragedies and ensure safer and more sustainable mining. Iron mining tailings in the Quadrilátero Ferrífero region pose a high potential for contamination of physical and biotic environments in the short and long term due to the presence of fine ore and heavy metals (Carvalho et al., 2017; Queiroz et al., 2018).

Given the need to assess contamination levels, this study applies the Electrical Resistivity Method (TELFORD; GELDART; SHERIFF, 1990) in a mining waste environment, aiming to identify the presence of contaminants, their location, and possible migration beyond the dam.

**Method and Theory**

Electrical Resistivity (ER) is a geophysical method based on determining the apparent electrical resistivity of materials, which—along with the dielectric constant and magnetic permeability fundamentally expresses the electromagnetic properties of soils and rocks. The resistivity of the investigated medium is calculated using Equation (1) (BRAGA, 2016):

Given the need to assess contamination Where:

$$\rho_a = k\frac{\Delta V}{I}, \quad (1)$$

onde:

$$k = 2\pi\left(\frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} + \frac{1}{BN}\right)^{-1}, \quad (2)$$

- $\rho_a$ = Apparent resistivity
- K = Geometric factor of the general quadrupole arrangement AMNB
- $\Delta V$ = Electrical potential
- I = Current intensity
- AMNB = Distances between electrodes

The electrical profiling technique was used to acquire data in this research, using the Dipole-Dipole and Schlumberger arrays along the surveyed lines.

## Results

The data acquisition model was based on lines oriented north–south and east–west, laid out in the field during the campaign. **Figure 2** shows the 2D resistivity section with topographic correction. From the processed results, an anomaly was detected on the right side (in red, around 280 m in the pseudo-section). Light blue to dark blue colors may indicate the accumulation of conductive material, especially in areas with resistivity between 80 and 160 ohm·m at shallow depths. The continuity and homogeneity of conductivity may suggest lateral movement of contaminants with water flow. Therefore, through interpretation and more in-depth studies of this data, it is possible to prioritize actions to be taken, aiding in the development of recovery strategies for the degraded area and contributing to preventive measures to reduce environmental impacts.the results are written. In case you have a figure, chart, graphic, equation, please make sure to insert a legend.

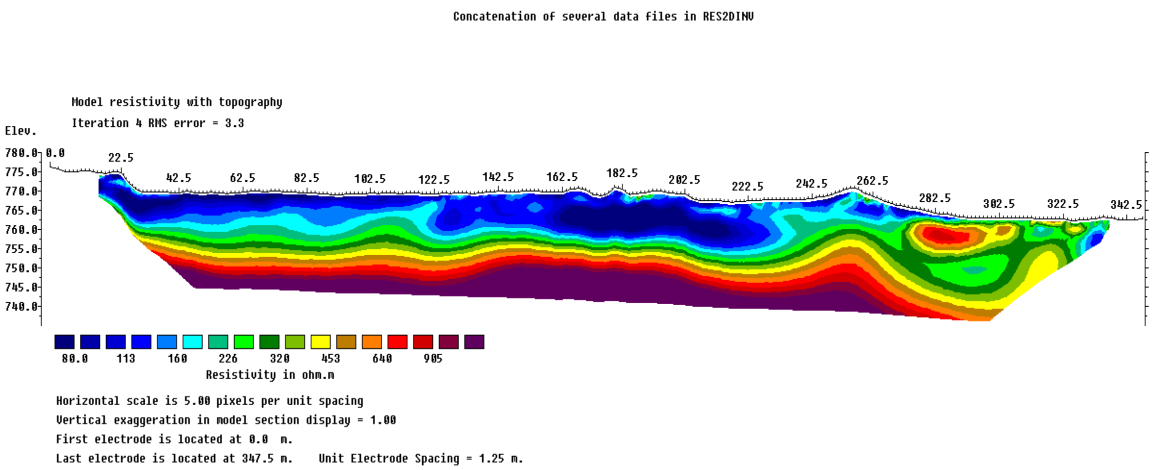


**Figure 2**: Result of the inversion of electrical resistivity data performed with the RES2DINV software in 2D, considering topography indicated by the irregular line at the top of the section, representing terrain elevation variations (vertical axis on the left ranges from 740 to 780 meters). Horizontal interval X from 0.0 m to 347.5 m and electrode spacing of 1.25 m.

**Conclusions**

The resistivity profiles created for the tailings contamination area survey showed good results using real data. The array configurations used in the profiles are the same as those used in the field survey. The modeling software chosen for this study was **RES2DINV**, which proved to be a good tool for processing and interpreting electrical resistivity data. The analysis of this data will help delineate the most affected areas, and these results can contribute to planning actions, impact reduction, and environmental recovery, as well as support future dam monitoring studies.

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