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LABORATORY STUDY OF CONTAMINATION CAUSED BY OIL RESIDUES IN BEACH ENVIRONMENT BY ELECTRICAL GEOPHYSICAL METHODS

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Abstract Summary

The study involves conducting laboratory simulations to assess whether residues from the oil spills can be detected using the geophysical method of electrical resistivity. For this purpose, an aquarium was set up to simulate a beach environment by filling it with sand and seawater collected from the São Paulo coast. We analyzed the 2D resistivity section and quasi-3D model and concluded that the electrical resistivity method is effective in characterizing the presence of oil in coastal environments and it is recommended to assist in the remediation of future disasters.

Introduction

Since 1975, oil spills from tankers have been decreasing, nevertheless every year we had at least 3 medium to large spills worldwide (ITOPF, 2024). Those events are harmful for both society and environment, affecting the ecosystem, tourism, local communities and economy in general. One example occurred in Pernambuco, Brazil in 2019, the largest coastal contamination disaster in 30 years in the state which spilled 200 tons of oil and reached 2.880 km of extension (IBAMA, 2019; Bomtempo Filho, 2022). Thus, we should prepare ourselves for future cases, working on prevention and ways to minimize its impact.

To remedy future cases as supracited, the geophysics methods have great usability by providing information about the location of residues under the sand. In cases where a high resistivity body or fluid is surrounded by a low resistivity medium, resistivity method has the ability to map resistivity contrast between them. Therefore, knowing that oil is resistive and sand with sea water is conductive, we simulated the situation in an aquarium where an oil plate was buried. The goal was to characterize the response of the geoelectric method to optimize the work of authorities during the cleanup of future disasters, reducing the time oil remains exposed to tidal reworking, which gradually directs the residues back to the sea (Bomtempo Filho et al., 2022).

Method and/or Theory

Electrical methods map the physical properties of the subsurface based on its response to an electrical current. The electrical resistivity method (Orellana, 1972), used in this study, involves analyzing the resistivity contrast within the subsurface to detect solid objects or contaminated water bodies.

The technique employed was electrical profiling with a dipole-dipole array. The experiment involved placing 13 electrodes, connecting the wires to the first 8 electrodes, and then moving the connectors one by one until the end of the array (65 cm total, with 5 cm spacing between electrodes). Figure 1 shows the photo of the experiment. The array determines how the electrodes are organized, where the two current electrodes form a dipole, as do each electrode and its adjacent ones in the array.

The equipment used was the ELREC PRO for resistivity measurements and the SYSCAL R2 for current injection.

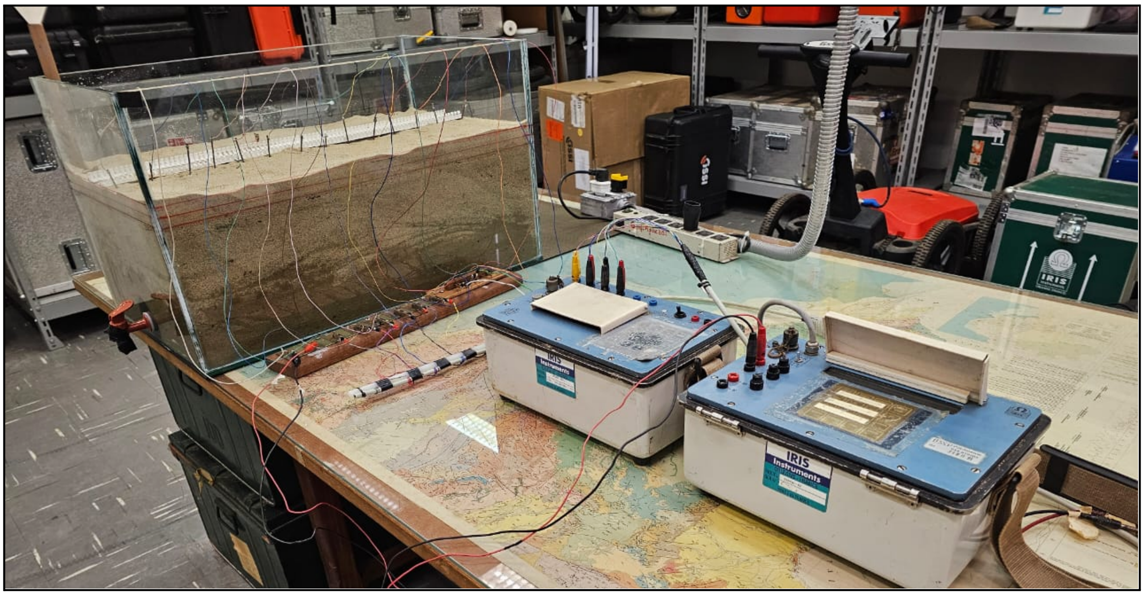

Figure 1: Photo of the experiment, the oil plate was approximately at the middle red line on the tank.

Results

Three acquisitions were conducted for the experiment, with the same procedure followed for all: seawater was added to the terrarium through a pipe until the sand at the depth of the oil plate became saturated. The electrodes were then positioned, connected to the equipment, and the settings were adjusted accordingly. The oil plate is composed of the material collected in the disaster that occurred in Pernambuco in 2019.

Three software programs were used for data processing: Prosys III (to convert the data format from .bin to .dat), RES2DINV (for 2D modeling), and ResIPy (for quasi-3D modeling).

In first acquisition the data were collected in the central profile. The response from the oil layer showed excellent contrast with the surrounding medium in all acquisitions (Figure 2). In the first acquisition, the nonlinear scale caused small resistivity contrasts to appear as other structures. However, these were not interpreted as distinct features, considering the scale of values relative to the oil layer's response. As a result, these anomalies were attributed to heterogeneities in the medium. The oil plate was identified as an anomaly with resistivity values above 33 ohm.m. The surrounding environment presented very low resistivities (<5 ohm.m).

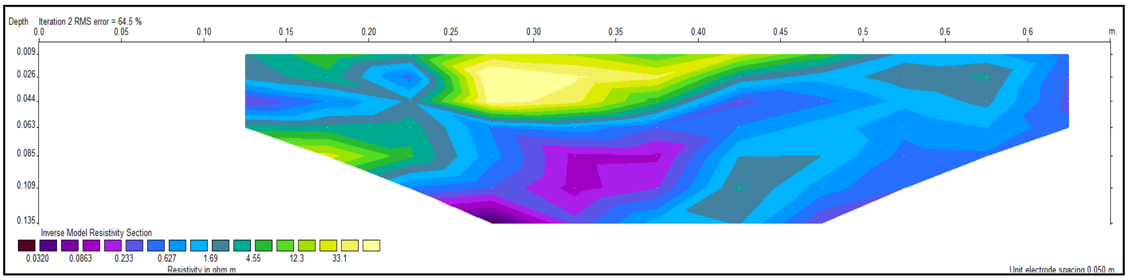

Figure 2: Illustration of the post-processing data. The plate, in yellow, has a value of ~33 Ω·m, and the vertical scale ranges from 0.9 cm to 13.5 cm.

For the second acquisition the data were collected in five parallel profiles. The results were satisfactory but showed an second anomaly with values close to those of the plate's resistivity (Figure 3). This phenomenon was attributed to a possible error during measurement due to a cable break that was only noticed near the end of the acquisition.

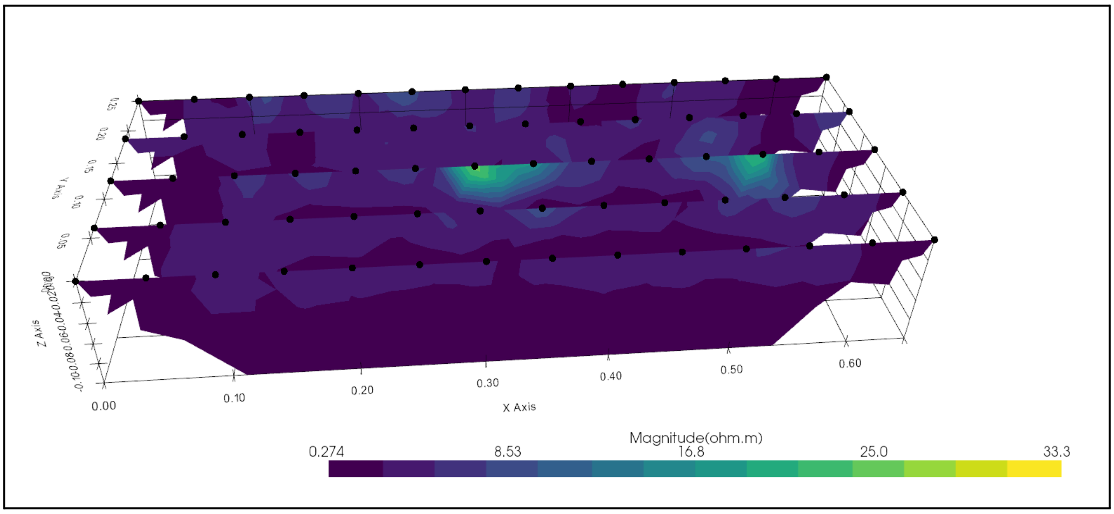

Figure 3: Image of the acquisition in pseudo-3D format. The x-axis ranges from 0 to 65 cm; the y from 0 to 25 cm; and the z, from 0 at the top to -10 cm.

As it was considered that this acquisition was not very reliable, a new acquisition was made. For this third acquisition, the plate was replaced with a new one made of the same material. Its dimensions were increased to minimize noise, and it was buried approximately 2 centimeters deeper. The goal was to minimize signal noise ratio and test if the method reacts to depth difference. The data were collected in tree parallel profiles. The results are showed in Figure 4. The anomaly from the oil plate can be easily observed in central profile, characterized by resistivity values above 28.3 ohm.m.

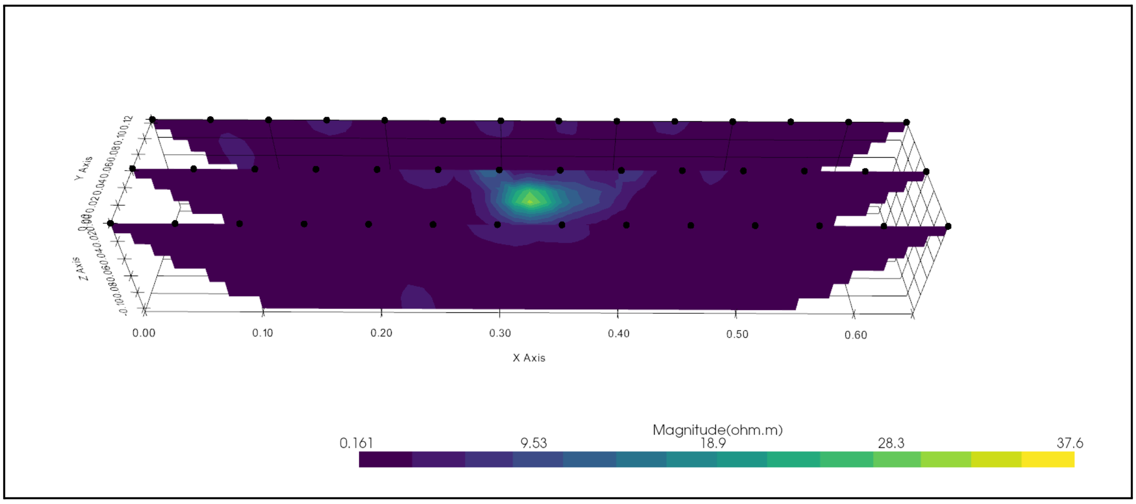

Figure 4: Image of the acquisition in pseudo-3D format. The x and z axes remained unchanged, while the y-axis ranges from 0 cm to 12.5 cm.

Conclusions

The reduced model constructed to perform geoelectrical tests showed that the resistivity anomaly signature generated by the oil plate in the beach sand was very distinct due to the resistivity difference of several orders of magnitude between the oil and the saturated sand. The results suggest that the Electrical Resistivity Method can be effective in characterizing the presence of oil in coastal environments and is recommended to assist in the remediation of future disasters like the one in Pernambuco.

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