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Past metallurgical sites and deposits characterization using complex conductivity measurements

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nterreg **North-West Europe NWE-REGENERATIS**

Context

This study is part of a North West Europe (NWE) Interreg project called NWE-REGENERATIS (NWE-REGENERATION of Past Metallurgical Sites and Deposits through innovative circularity for raw materials) that aims at the regeneration of past metallurgic sites and deposits through innovative circularity for raw materials. Metal foundry sites account for a significant proportion of potentially contaminated sites in the European Union. While recent wastes from sites still in operation are commonly recovered, this is not the case for old aggregated materials with a high content of ferrous (and other) metals, white and black slag, etc., which are considered to be sources of pollution and are costly to manage or dispose of.

The NWE-REGENERATIS project transforms this situation into an opportunity: large volumes of resources (metals, materials and land) from former metallurgical sites and dumps can be recovered by urban mining techniques.



NWE-REGENERATIS combines innovative geophysical characterization of sites with efficient material recovery processes, a harmonized inventory structure and the use of artificial intelligence algorithms (development of an open source 4D Smart Tool called SMARTIX), for resource recovery from metallurgical sites. Its final goal is to design and implement a new model, which enables the reintegration of raw materials and land in the regional economy.

Pompey's site

Pompey (France) has been chosen as one of the three pilot test sites for the NWE-REGENERATIS methodology. It is a former tailing pond, part of the past metallurgic site of Pompey-Frouard-Custine. It hosted various activities for iron-based alloys production, including special manganese steel. The last blast furnace of the iron and steel complex was stopped in 1986. Over time, a forest ecosystem, including diversified deciduous vegetation, more or less dense depending on the area, developed on the former tailing pond. The geological substratum consists of the Lias marl formations, which are covered by alluvium from the two rivers, composed of coarse siliceous materials (sands, gravel and pebbles) at the base, and finer materials (sands, silts and clays) on first 1 to 3 m depth. These alluvial formations were locally exploited and backfilled with metallurgical site deposits (e.g. waste rock, iron and steel by-products).

Several qualitative observations can be made on the TDIP results:

- 3 pseudo-horizontal layers are observed on the entire surface of the pond, in terms of electrical resistant (R4) at the surface (between 2 and 3 m thick); (2) one conductive in the center (C3), with a thickness ranging from 4 (northern part) to 10 m southern part); (3) one with a medium resistivity at the base (R3) (between 8 and 9 m deep), that can be interpreted as the natural terrain (quaternary alluvium). Other more localized layers can also be identified (i.e. R1 or R2).
- For the conductive layer C3, a distinction can be made between the SSE and NNW parts of the ERT profiles. These variations could correspond to the presence of 2 different settling pounds (not mentioned in the historical documents) with two different variations in the composition of the deposited material (observed on historical aerial photos).
- Chargeability anomalies, especially localized in the first resistant layer (e.g. layer R1), are potentially linked to all-comers household and construction wastes, including large metallic pieces.
- The chargeability of the intermediate layer could be mitigated by the high conductivity of this layer. The metal factor might be a better parameter to reveal pronounced anomalies in the conductive intermediate layer interpreted as the main tailing material layer.





New developments to extract frequency data from TDIP measurements

6 TDIP profiles were measured in Pompey. On one of the profile, IP data were acquired in several ways: \circ in 50 % duty cycle with an acquisition time of 2 s;

 \circ in full cycle with an acquisition time of : 500 ms 250 ms 2 s 1 s

This measurement with different time windows (different frequencies) gives us access to SIP processing and interpretation, not only at the fundamental frequency, but also at the first four odd harmonics.

These new frequency interpretations of the TDIP data allows us to better understand the polarization processes occurring at the field scale. Indeed they can be compared to lab measurements run on samples from the site as well as petrophysical relationships developed in the lab. The upscaling of these relationships is thus facilitated.





Towards quantitative interpretation

In order to interpret the TDIP results in terms of concentration of metallic particles, known petrophysical relationships and geochemical measurements obtained at the lab scale need to be interpreted at the field scale.

Indeed, the geophysical properties estimated by the field-scale study are impacted by factors such as complex averaging of heterogeneity at the survey scale, and also artifacts introduced through data inversion.

With the data from Pompey, we propose to use a Bayesian framework for inferring field-scale metallic particles concentrations. This work is ongoing.

- \rightarrow Generate a set of resistivity field analogs, resolved at y scale
- \rightarrow Use petrophysical relatioships to solve targeted parameter at y scale for the set of field





Conclusion and Prospects

The interest of using TDIP measurements to characterize metallurgical past deposits has been shown through an example at the Pompey pilot site.

The combination of resistivity and chargeability data shows potential to estimate the volume of metallic compounds that could be re-used within the tailing pond.

To reach a more quantitative interpretation in terms of concentrations of different metallic particles, several approaches are explored:

- The extraction of frequency data from TDIP measurements shows promising results to delineate areas with different frequency signatures
- The upscaling approach through numerical simulations is yet to be completed, but seems to present interesting outgrowth

To go even further, these geophysical characterizations will be part of the entry parameters in the artificial intelligence software SMARTIX that will provide a fully integrated response to resource recovery potential of the studied field site.