Case of study of a hydrocarbon contaminated site using the spectral induced polarization method: contribution of laboratory measurements for the interpretation of field results

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A geoelectrical study was initiated in 2012 in order to delineate a massive hydrocarbon spill, which occurred because of a petroleum pipe breakdown in 2009. These measurements have been compared with both field resistivity measurements made in 2009 and with laboratory measurements made on the petroleum oil at different stages of biodegradation.

From a physicochemical point of view, a hydrocarbon contamination has to be understood as a spatially and temporally varying object, responsible for a change in geoelectrical response (Atekwana et al. 2000; Sauck 2000; Revil et al. 2012). The pipe breakdown in 2009 has impacted a surface of 60 000 m^2. The initial contamination infiltration has created a residual zone that can be defined as the zone which presents a residual saturation of petroleum oil. According to Lee et al. (2001), this zone is the most favourable to the degradation of hydrocarbons by bacterial processes. Since 2010, a free phase of petroleum oil is also present at the top of the water table, with a maximal thickness of 1 m, at depths comprise between 8 and 11 m.

In a first time, to evaluate the evolution of the geoelectrical signal, laboratory induced polarization measurements were performed on a well-constrained sandy medium with both fresh and partially biodegraded petroleum oil, extracted from the site in 2012. The fresh oil (oil F) has been taken from the free-phase and seems not to be degraded. The partially degraded oil (oil B) has been taken from the top of a recovery tank where active biodegradation occurs. The non-degraded oil shows an increase in resistivity, normalized chargeability and quadrature conductivity with oil content (Fig.1). On the contrary, the partially biodegraded oil a slight decrease in resistivity but no modification of the phase-lag and chargeability parameters. According to the degradation state of the petroleum oil, different electrical behaviours are measured: the increase of the degradation state of the oil causes a modification of its physical properties.

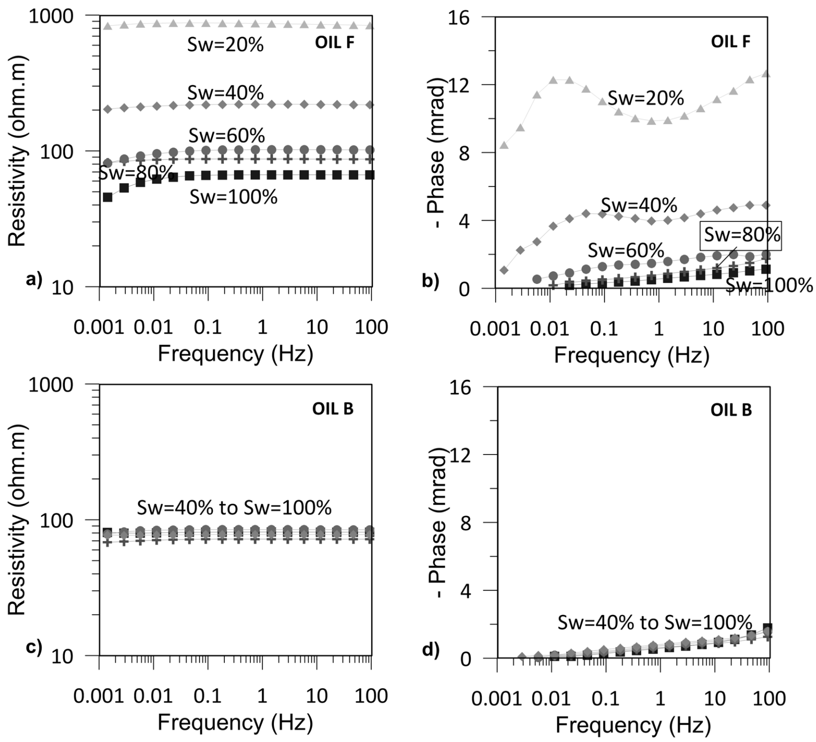

Fig. 1: SIP laboratory measurements acquired for non degraded Oil F: a) resistivity vs. frequency, b) phase-lag vs. frequency; and for partially degraded Oil B: c) resistivity vs. frequency, d) phase-lag vs. frequency.

On a second time, field measurements have been performed. Resistivity measurements were performed in 2009, just after the pipe breakdown. Only weak changes in the resistivity have been measured over the contaminated area (Fig.2). Resistivity measurements have also been made in 2012, three years after the pipe breakdown. It appears that the resistivity values in the residual zone are lower compared to the non-contaminated area. Moreover, over the contaminated area, in the first 10-m depth, we can notice a decrease of 40 % of the resistivity values between 2009 and 2012.

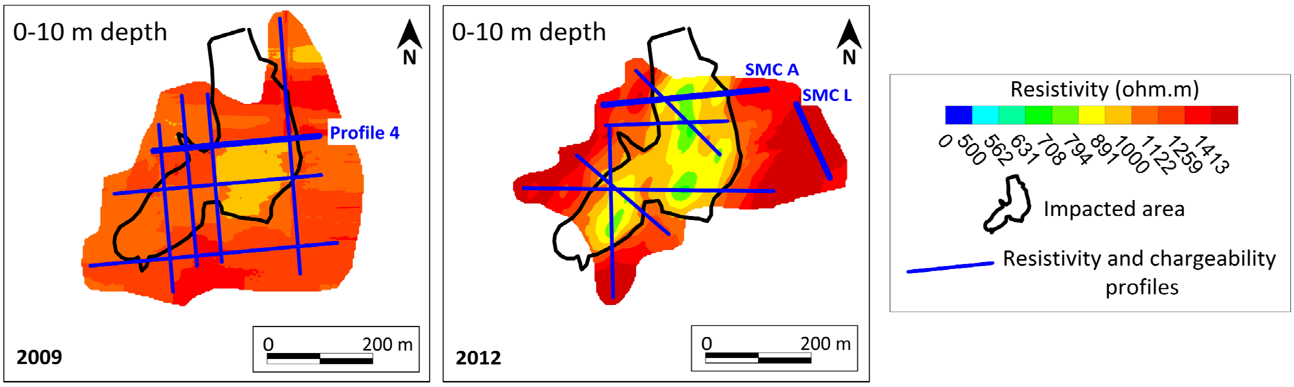

Fig. 2: Evolution of the resistivity values of the 0 □ 10 m deep slice for the period 2009-2012.

Actually, between 2009 and 2012, the bacterial degradation of the oil in the residual zone has caused an evolution of the physicochemical properties of the oil. This statement is confirmed by the laboratory measurements. Besides, bacterial processes produce conductive by-products, as bicarbonate ions, which modify the DC electrical resistivity measured on the field.

Temporal induced polarization tomographies have also been performed in 2012. No evolution has been noticed between the contaminated area and the non-contaminated area, neither for the chargeability parameter nor for the normalized chargeability parameter. Chargeability parameters seem not to be impacted by the presence of contamination or by its biodegradation, in spite of the presence of bacterial populations.

These observations led us to the conclusion that to made efficient geoelectrical measurements in the field, it is necessary to know whether the majority of the oil is non-degraded or degraded.

In the present study case, there is no need to acquire chargeability and phase-lag parameters to locate the contamination in the field, as they do not undergo any change. Nonetheless, chargeability parameters have been useful in this study case to characterize the lithological geometry.

On the other hand, the resistivity parameter is a good indicator of the presence of partially biodegraded oil. Resistivity measurements have led us to precisely locate contamination contours.

References

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