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Geoelectrical investigations on a contaminated site during biostimulation

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A - Introduction

Methods using in situ bioremediation are more and more used on contaminated sites. Assessing their effectiveness only with drilling and sampling remains however difficult. In that context, geophysical methods can complement ideally the classical approach because they allow volumetric measurements of important physical properties with a high resolution on large distances. However, work on the relationship between microbial activity and geophysical signals during bioremediation are relatively new and in full swing (Atekwana et al. 2006, Allen et al. 2007, Williams et al. 2009).

In our study, we monitored for a year the remediation by biostimulation of a site contaminated by LNAPL using electrical resistivity tomography (ERT). The objective of our work was to better understand the impact of bacterial activity on DC-resistivity properties of contaminated soils.

B – Background

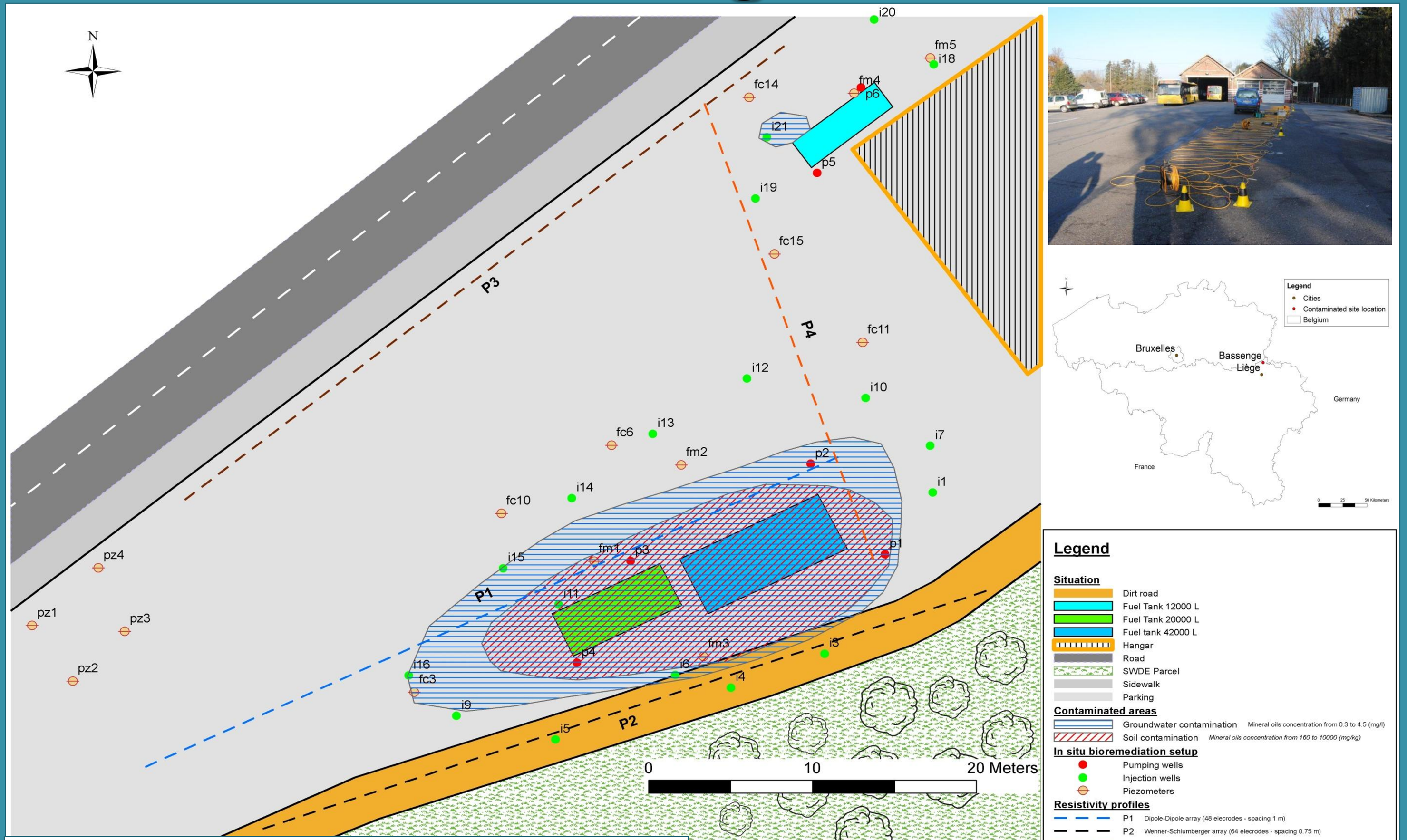

Figure 1. Site position and study area

The site is a bus station since 1976 and is located in Bassenge, province of Liège (Belgium). (see Fig. 1). The contamination of the ground comes from three leaking diesel underground storage tanks (see Fig. 1).

The local site geology is composed of backfill deposits (thickness of <1 m) underlain by a clayey loam unit (thickness ≈ 10 meters).

The contamination was detected analytically until a depth of 5 meters. Within the study area, the groundwater table varies between -1 and -2 meter. Hydraulic conductivity of loam is expected to be low (≈ 10^{-7} m/s).

The biostimulation device was set up mid-2008 and stopped in July 2011. Practically, the biostimulation can be decomposed in 3 steps (see Fig. 2):

1. Pumping of groundwater in the middle of the contaminated area (symbol: ● in Fig. 1)
2. Biological treatment of the contaminated water in the bioremediation unit
3. Reinjection of the treated water amended with nutrients in the periphery of the contaminated area (symbol: ● in Fig. 1)

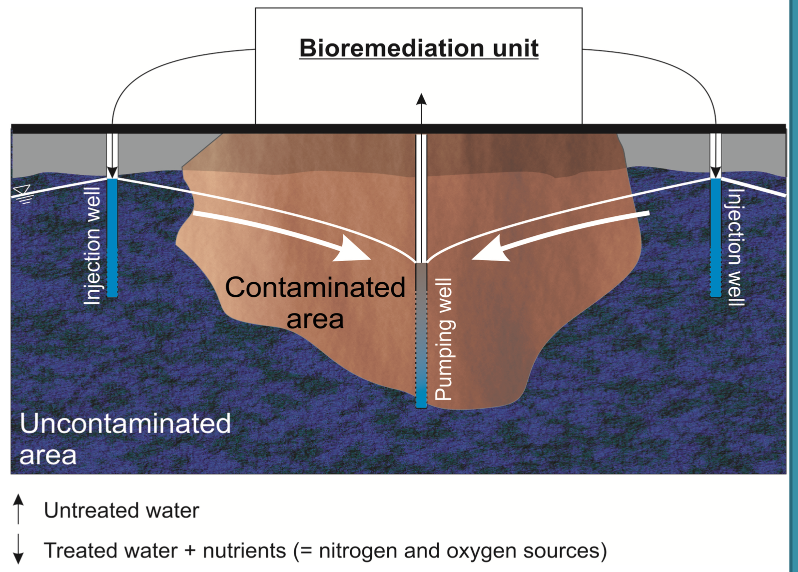

Figure 2. Biostimulation principle

C – Geophysical results

In order to monitor the geoelectrical properties of the site during biostimulation, several resistivity profiles (see Fig. 1) were taken at different time intervals.

Geophysical monitoring started in November 2010. Note that all presented profiles are oriented East to West.

Profile 1 - P1 (48 electrodes – 1 m – Dip-Dip)

Resistivity anomalies are correlated with the presence of contaminants within the first 30 meters along the profile. Homogeneous resistivities are observed at depth in what is expected to be the uncontaminated area.

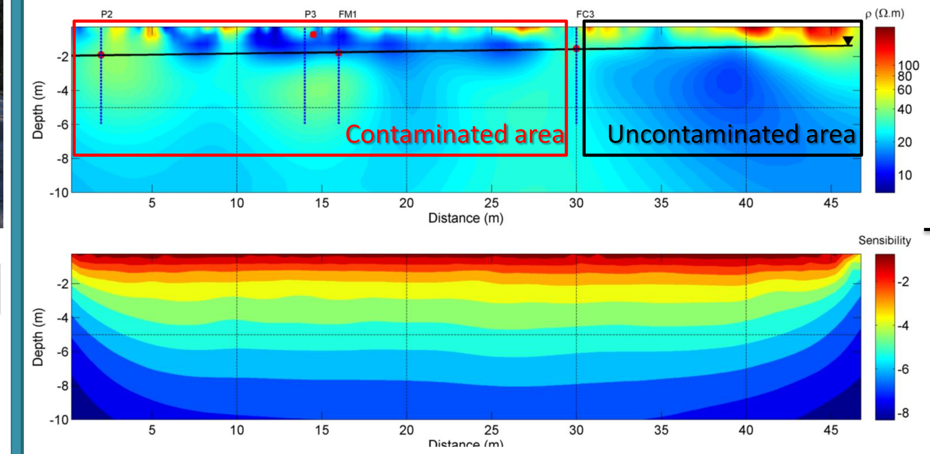

Figure 3. Electrical resistivity model for P1

Profile 2 – P2 (64 electrodes – 0.75 m – Wen-Schl)

No contamination found during sampling. The very homogeneous resistivities obtained are consistent with expected values for clayey loam .

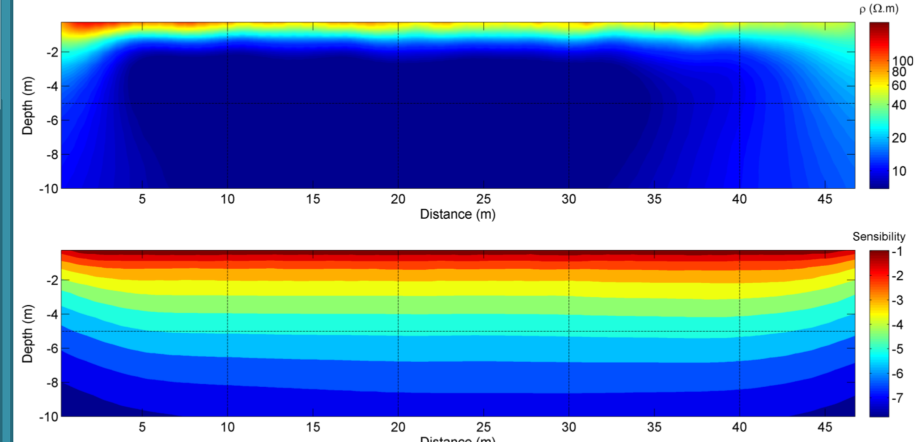

Figure 4. Electrical resistivity model for P2

Profile 3– P3 (48 electrodes – 1 m – Dip-Dip)

The two resistivity anomalies present at a depth below 2 meters indicate a possible contamination coming from a leaking tank (see Fig. 1) but the correlation cannot be confirmed since no chemical data are available for P3.

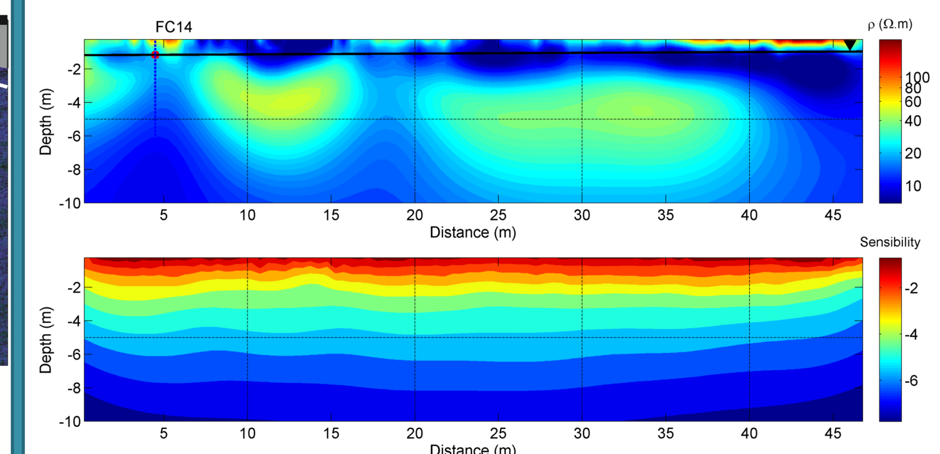

Figure 5. Electrical resistivity model for P3

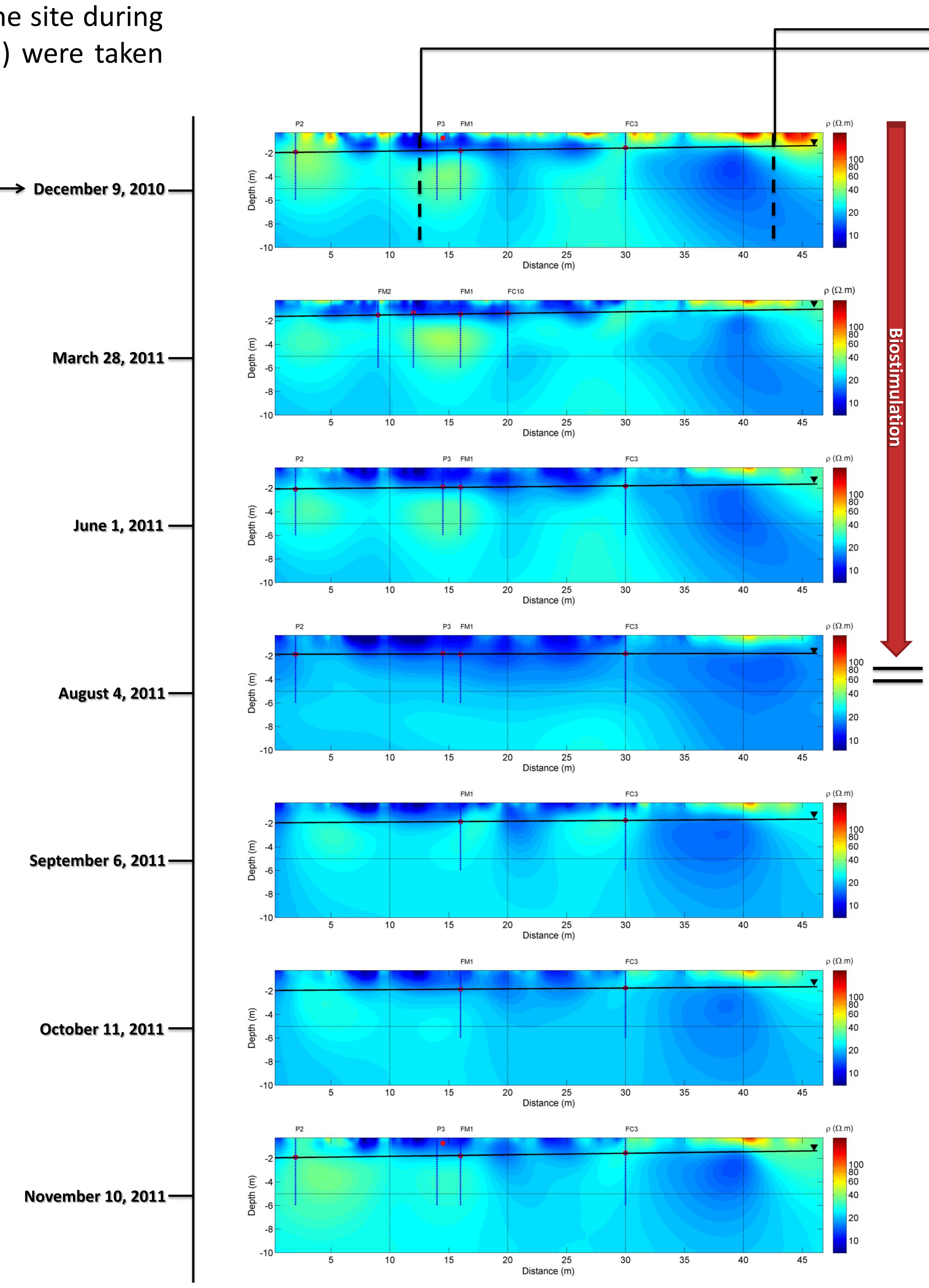

Figure 6. Evolution of electrical resistivities for P1 from December 2010 to November 2011

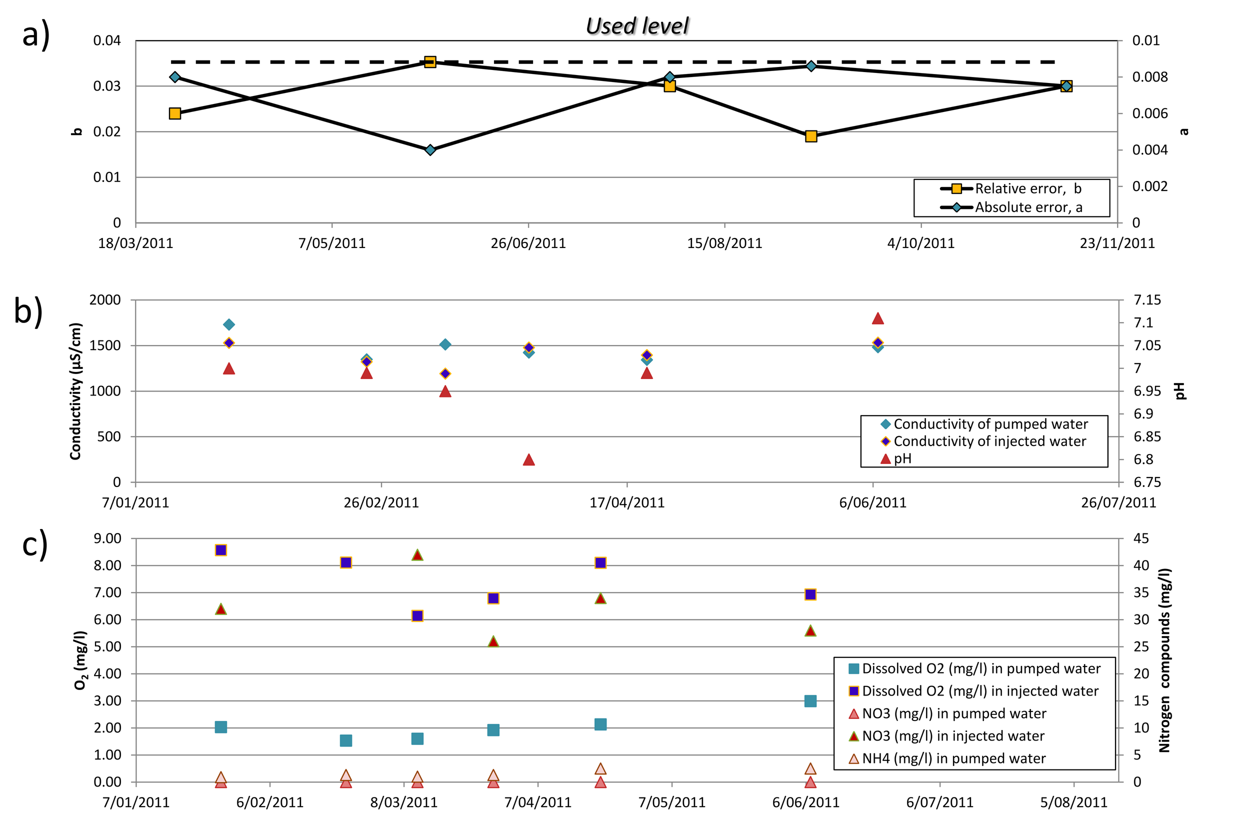

Figure 7. Evolution in function of time of a) coefficient of the error model: e=a+b×R , b) conductivity and pH of water and c) dissolved O_2 and nitrogen compounds

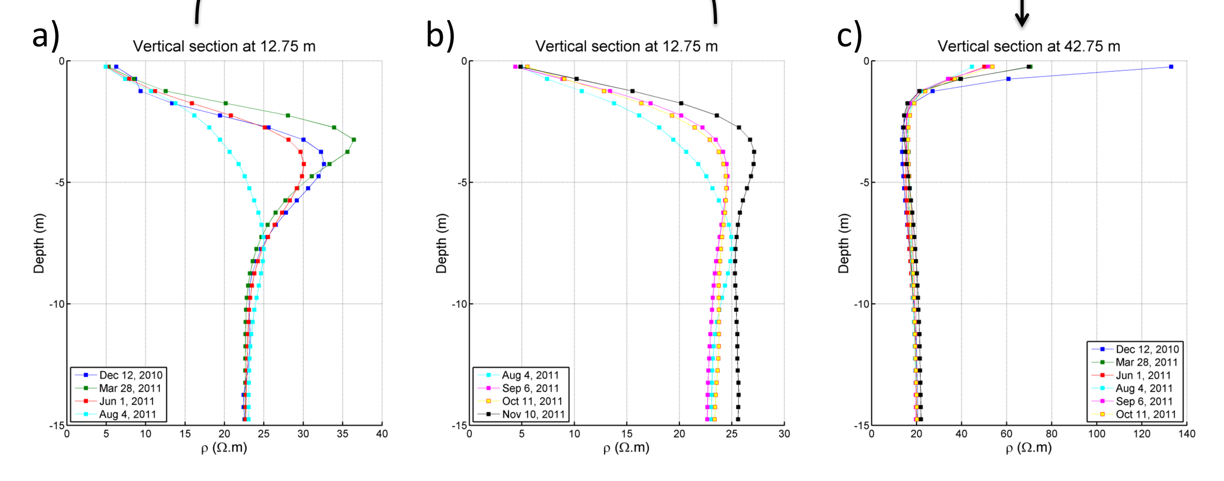

Figure 8. Evolution of resistivities with depth at a) 12.5 m from December 2010 to August 2011, b) 12.5 m from August 2011 to November 2011 and c) 42.5 from December 2010 to November 2011

D – Interpretation

Changes in macroscopic electrical properties of contaminated soils during biostimulation depend on series of coupled phenomena whose relative importance is still poorly controlled and site specific (Atekwana et al., 2006). In the contaminated area, we observe a decrease of resistivity anomalies from December 2010 to August 2011 (see Fig. 6 and 8a). The resistivity increased again from the moment the biostimulation device was stopped (see Fig. 6 and 8b) . No variation at depth is observed in the uncontaminated area (Fig. 6 and 8c.). To explain the observed behavior in P1, several assumptions were made.

- *Change in noise level over time?*

Only small variations of coefficients of the error model estimated from reciprocal measurements (see Fig. 7a)

- *Evolution of temperatures?*

Only small variation of temperatures (≈2°c) at depth during the year
⇨ 1 – 2% of resistivity change

- *Degradation of hydrocarbons?*

Yes, but not complete and cannot explain the increase of resistivities observed from August to November.

- *Direct or indirect effects of microbial activity?*

Evidences of bacterial activity during biostimulation
- Consumption of O_2 (see Fig. 7c)
- Consumption of NO_3^- and production of NH_4 (see Fig. 7c)

No variation of pH and no variation of groundwater conductivity (see Fig. 7b)

⇨ **Formation of conductive biofilms during biostimulation**

In a near future, contaminated samples of soils will be collected and will be subject to controlled biostimulation in columns and in a tank in order to validate that hypothesis

E – References

- Allen J.P., E.A. Atekwana, et al. (2007). "The microbial community structuvre in petroleum-contaminated sediments corresponds to geophysical signatures ". Applied Environmental Microbiology
- Williams, K. H., A. Kemna, et al. (2009). "Geophysical Monitoring of Coupled Microbial and Geochemical Processes During Stimulated Subsurface Bioremediation." Environmental Science & Technology.
- Atekwana, E. A., D. D. Werkema, et al. (2006). " Biogeophysics: the effects of microbial processes on geophysical properties of the shallow subsurface ". Applied Hydrogeophysics. H. Vereecken, A. Binley, G. Cassiani, A. Revil and K. Titov, Springer Netherlands. 71: 161-193