HC-Biodegradation monitoring by geo-electrical measurements and CO2 analyses: field implementation

Cécile Noel, Jean-Christophe Gourry, Jacques Deparis, Fabienne Battaglia-Brunet, Michaela Blessing, Christophe Guimbaud, Ioannis Ignatiadis

To cite this version:

Cécile Noel, Jean-Christophe Gourry, Jacques Deparis, Fabienne Battaglia-Brunet, Michaela Blessing, et al.. HC-Biodegradation monitoring by geo-electrical measurements and CO2 analyses: field implementation. 6th European Bioremediation Conference, Jun 2015, Chania, Greece. hal-01144043

HAL Id: hal-01144043
https://hal-brgm.archives-ouvertes.fr/hal-01144043
Submitted on 20 Apr 2015

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
HC-BIODEGRADATION MONITORING BY GEO-ELECTRICAL MEASUREMENTS AND CO₂ ANALYSES: FIELD IMPLEMENTATION

Cécile Noel¹, Jean-Christophe Gourry¹, Jacques Deparis¹, Fabienne Battaglia-Brunet¹, Michaëla Blessing¹, Christophe Guimbaud², Ioannis Ignatiadis¹

¹BRGM, 3, av. Claude Guillemin, 45060, Orléans, France
²LPC2E, CNRS, 3, av. De la recherche scientifique, 45071, Orléans, France

Corresponding author email: cecile.noel@cnrs-orleans.fr

ABSTRACT

Hydrocarbon contaminated aquifers can be successfully treated through biodegradation. However, in situ monitoring of the treatment is expensive, invasive and can be insufficient as the information provided is restricted to vertical profiles at discrete locations. An alternative method was tested in order to improve the robustness of the monitoring. Geophysical methods, Electrical Resistivity (ER) and Induced Polarization (IP), was combined with gas analyses, CO₂ concentration and its carbon isotopic ratio, to propose a non-destructive method for monitoring in situ biodegradation of hydrocarbons. It was tested at a BTEX-polluted site under aerobic bio-treatment. Geophysical monitoring show a more conductive and chargeable area which corresponds to the contaminated zone. Moreover, in this area, CO₂ emissions have been measured with an isotopic signature typical of biodegradation. Combining geophysics with gas analyses is thus promising to provide a new methodology for in situ monitoring.

KEYWORDS: biodegradation; hydrocarbons; monitoring; induced polarization; carbon isotopic fractionation

1. INTRODUCTION

Hydrocarbon contaminated aquifers can be successfully treated through biodegradation. However, this process still remains partially unexploited, mainly because in situ monitoring before and during soil treatment operations is often expensive and technically challenging. Indeed, where significant subsurface heterogeneity exists, conventional intrusive groundwater sampling campaigns can be insufficient to obtain relevant information as they are restricted to costly monitoring wells at discrete locations. New monitoring tools are needed to overcome these limitations and make the in situ bioremediation more reliable, robust, as well as economically competitive.

Geo-electrical techniques, especially induced polarization (IP), can be used to study the effects of biodegradation (Atekwana and Atekwana, 2010). Indeed, biodegradation processes modify ground electrical properties because they alter biogeochemical conditions: bacteria modify local redox conditions; microbial activity can produce organic acids that affect the pore water conductivity; during microbial growth and formation of biofilms, biomass can clog pores and potentially change the porosity and hydraulic conductivity. Thus, IP is expected to be an effective non-intrusive tool to monitor bioremediation.

Geo-electrical methods are often used in conjunction with geochemical measurements (temperature, pH, redox potential, water conductivity and dissolved oxygen content) to detect changes in the chemical properties of the soil and groundwater caused by microbial metabolism. In the aim to propose a complete non-destructive monitoring methodology, we follow microbial metabolism by studying gas emissions at the ground surface. Indeed, biodegradation of organic compounds induces CO₂ production and isotopic fractionation of carbon. CO₂ produced by hydrocarbon degradation may be distinguished from that produced by other processes based on the carbon isotopic compositions characteristic of the source material and/or fractionation accompanying microbial metabolism. Indeed, carbon isotopic signature of CO₂ reaches that of contaminant and it can be accompanied by significant carbon isotope fractionation. (Aggarwal and Hinchee, 1991).
From these findings, we propose to combine geo-electrical methods and gas analyses to develop a new non-invasive technique for monitoring in situ biodegradation of hydrocarbons. These tools were previously tested at laboratory scale in sand-columns with toluene as model pollutant and an exogenous bacterial strain. The promising results from the column study allowed implementing a monitoring strategy at the field scale. The site is a gasoline station where gasoline and diesel fuels leaked fifteen years ago. The fraction of benzene, toluene, ethyl-Benzene and xylenes (BTEX) represent a consequent part of the pollutants. A trench supplies the necessary oxygen to the aquifer in order to stimulate the aerobic bacterial processes. ER and IP surveys and CO$_2$ analyses have been performed since February 2014.

2. MATERIALS AND METHODS

2.1 Site

The field site studied is a gasoline station where gasoline and diesel fuels leaked in 1997 (Figure 1.A). It is still in activity but the former tank installation (source of contamination) was dismantled. Several boreholes had been drilled for previous studies on this site. These studies showed that: the ground is mainly composed with silts and clays and it has a low permeability (between $10^{-6}$ and $10^{-7}$ m/s); the direction of flow is North-West; the water table is between 2.5 and 4.5 m depth; there is a presence of hydrocarbons (BTEX) in the area of the former tank installation; there are indications of a natural attenuation which prove the presence of a bacterial flora, such as absence of dissolved oxygen, that match the BTEX plume in water.

![Figure 1. A/ Map of the site showing gasoline station, former tank installation, monitoring wells and the benzene concentrations measured in water. B/ Map of the site showing the reactive barrier and the monitoring disposal: electrical profiles and gas metering stations.](image)

As a natural biodegradation of hydrocarbons is already in process, a bio-treatment by an oxygen supply to stimulate aerobic metabolic processes has been decided for this site. A permeable reactive barrier was implemented to stop the plume migration. Diluted H$_2$O$_2$ is added to pumped water in the barrier and reinjected below water table.
2.2 Electrical measurements

Electrical resistivity (ER) and Induced polarization (IP) measurements are made by injecting an electrical current into the ground between two current electrodes and making measurements of the induced voltages between two receiving electrodes. By comparing the transmitted signal to the received signal we can analyze the electrical response of the ground. In ER measurements, we obtain resistivity (the ability of the ground to conduct electrical current) by multiplying the resistance (I/V) by a geometrical factor (which depends of disposal geometry). In time domain IP measurements, we measure the relaxation time of the potential when the current is switched off. It allows calculating the chargeability, the capacitive properties of the ground.

Time domain IP and ER surveys were performed regularly since February 2014 to monitor the stimulated biodegradation and the progress of depollution until soil cleanup. There is a permanent (buried) electrical profile perpendicular to the reactive barrier, 120m long (60 electrodes separated by 2m) and temporary profile parallel to the barrier (48 electrodes separated by 1m) (Figure 1.B). Both profiles are transverse to the contaminant plume. Measurements are taken every two days for the permanent profile, and every two months for the temporary one.

2.3 CO₂ analyses: emissions fluxes and carbon isotopic ratio

CO₂ concentration and δ₁³C isotopic ratio in produced CO₂ are measured by infrared laser spectroscopy. The δ₁³C is the difference between the isotopic ratio R = ¹³CO₂/¹²CO₂ of the sample and of a standard. (δ₁³C(‰) = [(¹³C/¹²C)sample/(¹³C/¹²C)VPDB -1] *1000, with (¹³C/¹²C)VPDB = 0.011237). The spectrometer is directly connected with a closed accumulation chamber set on a permanent PVC cylinder collar (diameter = 30cm) sunk into the soil to measure CO₂ emission fluxes and δ₁³(CO₂). We have 21 measuring points on the site, upstream, above and downstream the reactive barrier (Figure 1.B). Measurements are performed every two months since February 2014.

3. RESULTS AND DISCUSSION

3.1 Electrical measurements

Time Domain IP and ER data of the permanent profile are represented on resistivity and normalized chargeability (ratio of raw chargeability over resistivity) sections (Figure 2). On the resistivity section, we show a conductive zone at 2-6m depth, between 50 and 72m. This area is also very chargeable and it may match the top of the water table, where hydrocarbon biodegradation produced conductive and chargeable metabolites. Moreover, we can clearly see that the more conductive and chargeable zone matches the polluted zone defined by geochemical borehole analyses (Pz24, P7), downstream the former tank installation.

Figure 2. Resistivity and normalized chargeability sections across the plume for the permanent electrical profile, May 2014.
3.2 CO₂ analyses

The same zone produces high CO₂ fluxes (up to 1500 ppb.s⁻¹, three to four times higher than a non polluted soil) (Figure 3). It is probably due to bacterial respiration. Moreover, in this area, CO₂ emissions have been measured with an isotopic signature typical of hydrocarbon biodegradation. Indeed, δ¹³(CO₂) are measured between -27 and -30‰ since February 2014, in accordance with the BTEX signature measured in water (around -25 – -26‰). Moreover, results show a light isotopic fractionation (1 to 3‰) where δ¹³(CO₂) is lower than δ¹³(hydrocarbons source), which means that molecules with light isotopes (¹²C) are preferred by bacterial metabolism.

Figure 3. Maps of measured CO₂ emissions (left) and its carbon isotopic ratio (right), July 2014.

4. CONCLUSIONS

Results have shown a more conductive and chargeable zone at around 3 meters depth, which matches the polluted zone defined by geochemical borehole analyses. Moreover, CO₂ emissions have an isotopic signature typical of hydrocarbon biodegradation. Our results argue for combining geophysics with gas content and isotopic measurements to monitor zones of biodegradation and will allow us to give a practical non-intrusive method of monitoring and evaluating in situ remediation.

ACKNOWLEDGEMENTS

We thank the French Research Agency (project BIOPHY, ANR-10-ECOT-014) and the LABEX VOLTAIRE (Excellence Laboratory for Atmosphere, Resources and Environmental interactions study, University of Orleans, France) (ANR-10-LABX-100-01) for financial support. We also thank all the cooperation partners of the BIOPHY project: BRGM, LPC2E, Serpol and Total.

REFERENCES

