On the $\alpha$-polarization of bacterial suspensions: SIP measurements on four bacterial strains

Tamara PILAWSKI(1)*, Wolfgang TAPPE(2), Egon ZIMMERMANN(3), Johan Alexander HUISMAN(3), Frank DELVIGNE(4), Frédéric NGUYEN(5)

(1)Applied Geophysics Research Unit, Department ArGEnCo, Faculty of Applied Sciences, University of Liège, Allée de la Découverte 9 (B52), 4000 Liège, Belgium; (2)Institute of Bio- and Geosciences, Agrosphere (IBG-3), Forschungszentrum Jülich GmbH, 52425 Jülich, Germany; (3)Central Institute for Engineering, Electronics and Analytics (ZEA-2), Forschungszentrum Jülich GmbH, 52425 Jülich, Germany; (4)Microbial Processes and Interactions, Gembloux Agro-Bio Tech, University of Liège, Passage des Déportés 2, 5030 Gembloux, Belgium

Introduction

This experiment is part of a PhD thesis aiming at a better understanding of complex conductivity measurements during hydrocarbon biodegradation. The goal is to quantify different mechanisms proposed to explain the influence of bacteria on the electrical properties with lab experiments of increasing complexity. This experiment was designed to study direct bacterial polarization on bacterial suspensions at frequencies below 10 kHz, so-called $\alpha$-polarization. To our knowledge, only a few studies have reported $\alpha$-polarization measurements and they were performed by dielectric spectroscopy techniques relying on two electrodes and models to correct for electrode polarization at low frequencies.

Objectives

• Measuring the complex conductivity of bacterial suspensions from 1 Hz to 10 kHz with an impedance spectrometer based on a four point measurement method as described in Zimmermann et al. (2008) and Huisman et al. (2015).

• Determining the $\alpha$-polarization associated with bacterial cells in this frequency range.

Bacterial strains

Four bacterial strains were chosen for their different surface electrical properties.

<table>
<thead>
<tr>
<th>Gram-positive bacteria</th>
<th>Gram-negative bacteria</th>
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<tbody>
<tr>
<td>Bacillus subtilis GA1</td>
<td>Escherichia coli K12</td>
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<tr>
<td>Rhodococcus erythropolis T902.1</td>
<td>Pseudomonas putida KT2420</td>
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</tbody>
</table>

Experimental protocol

Incubation until early stationary phase

Washing

Dilution

SIP measurement

Results

- Imaginary part of the complex electrical conductivity ($\sigma''$) measured on the 4 bacterial suspensions. The vertical error bars represent the standard deviation of the data.
- Real part of the complex electrical conductivity ($\sigma'$) measured on the four bacterial suspensions. They were obtained by averaging triplicates. The vertical error bars represent the standard deviation of the data.

References


Conclusions

$\alpha$-polarization has been postulated to explain changes in the complex electrical conductivity observed in geological media affected by bacterial activity below 10 kHz. To date, $\alpha$-polarization measurements on bacteria remain rarely reported expect in a few dielectric spectroscopy studies (e.g. Bot and Prodan, 2009; Zhang et al., 2013) because of the magnitude of the correction resulting from electrode polarization that occurs in the kHz frequency range and below (Asami, 2014). We performed complex electrical conductivity measurements on four bacterial suspensions using an impedance spectrometer at frequencies from 1 to 10 kHz. We observed small polarization for B. subtilis from 100 to 10 kHz (corresponding to a phase shift of 0.1 rad). SEM observations showed that B. subtilis was the only strain to form aggregates of tens of $\mu$m and to produce some extracellular polymeric substance, like in biofilms. Whether the cause of the polarization could be attributed to the size of the aggregates and/or to the extracellular polymeric substance is still to be determined. Future experiments will focus on bacterial growth and attachment, and biofilm formation in silica sands.

Bacterial strains

- R. erythropolis T902.1
- E. coli K12
- B. subtilis
- Ps. putida

Scanning electron microscope images of (a) R. erythropolis, (b) E. coli, (c) B. subtilis and (d) Ps. putida. Only B. subtilis forms large aggregates.

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References