Extreme microbiology on a chip: introducing high pressure microfluidics for investigating deep microorganisms

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Abstract

A majority of Earth's prokaryotes live under high pressure conditions (deep sea or deep underground environments). This deep biosphere represents the unseen majority (˜ 99 %) of the total biosphere on Earth and has gained increasing attention given its significance in a variety of critical processes and topics (carbon cycle, origin of life, biomining, etc.). Conventional cultivation and analysis techniques offer both limited optical access and *in situ* characterization, while generally requiring sufficient amount of sample, thus narrowing the ability to investigate deep subsurface microbial communities. Oppositely, high pressure microfluidics tools are able to overcome these limitations being able to propose fast screening approaches and *in situ* monitoring in real conditions using small quantities of biological materials. These tools were developed on the idea of combining the advantages of microfluidics (reduction in size, fast screening, *in situ* analyses, reproducibility, hydrodynamic control, improvement of heat and mass transfers, low consumption of reagents during optimization phases, etc.) with fluid systems used under high-pressure (and high temperature) conditions. It appears they are particularly well adapted to the investigation of microbiology under extreme conditions such as microorganisms living in the deep biosphere.

In this presentation, we will first detail the interest of this technology and the different strategies developed to manufacture and use high-pressure microreactors. Then, we will present the use of on-chip biocompatible high pressure geological laboratories (BioGLoCs) for the culture and the study of methanogenic microorganisms living in deep geological environments. BioGLoCs are a significant tool to mimic the *in situ* biogeological reservoirs conditions to study CO2 bioconversion within deep aquifers. Eventually, we will show another example of HP microfluidics approaches for the fast phenotyping (determination of the optimum growing conditions) of a model deep sea vents microorganism.

In conclusion, high-pressure microreactors turn out to be excellent experimental tools for investigating microbiology under extreme conditions at the lab scale. After summarizing the advantages of these new experimental approaches compared to traditional instrumentation, we will give some perspectives concerning other future applications of this technology applied to the study of extremophilic microorganisms (thermophiles, piezophiles).

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