

NEW INSIGHTS ON BIODEGRADATION PROCESSES IN POROUS MEDIA: EXPERIMENTAL APPROACHES AND GEOCHEMICAL IMPLICATIONS

Denis BLANCHET¹, Françoise BEHAR² and Frank HAESLER²

Institut Français du Pétrole – 1 à 4 avenue de Bois Préau – F 92500 Rueil Malmaison ¹ *Biotechnology department,* ² *Geochemistry Department*

Hydrocarbon biodegradation in oil reservoirs has been recognised as one of the major mechanisms leading to significant compositional changes. These alterations also affect the physical chemical properties (viscosity, API grade...), the sulphur content and consequently the market value of the product. The potential economical impact of the biodegradation becomes a major challenge for deciding the production of a reservoir. As such the basin modelling will increasingly need reliable tools for predicting the compositional changes of the oil due to biodegradation. The bottleneck for predicting the oil biodegradation is linked to the availability of kinetic data and to the knowledge of the limiting factors in a porous medium. Accurate data for biodegradation rate of oil phases in natural attenuation are scarce in the literature and even more rarely associated with rigorous characterization of the porous media (porous volume, respective oil, water, gas saturation). Moreover, these data might be integrated into a basin simulator in which geological parameters play a major role such as hydrodynamism, porosity, mineralogy etc...

At a preliminary stage, it is important to design an experimental setup which is representative of geological settings. For that purpose, an original experimental setup was established (see figure 1) which is a structured porous medium under well defined and reproducible saturations (gas, water, oil).

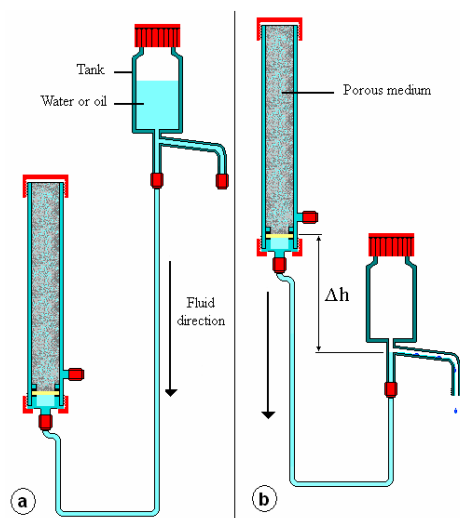


Figure 1. A novel technique developed to place oil and water homogeneously into the porous medium. The porous medium is constituted with different grain-size sands. This innovative experimental set-up included ceramic plates and a respirometer technique for introducing oxygen.

In order to quantify and to follow the biodegradation kinetics for determining the limiting factors, these experiments were done under aerobic conditions. Even though anaerobic processes are predominant in reservoirs the only way to quantify the limiting factors in the laboratory is to work under aerobic conditions. Even so the experiment time necessary to obtain significant results was up to 500 days. Mass balances done during and at the end of the experiments indicated the mineralization level and the hydrocarbon consumption. Our experimental data show that the kinetic of the oxygen consumption was reproducible. The phenomenology of the microbial degradation of the n-hexadecane was highlighted by the oxygen consumption rate.

In a first set of experiments, limited n-hexadecane quantities were dissolved in a non biodegradable oil phase (heptamethyl nonane). Instantaneous biological oxygen demand, correlated to the synthesis of biomass, became more and more limited due to drastic decreasing n-hexadecane transfer rate from the HMN phase to the water phase. So an exponential growth step appeared, followed very quickly by a non exponential growth step. In a second set of experiments n-hexadecane was introduced in the porous medium as pure phase. The n-hexadecane/nitrogen ratio was indisputably larger, so decreasing n-hexadecane transfer rate to the water phase couldn't appear only before significant n-hexadecane pool consumption. Only a very small fraction of n-hexadecane was used for biomass synthesis, depending of the nitrogen quantity introduced, through finish water volume. So the complete biomass synthesis could occur without limitation in the n-hexadecane transfer to microorganisms.

Elevated nitrogen quantities were used to raise the biological demand of n-hexadecane. This n-hexadecane biological degradation permitted to obtain maximal transfer rates of a model hydrocarbon for different pores networks, depending of the granulometric fractions used for the porous medium.

In conclusion, these preliminary experiments gave us first rates of hydrocarbon biodegradation obtained in porous media which can be later used for tentative quantification of biodegradation rates at geological scales. Such experimental device will be further used with other compounds and complex hydrocarbons mixtures.