Contribution ID: **284** Type: **Poster Presentation**

Stability assessment of foam enhanced by surfactant, polymer and nanoparticles in the presence of petroleum hydrocarbons

Tuesday, 23 May 2023 10:30 (1h 30m)

The risk of environmental pollution, particularly groundwater contamination, has increased over the last century as a result of the growth of industry. Light non-aqueous phase liquids (LNAPLs) are one of the most common contaminants and refined petroleum hydrocarbons (RPHs-diesel, gasoline, motor oil, etc.) are typical examples [1, 2]. Heterogeneity in the subsurface represents one of the main issues for LNAPLs remediation, conventional pump-and-treat method rarely exceeds 60% of efficiency [3]. However, some studies demonstrating the non-Newtonian shear-thinning behavior of foam in highly permeable porous media point to the promising potential of foam to improve remediation yields [4, 5].
The use of aqueous foam in environmental remediation (ER) was inspired by enhanced oil recovery (EOR), and it has already proven to be an excellent displacing fluid for in situ remediation of NAPLs [6 –8]. However, contact with petroleum compounds tends to deteriorate the stability of foam significantly and thus it is a challenge for both foam applications [9, 10]. Many researchers are currently focused on strategies to enhance foam employing numerous additives: i.e. co-surfactants [11, 12], polymers [13, 14], and nanoparticles (NPs) [15, 16]. It is worth noting that all of these studies mainly address foam applications in EOR. The main objective of our work is to evaluate experimentally the stability of foam generated with two or more additives in the presence of RPHs, both in bulk and in porous media.
In order to implement the concept, two environmentally friendly surfactants (sodium dodecyl sulfate (SDS) and cocamidopropyl hydroxysultaine (CAHS)) were experimentally investigated for their foaming ability and stability in the presence of diesel oil using the bulk foam screening method. Stability of complex foam formulations including a combination of surfactants, polymers and NPs were then examined. Two one-dimensional columns packed with sand and coupled in series were used to (i) generate a fully developed foam flow, (ii) evaluate foam stability and recovery efficiency of diesel initially at residual saturation. Mass balance and differential pressure were measured during each injection experiment.
The bulk foam study demonstrated an apparent increase in foam stability in the presence of Diesel when complex foaming solutions were used. The mixture of SDS and CAHS (SC) at a ratio of 1:1 could improve 7.5 times the bulk foam stability in contrast to SDS alone. The presence of NPs enhanced the bulk foam stability up to a factor of 2.6 for the SDS alone and 1.2 for the SC. Among the three types of tested environmentally friendly polymers, xanthan gum (XG) showed the best stabilizing properties compared to carboxymethyl cellulose and guar gum, with increased stability by factors of 3.4, 2, and 1.3 times respectively. Concerning the performance of foam in porous media, complex foaming solutions ranked as SC+XG > SC+NPs > SC > SDS.
Further studies are ongoing to explain how the addition of NPs and polymers affects recovery. Nevertheless, advanced foam formulations clearly exhibited promising perspectives to develop an efficient remediation technique for highly permeable soils contaminated by RPHs.

Participation

In-Person

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Primary author: Mr BAIGADILOV, Adil (BRGM (French geological survey); Université Grenoble Alpes, CNRS, G-INP, LRP/IGE)

Co-authors: Dr COLOMBANO, Stéfan (BRGM (French geological survey)); Dr OMIRBEKOV, Sagyn (BRGM (French geological survey); Nazarbayev University); Dr DAVARZANI, Hossein (BRGM (French geological survey)); Mr LION, Fabien (BRGM (French geological survey)); Prof. OXARANGO, Laurent (Université Grenoble Alpes, CNRS, IRD, G-INP, IGE); Prof. BODIGUEL, Hugues (Université Grenoble Alpes, CNRS, G-INP, LRP)

Presenter: Mr BAIGADILOV, Adil (BRGM (French geological survey); Université Grenoble Alpes, CNRS, G-INP, LRP/IGE)

Session Classification: Poster

Track Classification: (MS18) Innovative Methods for Characterization, Monitoring, and In-Situ Remediation of Contaminated Soils and Aquifers