Contribution ID: **269** Type: **Oral Presentation**

Evaluation of zero-valent iron nanoparticles (nZVI) injection tests in porous media using synchrotron X-ray computed microtomography

Monday, 30 May 2022 11:05 (15 minutes)

This study aims to investigate the mobility and entrapment of zero-valent iron nanoparticles (nZVI) in porous media at a pore-scale, using synchrotron X-ray microtomography (µCT). As the dynamics of fluid flow in porous media is a fast process, benchtop CT scanners are unable to capture the details of this process, thus requiring high time resolution only made possible by synchrotron techniques [1-3].
Two sand-packed columns were analysed by µCT imaging. They were first saturated with water and subsequent injected with the nanoparticle suspension. A post water flushing was done to remove the mobile nanoparticles. Using an X-ray transparent flow cell allowed capturing a sequence of 3D images during the experiments. The column was imaged in three segments by moving the µCT stage in the vertical direction, helping to preserve image resolution whilst analysing a relatively large sample (1 cm tall, 0.29 cm diameter), and thus to investigate nanoparticle mobility along the entire column length at each experiment step. Each segment image has temporal resolution of 6 minutes, and spatial resolution of 1024^3 voxels with 3.28 µm side. Image processing includes filtering, segmentation and analysis regarding the degree of nZVI mobility in the different samples, and the calculation of flow properties (e.g. permeability) based on the images collected before and after nZVI injections. Some of the challenges encountered during segmentation were related to ring artifacts, particularly in the centre of the image, and to less concentrated portions of the nZVI suspension, which presented a similar texture and greyscale when compared to some of the sand grains.
Label analysis has shown that grain size distribution is quite similar between samples, despite one of the samples having a few bigger grains. Nonetheless, their total porosity is very similar, with high values compatible with unconsolidated sand (40 and 45%).
We were able to increase nZVI saturation on the second sample during the injection experiment, by increasing the injection rate (from 400 to 800 µL/min). As samples consisted of packed unconsolidated sand, some grains moved after nZVI injection. Despite differences in saturation, in both cases about half of the nanoparticles injected was mobile and was removed with the final water injection. The trapped nanoparticles are mainly observed to occupy the pore-throats, that is, the narrowest parts of the flow pathways.
The nZVI suspension is not miscible with the water phase, first occupying the larger pore-spaces. The images also show the formation of a water film covering some of the sand grains in presence of the nanoparticle suspension phase, making water the wetting phase. Nonetheless, this is not observed in all cases, which could be related to the irregular surface of grains –or even to image resolution.
This experiment shed light on the pore-scale mechanisms involved in nZVI entrapment in porous media. Future studies shall take advantage of the higher spatial and temporal resolution at the new beamline at Sirius, allowing the analysis of the nZVI suspension front during injection, observing the movement and trapping of the nanoparticles in nearly real time.

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References

[1] Pak, T.; Luz, L. F. L.; Tosco, T. Costa, G. S. R.; Rosa, P. R. R.; Archilha, N. L. (2020). Pore-scale investigation of the use of reactive nanoparticles for in situ remediation of contaminated groundwater source. Proceedings of the National Academy of Sciences 117 (24), 13366-13373.
[2] Pak, T.; Archilha, N. L.; Mantovani, I. F.; Moreira, A. C.; Butler, I. B. (2018). The Dynamics of Nanoparticle-enhanced Fluid Displacement in Porous Media - A Pore-scale Study. Scientific Reports, 8: 11148.
[3] Pak, T.; Archilha, N. L.; Mantovani, I. F.; Moreira, A. C.; Butler, I. B. (2019). An X-ray computed micro-tomography dataset for oil removal from carbonate porous media. Scientific data, 6 (1): 1-9.

Time Block Preference

Time Block B (14:00-17:00 CET)

Participation

In person

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