

TIME-RESOLVED SYNCHROTRON X-RAY COMPUTED TOMOGRAPHY AS A TOOL FOR GROUNDWATER REMEDIATION

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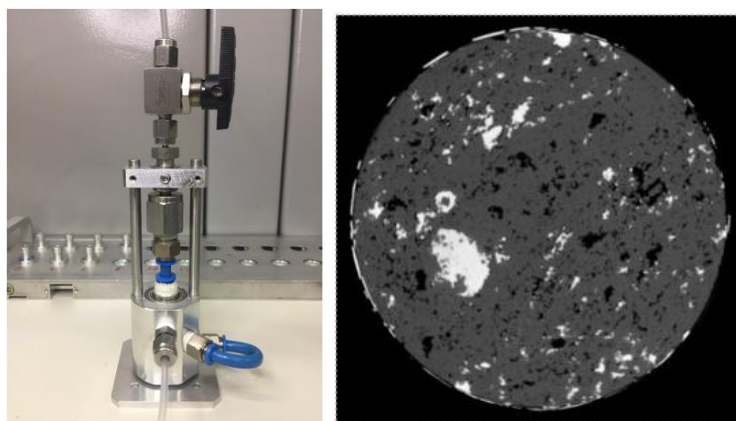
INTRODUCTION

X-ray computed tomography (XCT) is a relatively new technique. Historically, research in this field started in the 1960s and, only 10 years later, CT was consolidated as the first method to non-invasively study the interior of a human body. This fact was a huge step toward the advance of diagnostic possibilities in medicine, especially because CT images yields images with much higher contrast compared to conventional radiography. During the last century, conventional CT scanners were present in hospitals, and important progress has been made in terms of reduction of the radiation dose, reconstruction algorithms and detector technology.

Although the focus has been concentrated in medicine for many years, early CT applications include studies in soil science, meteoritic, paleontology, geotechnics and petroleum geology. The possibility to obtain inner information from a sample, without destroying it, opens new fields of study in different areas. As an example, a group of fossil found in Malapa cave (Johannesburg, South Africa) and dated as early as 2 million years. The research team argues, based on 3D images, that the fossils have many typical characteristics of later humans and this new species may be the best candidate yet for the immediate ancestor of our genus.

There is no doubt, 3D X-ray tomography is a powerful tool and has a wide application in many different areas. Nevertheless, what is a much newer technique is 4D tomography, which opened a new range of possibilities since, approximately, 2010: now we can have a 3D image resolved in time. In practical terms, it means that now it is possible to study a fluid flow inside a porous media or study the pore geometries changes in a pressure test, for example.

Experimental apparatus for these two applications are very common; however, the fraction that is compatible with X-ray tomography is almost nonexistent. For this reason, we developed an X-ray transparent flow cell (Figure 1 - left), where three different fluids can be injected, flow rate can be controlled, and fluid pressure can be measured. Sample diameter can vary from 4 to 6mm. Figure 1 (right) shows an example of tomographic image – this is a carbonate rock filled with two different liquids: oil and water.



The goal of this work is to provide illustrative examples of what is achievable with this cutting-edge technique applied to fluid flow in porous media, more specifically, groundwater remediation. This technique is already available at the Imaging Beamline (IMX) from the Brazilian Synchrotron Light Source, but at SIRIUS, the new Light Source that Brazil is building in Campinas/São Paulo, a new beamline will be open for the community, which will provide better measurements in terms of timescales and spatial resolution.

SCIENTIFIC MOTIVATION

Chlorinated solvent contaminants are among the most recalcitrant aquifer contaminants which can cause serious health problems (e.g. kidney and liver damage) and some are considered as carcinogenic. They are a significant problem, both in the UK, in Europe, and globally, due to their wide industrial use since the beginning of 20th century e.g. in metal processing plants. Removal of chlorinated contaminants from the host aquifers can be done by water injection. In this context water is the wetting phase and the chlorinated solvent acts as the non-wetting phase. It is known that such a displacement is always less than 100% efficient, therefore, a portion of these contaminants will remain trapped in the host aquifer. Aquifer remediation technologies are designed to target this trapped contaminant to either (i) pump it out for ex-situ treatment, or (ii) degrade it in-situ into less harmful substances.

In this work, we will discuss and highlight all the advantages of using a time-resolved X-ray tomography for groundwater remediation and we will also present outcomes of two experiments: (i) the progressive pore-space clogging induced by nanoparticle deposition, at pore-scale, and (ii) the evolution of the 3D distribution of the contaminants during the nanoremediation process. Time resolved X-ray tomography can reveal the pore scale of the rock and distinguish different fluids within a single pore. Dynamic (time-resolved) image of fluid injection in a porous media can provide important insights and contribute to optimizing the groundwater remediation process.

REFERÊNCIAS BIBLIOGRÁFICAS

Pak, T., Butler, I. B., Geiger, S., van Dijke, M. I. J. & Sorbie, K. S. Droplet fragmentation: 3D imaging of a previously unidentified pore-scale process during multiphase flow in porous media. *Proc. Natl. Acad. Sci.* **112**, 1947–1952 (2015).