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Visualizing biofilms within porous media using contrast-enhancing staining agents

Tuesday, 31 May 2022 17:00 (15 minutes)

Bacteria colonize almost every habitat, including porous media such as rocks, sediments and soils. They are usually attached to the surface and agglomerated in biofilms. The location, extent and composition of the biofilm depend on the environmental conditions and chemical and physical characteristics of the material (Miller et al., 2012). They affect the material properties and influence fluid transport by obstructing the pore space, reducing the permeability and hydraulic conductivity (Baveye et al., 1998). Their influence is investigated for numerous industrial fields as they could contribute to wastewater treatment (di Biase et al., 2019), bioremediation of groundwater (Meckenstock et al., 2015) and carbon dioxide sequestration (Ebigbo et al., 2010).

It is important to visualize biofilms within a porous rock, know their location, and understand their effect on fluid flow inside the pore system. Within porous media, this could be achieved by X-ray micro-computed tomography (µCT). However, distinguishing biofilms from the pore fluid, such as water, is hard due to a similar X-ray attenuation coefficient. Contrast-enhancing staining agents (CESAs) could enhance the X-ray attenuation, and a few CESAs such as particulate BaSO4 (Davit et al., 2011), silver-coated microspheres (Iltis et al., 2011), 1-chloronaphtalene (Rolland du Roscoat et al., 2014) proved to be successful. However, these CESAs have some drawbacks, such as sedimentation, heterogeneous distribution of the particles and the fact that they change the pore fluid properties, such as the viscosity and wettability (Carrel et al., 2017). FeSO4 could overcome these drawbacks (Carrel et al., 2017), and other CESAs, like Mono-WD POM and Hf-WD POM, could be interesting as they proved to be powerful staining agents for tissues (de Bournonville et al., 2020).

Within this research, numerous CESAs (KBr, FeSO4, BaCl2, Hexabrix, CA4+, Mono-WD POM, Hf-WD POM and Hexabrix) were tested that bind to the biofilm, and which could afterwards be replaced by the original pore fluid. These CESAs were screened for their potential to stain bacterial biofilms in between sand grains and on stones. The biofilms were imaged by HECTOR at the Centre for X-Ray Tomography (UGCT) of Ghent University (Masschaele et al., 2013).

In our experiments, most CESAs had a limited effect on the X-ray attenuation of the biofilms. However, Hf-WD POM and isotonic lugol were very promising CESAs for biofilm visualization using µCT. Both were able to visualize cyanobacterial biofilms on rocks. Isotonic lugol led even to the visualization of (bundles of) filaments, and provides opportunities for future 3D microbial mat visualization. Moreover, it was possible to image and quantify the spatial distribution of biofilms inside a sand column.

Hf-WD POM and isotonic lugol create thus new possibilities to increase our understanding of the effect of biofilms on the pore scale. It could be possible to directly visualize their effect on flow paths, flow velocities and pressure gradients during a dynamic µCT experiment. Moreover, µCT could link the presence or absence of biofilms with changes in the pore system, including dissolution or precipitation.

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References

Baveye, P., Vandevivere, P., Hoyle, B.L., DeLeo, P.C., de Lozada, D.S., 1998. Environmental Impact and Mechanisms of the Biological Clogging of Saturated Soils and Aquifer Materials. Crit. Rev. Environ. Sci. Technol. 28, 123–191. https://doi.org/10.1080/10643389891254197

Carrel, M., Beltran, M.A., Morales, V.L., Derlon, N., Morgenroth, E., Kaufmann, R., Holzner, M., 2017. Biofilm imaging in porous media by laboratory X-Ray tomography: Combining a non-destructive contrast agent with propagation-based phase-contrast imaging tools. PLoS One 12. https://doi.org/10.1371/journal.pone.0180374

Davit, Y., Iltis, G., Debenest, G., Veran-Tissoires, S., Wildenschild, D., Gerino, M., Quintard, M., 2011. Imaging biofilm in porous media using X-ray computed microtomography. J. Microsc. 242, 15–25. https://doi.org/10.1111/j.1365-2818.2010.03432.x

de Bournonville, S., Vangrunderbeeck, S., Ly, H.G.T., Geeroms, C., De Borggraeve, W.M., Parac-Vogt, T.N., Kerckhofs, G., 2020. Exploring polyoxometalates as non-destructive staining agents for contrast-enhanced microfocus computed tomography of biological tissues. Acta Biomater. 105, 253–262. https://doi.org/10.1016/j.actbio.2020.01.038

di Biase, A., Kowalski, M.S., Devlin, T.R., Oleszkiewicz, J.A., 2019. Moving bed biofilm reactor technology in municipal wastewater treatment: A review. J. Environ. Manage. 247, 849–866. https://doi.org/10.1016/j.jenvman.2019.06.053

Ebigbo, A., Helmig, R., Cunningham, A.B., Class, H., Gerlach, R., 2010. Modelling biofilm growth in the presence of carbon dioxide and water flow in the subsurface. Adv. Water Resour. 33, 762–781. https://doi.org/10.1016/j.advwatres.2010.04.004

Iltis, G.C., Armstrong, R.T., Jansik, D.P., Wood, B.D., Wildenschild, D., 2011. Imaging biofilm architecture within porous media using synchrotron-based X-ray computed microtomography. Water Resour. Res. 47. https://doi.org/10.1029/2010WR009410

Masschaele, B., Dierick, M., Loo, D. Van, Boone, M.N., Brabant, L., Pauwels, E., Cnudde, V., Hoorebeke, L. Van, 2013. HECTOR: A 240kV micro-CT setup optimized for research. J. Phys. Conf. Ser. 463, 012012. https://doi.org/10.1088/1742-6596/463/1/012012

Meckenstock, R.U., Elsner, M., Griebler, C., Lueders, T., Stumpp, C., Aamand, J., Agathos, S.N., Albrechtsen, H.-J., Bastiaens, L., Bjerg, P.L., Boon, N., Dejonghe, W., Huang, W.E., Schmidt, S.I., Smolders, E., Sørensen, S.R., Springael, D., van Breukelen, B.M., 2015. Biodegradation: Updating the Concepts of Control for Microbial Cleanup in Contaminated Aquifers. Environ. Sci. Technol. 49, 7073–7081. https://doi.org/10.1021/acs.est.5b00715

Miller, A.Z., Sanmartín, P., Pereira-Pardo, L., Dionísio, A., Saiz-Jimenez, C., Macedo, M.F., Prieto, B., 2012. Bioreceptivity of building stones: A review. Sci. Total Environ. 426, 1–12. https://doi.org/10.1016/j.scitotenv.2012.03.026

Rolland du Roscoat, S., Martins, J.M.F., Séchet, P., Vince, E., Latil, P., Geindreau, C., 2014. Application of synchrotron X-ray microtomography for visualizing bacterial biofilms 3D microstructure in porous media. Biotechnol. Bioeng. 111, 1265–1271. https://doi.org/10.1002/bit.25168

Time Block Preference

Time Block A (09:00-12:00 CET)

Participation

In person

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