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Implication of Biofilm on the Biodeterioration of Cementitious Materials under Anaerobic Digestion Conditions

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1 Introduction

Anaerobic digestion is a process where organic matter is degraded while producing two products of interest: the biogas and the digestate. The digestate can be used as a fertilizer for agriculture and the biogas has an energetic interest as it can either be burned to produce heat and/or electricity or be processed into natural gas or biofuel. Usually anaerobic digestion tanks are made in concrete. Furthermore, it is known that some chemical components, produced by the microorganisms during the anaerobic digestion process, are aggressive towards cementitious materials. Those components are the volatile fatty acids, the ammonium and the carbon dioxide (Voegel et al., 2016). It is also suspected that the occurrence of microorganisms forming a biofilm attached to the concrete is responsible of increasing the deterioration kinetics.

Even if the mechanisms behind this catalytic effect are not well known, it is expected that the biofilm activity is locally increasing the concentrations of aggressive components (Bertron, 2014; Magniont et al., 2011). Our goal is then to understand and evaluate the specific role of biofilms in the biodeterioration of cementitious materials during an anaerobic digestion process. More precisely, we wanted to give more insights in the spatial and temporal heterogeneity of the biofilm, and link it with the biodeterioration observed.

For that, CEM I Portland cement paste pellets were immerged in cultures mimicking industrial anaerobic digestion conditions during 2, 3, 4 and 5 weeks. Those cultures were made of synthetical biowaste inoculated with activated sludge. The pellets were then taken out and both the paste and the biofilm were analysed (Fig. 1). The spatial heterogeneity of the biofilms is evaluated through successive chemical removal of the biofilm layer. The microbial population of each layer was determined through 16S RNA sequencing. The concentration of the aggressive components (ammonium ions, total inorganic carbon and volatile fatty acids) at 2, 3, 4 and 5 weeks was measured. The biodeterioration of cementitious pellets was evaluated using SEM/EDS observations.

The deterioration profile of the cement paste immerged for 2, 3, 4 and 5 weeks was roughly the same: 4 deteriorated zones and the sound paste. Only the thickness of the deteriorated zones was changing from one duration of exposition to another while their composition was similar from one exposition time to another. The first zone had a thickness of about 100 µm and was devoid of calcium with as well higher proportions of silicon aluminum and phosphor than the sound paste. The second zone was very thin, about 25 µm, and enriched in calcium while impoverished in silicon. Finally, the thickness of third and fourth zones was very heterogeneous, from 100 µm to 400 µm, while having a composition close to that of the sound paste. It seems that the global thickness of the biodeteriorated zone is increasing over time, but observations on pellets immerged in longer time are necessary to confirm that tendency.

Microbial analyses showed that the liquid media had higher concentrations of microorganisms involved in the methanogenesis, mainly the archaea genus *methanosarcina*, which represent about 18% of the detected species in the media. Concerning the biofilm populations, about 50% of the detected species in the most deepest layer of the biofilm were acidogens, such as the genus *Clostridium*. This heterogeneity between sessile and planktonic biomass could be a lead to explain the biofouling effect of the biofilm since, as suspected, the higher proportion of acidogens in the biofilm could locally increase the concentrations of volatile fatty acids inside the biofilm.

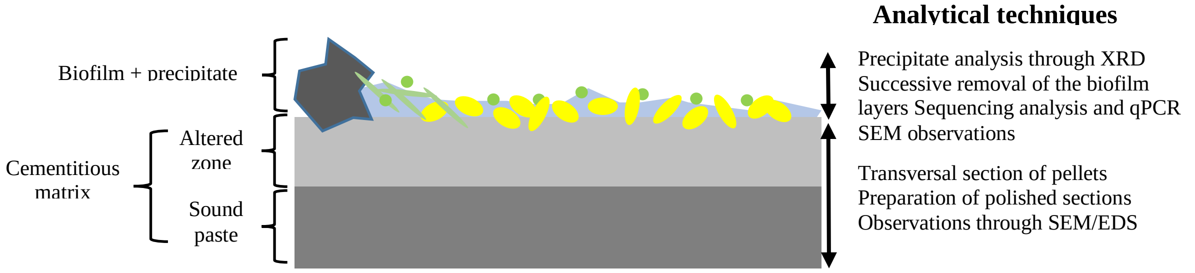

Figure 1. Synthesis of the analytical techniques used.

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References

Bertron, A. (2014). Understanding interactions between cementitious materials and microorganisms: a key to sustainable and safe concrete structures in various contexts. *Materials and Structures*, *47*(11), 1787–1806. https://doi.org/10.1617/s11527-014-0433-1

Magniont, C., Coutand, M., Bertron, A., Cameleyre, X., Lafforgue, C., Beaufort, S., and Escadeillas, G. (2011). A new test method to assess the bacterial deterioration of cementitious materials. *Cement and Concrete Research*, *41*(4), 429–438. https://doi.org/10.1016/j.cemconres.2011.01.014

Voegel, C., Bertron, A., and Erable, B. (2016). Mechanisms of cementitious material deterioration in biogas digester. *Science of The Total Environment*, *571*, 892–901. https://doi.org/10.1016/j.scitotenv.2016.07.072