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Microbial biofilms' microenvironments and metals cycling in the Seine River, France

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Microorganisms constitute a highly reactive compartment known to partly control metal(loid)s cycling in environmental systems. There, they are usually organized as biofilms where microbial cells are encased in a self-secreted exopolymeric matrix. Moreover, these particular structures exhibit gel-like properties that result in transport limited conditions for chemical elements and metabolites, and generate microenvironments of very specific physico-chemical conditions. Several lab studies demonstrated that these microenvironments constituted a major part of biofilms reactivity, by favoring biomineralization processes through local oversaturation or by modifying local redox conditions. However, whereas being crucial, this information remains poorly documented in the field, impairing an accurate quantification of the real impacts of such microbial colonies on metal cycling in continental environments.

To better constrain their environmental impact toward metals cycling, 4 biofilms were sampled in the Seine River (France) following an “anthropogenic” gradient. Colonization substrates were immerged upstream and downstream Paris, after a major wastewater treatment plant (accounting for 60% of Paris wastewaters), and immediately before the Seine estuary, for 5 months. Metabarcoding analysis showed a loss in microbial diversity along the transect. The overall mineralogy, indicated by powder X-ray diffraction, is dominated by calcite and clays. In addition, SEM-EDS analysis show the widespread presence of framboidal pyrites, indicating occurrences of reductive microenvironments. Simultaneously, Mn precipitates of tenth of nm clustered in what appear to be pockets of precipitation (*in situ*neo-formation rather than exogeneous origin), were observed, sometimes only few tenth of µm apart from pyrites. Identified as potential Mn oxides, and given the high redox potential associated to Mn species, these minerals could thus indicate the presence of highly oxidative areas within the biofilm thickness. Chemical analysis showed a strong metal(loid)s enrichment in all biofilms compared to the corresponding water column for all 55 chemical elements investigated. Particularly, Fe and Mn enrichment factors ranged between 5 to 7 orders of magnitude, demonstrating the importance of biofilms for metal cycling in the Seine River. Moreover, our results suggest that redox reactions within these microbial micro-environments may influence sequestration mechanisms of redox-sensitive elements.