Modelling Microenvironments Generated by Biofilms in Copper Drinking Water Pipes

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Copper is widely used as a plumbing material around the world. Although copper has antibacterial properties some bacteria can grow on copper surfaces and they may produce biocorrosion. Biocorrosion can cause two problems 1) it may enhance copper release to the drinking water generating health issues and 2) it produces pits which destroy the pipe making it useless.

The mechanism by which biofilms produce pits on copper pipes have been typically thought to be a local acidification of the environment. The pH gradient and its dynamics inside microbial biofilms are still open questions in biocorrosion research. Although there are some experience using microelectrodes in marine biofilms, to our knowledge, there is a lack of information about pH behavior inside biofilms formed in drinking water systems. Drinking water typically has low organic carbon content (compared with marine environments), reducing biofilm metabolism and its acidification effect. In consequence, pitting corrosion due to biofilm formation should be the result of the sum of different processes (i.e. metal ion complexation, differential aeration, ion migration) catalyzed by microorganisms occurring at the metal-liquid interface.

In this study, we developed a mathematical model of copper biocorrosion to study the microenvironment generated by heterotrophic biofilms within copper pipes in drinking water systems. We simulated different biofilms sizes, shapes and anode/cathode ratio; analyzing the global effect on pH due to: organic acid production (metabolism), ion migration, copper ions complexation and copper speciation below the biofilms. The results suggest that thin biofilms (less than 10 μm) can produce lower pH due to the diffusion limitation of organic carbon, the acidification by the metabolism alone may not lower the pH more than 1 point, not being enough to initiate pitting. Finally, simulations suggest that the capacity of the biofilm biomass to complex metals is a key mechanism of localized pH acidification.