Natural Moderation of Biofouling Formation by Exposure of Bacteria to Silver Nanoparticles

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Abstract

Biofouling is the undesired deposition, of microorganisms and their extracellular polymeric substrates (EPS) on surfaces [Flemming, 2002]. Controlling of biofouling and its negative effects on process performance of water systems is a crucial operation challenge in all of the water sectors including pipes, water distribution systems, filtration processes, cooling facilities and power plants. Common treatments in use for prevent or removal of biofouling include the use of oxidative disinfectants, minimizing nutrients in the feed, altering surface materials to prevent the development of the biofouling, or clean-in place (CIP) technique to remove a mature biofouling. Limitations such as production of by-products, low effective against specific microorganisms and development of tolerance, damage to system materials and more, have given a rise to consider alternatives techniques. In this study a treatment technique based on application of silver nanoparticles in the water for moderating biofouling built-up, is presented.

Silver nanoparticles are considered as a new class of materials that can be used in a broad range of biocide applications associated with microbial activity [Shrivastava et al., 2007]. For example, silver nanoparticles coated on catheters reported to reduce biofouling development [Roe et al., 2008] and few types of filtration membrane incorporated silver nanoparticles have demonstrated anti-biofouling properties [Lee et al., 2007; Zodrow et al., 2009].

The main goal of this study was to determine the ability of suspended silver nanoparticles produced in the research, to control biofouling formation in an aqueous environment. The treatment with silver nanoparticles was aimed at controlling or retarding biofouling built-up on surfaces in water; it was not meant as a treatment for the eradication of existing or mature

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biofouling or as a disinfection process. The approach herein is to induce interaction of bacterial cells with nanoparticles prior to their influent into the water system and impact the cells' ability to build-up biofouling.

To assess the effect of exposure to silver nanoparticles on biofouling formation, a screening method, quantifying the attached biomass to round-bottomed 96-well microtiter plates, was used. The method allows comparisons of various treatments, including incubation periods, presence and concentrations of the nanoparticles and cell concentrations, under the same environmental conditions. Results showed that a model Pseudomonas aeruginosa cells that were exposed to silver nanoparticles at a concentration of 45 μg/mL formed only 21-23 percentage of biofouling compared to the 100% of the control (non-exposed cells). To examine whether these results were outcome of decreases in the initial number of planktonic cells in the wells, the non-exposed cells were serially diluted to equal the amount of cells that survived the treatment with the nanoparticles. It was found that the diluted control bacteria reached the same relative biomass as the original non-diluted control after long incubation, whereas the exposed cells maintained their lower relative biomass, even under long incubation. In TEM HPH/freeze microscopy, the exposed cells appeared well preserved, but the intracellular material seemed to have been pushed to their periphery, possibly as a survival strategy.

The impact of exposure to silver nanoparticles on biofouling build-up was also tested in a dead-end ultra-filtration membrane apparatus operated under constant pressure; by tracing the alterations in permeate flux over time. In these experiments exposed or control P. aeruginosa cells were (a) seeded on a membrane preceded to sequential filtering of growth medium for 2.5 days and (b) filtered with the growth medium in the presence or absence of silver nnoparticles for 4 days. In both experimental methods, exposed samples resulted in a lower flux decline compare to respective control, improving the performance of the filtering process. SEM micrographs of the membranes showed biofouling growth on control membrane and scattered individual cells on treated membrane. In all of the experiments, exposure to Ag-NPs impacts the production of EPS and attachment of bacterial cells to the surface.

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