Impact of water treatment on biological stability in drinking water distribution networks

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1. Introduction

Uncontrolled microbial growth in drinking water distribution systems can cause turbid or colored water and exceedance of regulatory guidelines for microbial parameters. This is particularly relevant where drinking water is distributed without a disinfectant residual. In this study, two treatment facilities in the Netherlands and their connected distribution systems were compared. In distribution System A, repeated issues were experienced related to discolored water and exceedance of the Dutch *Aeromonas* guideline, while only occasional issues were experienced in System B. Customer complaints about discolored water and *Aeromonas* growth in the distribution system are both linked with the presence of sediments deposited in the distribution pipes [1,2]. Therefore, to mitigate issues experienced in System A, intensive pipe flushing effort is required. However, these mitigation actions to remove sediments from the pipes have only temporary effect. To identify factors controlling sediment formation in the distribution network is needed to define longer-term mitigation solutions.

Here we present a summary of findings obtained over 10 years of research on sediment formation mechanisms [3]. Both systems A and B were studied to compare a biological unstable with a biological stable system. The results have led to a proposal for mitigation solutions at treatment level. Alternative treatment trains are currently tested on a pilot scale, and preliminary results are included.

2. Materials and methods

The two treatment facilities produce drinking water from the same eutrophic lake, but with different treatment strategies. System A applies a direct treatment including two parallel pre-treatments, followed by advanced oxidation (H_2O_2/UV), activated carbon filtration and micro-sieving (35 µm). A low concentration of chlorine dioxide is dosed in the final water (0.01 mg/L) but is not maintained in the distribution network. System B includes artificial infiltration of pre-treated water via the sand dunes, followed by aeration, rapid sand filtration and UV disinfection. Part of the pre-treated water goes through ultrafiltration and reverse osmosis before mixing (40%) with the UV effluent.

Sediment formation dynamics were studied by placing 35 µm filters connected to distribution pipes 1) at one single location to study temporal dynamics for 10 years (system A only); 2) at several locations with increasing residence times to study spatial dynamics over one year (systems A and B). The filters were replaced weekly and brought to the laboratory for microscopic observation of the collected sediment (composition and counting of zooplankton). Besides, detailed chemical (FTIR, XRD) and microbiological (metaproteomics) analysis were performed on a selection of sediment samples.

To investigate the differences in microbial water quality produced by systems A and B, microbiological parameters such as cell counting by flow cytometry, and adenosine triphosphate (ATP) were monitored over several years at the treatment effluents and at various locations in the distribution networks.

3. Results

The volume of sediment collected in the filters displayed seasonal variations, that were congruent with temperature, *Aeromonas* concentrations in the water, and biomass of zooplankton present in the sediment. Numerous zooplankton were found in the sediment samples, among which the large isopod *Asellus aquaticus*. The sediment further contained detritus and *Asellus* feces. Chemical analysis indicated presence of proteins and compounds originating from biomineralization, while metaproteomic analysis indicated the presence of filamentous bacteria, EPS producers and iron and manganese oxidizers. Overall, all results point out that sediment formation is driven by microbiological activity.

Comparison of systems A and B showed that sediment was not released by the treatment but formed along both distribution systems, with sediment volumes and biomass of zooplankton higher in system A than in system B at locations with similar residence times. This result highlighted that microbiological-driven sediment formation in the distribution network is controlled by the water quality of the produced water. Further analysis of flow cytometry data in the distribution network confirmed clear bacterial growth in system A, while limited growth was observed in system B.

Comparison of water qualities at the treatment facilities A and B showed higher concentrations of assimilable organic carbon (AOC) and of biopolymers in system A (AOC = 15 µg C/L and biopolymers = 98 µg/L yearly averages) than in system B (AOC = 5 µg C/L and biopolymers = 8 µg/L). Besides, system B provides stable water quality over the year (e.g. ATP = 2 ng/L all along the year), due to the dune infiltration, while system A displays large seasonal variations in ATP concentrations, with peak values significantly higher than in system B (e.g. ATP up to 7 ng/L). The differences in water quality are attributed to dune infiltration, along with parallel membrane filtration, that both drastically decrease the content of organic matter in system B, compared to the direct treatment in system A. Besides, the addition of chlorine dioxide in system A also increases the risk of producing additional assimilable organic carbon.

4. Conclusions and follow-up

The results indicate that 1) sediment formation in the distribution system is caused by microbiological processes in the distribution system and 2) water quality at the treatment effluent is the main driver for microbiological growth in the system. Alternative treatment trains should decrease biodegradable organic matter, particles and zooplankton to improve biological stability of the produced water.

Two alternative treatment trains were proposed for system A, one applying slow sand filter as a polishing step, the other applying a parallel UF/RO line to the current treatment, to mimic treatment conditions of system B. Both treatments are tested at pilot scale for the produced water quality (e.g. organic matter and microbiology) and for microbiological growth under dynamic conditions in distribution pipe loops. Preliminary results show that both alternative treatments decrease the concentrations of biodegradable organic matter, compared to the current treatment, and decrease the biofilm formation in the pipe loops.

References:

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