

Popular science summary

Access to safe and clean drinking water by opening a tap is something many people take for granted. Our whole society is dependent on water. Each day we use it for a range of activities, and it is essential for various industries such as food and agriculture. This means that a constant production of water is crucial to ensure public health and a functioning society, making the drinking water system of treatment plants and distribution systems a crucial part of our civilization. This system of treatment and delivery needs to be prepared to meet challenges in the future, including those from climate change. Weather changes such as heavy rainfall and flooding will increase harmful microorganisms, so called pathogens, in the source waters and may cause more frequent outbreaks of waterborne illness. Increasing temperatures will favour growth of pathogens as well as microorganisms in the water that could affect taste and odour. These changes will demand more effective and advanced treatment of the water to ensure that consumers receive the same quality of drinking water as they do today.

Safe drinking water should always be free from pathogens, but this is not the same as saying that it needs to be completely free from all microorganisms. The drinking water treatment plant consists of multiple processes to remove and kill harmful microbes in the water, such as filtration and disinfection, but there will always be a community of microorganisms present. In fact, one millilitre of safe drinking water can contain anywhere from around one thousand, to several hundred thousands, bacteria. Every process in the treatment plant, and in the pipes of the distribution system, have the potential to change this microbial community. Currently, these changes are not controlled due to a lack of understanding, and as the living component in our drinking water, we need to understand factors that change this microbial community to be able to control it, and prepare it for, the future.

Many microorganisms also live in biofilms on the surface in the distribution system and on particles in the biofilters of the treatment plant. The biofilm is constantly in contact with the water and can cause problems by clogging filters, causing corrosion of pipes and produce compounds causing discoloration, unpleasant taste, or odour of the water. Pathogens can also hide in the biofilm and contaminate the flowing water. However, the microbial community in the biofilm can also clean the water by consuming contaminants as nutrients, making it difficult for unwanted microorganisms to live in the water. Since biofilms can be both harmful and useful for drinking water production, we need to understand the many details about how biofilm in drinking water systems affects the drinking water microbiome. In this thesis, processes governing the drinking water microbiome were explored. The interactions of the biofilm community in full-scale biofilters and a full-scale distribution system, were investigated to pinpoint important factors that can impact the drinking water microbiome.

In this thesis, the contribution of the distribution biofilm to the drinking water microbiome was investigated by counting and identifying the bacteria released from the biofilm, as water moved through a distribution system. This was possible because the microorganisms normally entering from the treatment plant were removed by installation of ultrafiltration. This new ultrafilter in the treatment plant changed the origin of the drinking water microbiome from the treatment plant to the distribution system. This also means that without ultrafiltration to remove the majority of the microorganisms in the water, the treatment plant had the greatest ability to influence the water microbiome compared to the distribution system.

In the treatment plant, slow sand filters were investigated to see how different age, sand composition and maintenance of the filters affected the biofilm community and the water microbiome governed by these filters. An established slow sand filter showed a robust function, with no passage of *Escherichia coli* and coliforms, good removal of organic carbon and consistent

transformation of the water microbiome. This function was not disrupted by maintenance, suggesting that the function of slow sand filters is both removal of harmful bacteria and transformation of the water microbiome. Two new slow sand filters did not have this behaviour, although the new filter that contained washed sand from other filters in the treatment plant developed over time to be similar to the older, established filter. This included a similar bacterial community on the surface of the sand bed and lower *E. coli* and coliforms in the water passing through. This identified the importance of the biofilm community in the sand for filter function and the drinking water microbiome, as well as the value of using adapted sand to build new filters.

Flow cytometry and DNA sequencing was used to characterise the water microbiome. These methods were compared and the suitability of flow cytometry for monitoring and optimising biological treatment of drinking water was shown. To be able to meet the future challenges in the drinking water industry these rapid methods and analysis tools, to follow and monitor the water microbiome, are required to optimise and control water treatment and distribution in the future, ensuring continued access and supply safe drinking water to consumers.