ATP measurements for monitoring microbial drinking water quality

Current standard methods for surveillance of microbial drinking water quality are culture based, which are laborious and time-consuming, where results not are available before one to three days after sampling. This means that the water may have been consumed before results on deteriorated water quality or potential contaminations are available. Moreover, the low frequency of grab sampling will most likely not even detect short-term contaminations. Methodology and instrumentation for rapid detection and quantification of microorganisms have advanced significantly over the past decades. Such rapid methods are vital for an improved surveillance and distribution of clean and safe drinking water. One of these rapid methods is the ATP assay. This thesis encompasses various methodological aspects of the ATP assay describing the principal and theory of the ATP assay measurement. ATP is the main energy carrying molecule in living cells, thus ATP can be used as a parameter for microbial activity. ATP is extracted from cells through cell lysis and subsequently assayed with the luciferase enzyme and its substrate luciferin, resulting in bioluminescence, i.e. light emission which can be quantified. The overall aim of this PhD study was to investigate various methodological features of the ATP assay for a potential implementation on a sensor platform as a real-time parameter for continuous on-line monitoring of microbial drinking water quality.

Commercial reagents are commonly used to determine ATP in drinking water. For on-line continuous real-time monitoring it is essential to choose an adequate enzyme reagent in terms of limit of detection, stability in catalytic activity and an efficient extraction of microbial ATP from cells. Experiments with different types of commercial and R&D reagents for the ATP assay demonstrated differences in previously mentioned features, which all are required for a successful ATP measurement.

The ATP assay has been used to measure and quantify the active biomass in drinking water systems in numerous studies – as a parameter for treatment processes at waterworks, microbial quality in distributed water, detection of aftergrowth, biofilm formation etc.

This PhD project demonstrated that ATP levels are relatively low and fairly stable in drinking water without chlorine residual despite different sampling locations, different drinking water systems and time of year of sampling. Moreover, microbial ATP – opposed to total ATP – was also evaluated to be a more accurate and dynamic parameter for monitoring microbial drinking water quality. The ATP assay also proved capable in detecting microbial ingress in drinking water by wastewater and surface water contaminants. These findings advocate the use of ATP as a real-time parameter for continuous on-line monitoring, where sudden and significant changes in microbial drinking water quality can be detected.

Initial experiments with an ATP sensor prototype for continuous real-time monitoring of drinking water definitely demonstrated a potential, with reproducibility in time-series on microbial activity in tap water monitored over the same time period on multiple days. Concerns related to the ATP sensor prototype were mainly mechanical instability and not the ATP assay itself. The use of rapid methods, such as ATP, will most likely increase the extent and quality of monitoring microbial drinking water quality, where several of the existing methods have prospects to further automation and implementation on sensor platforms.