Development of Automated Water Quality Monitoring Techniques for Producing Safe Drinking Water

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From the water source to the produced drinking water, water treatment plants have developed different treatment trains to deliver quality drinking water. However, many challenges remain. We developed three monitoring techniques. First, a facile method for counting odor-producing algae (*Pseudanabaena* sp.) in water source was designed to enhance the quality of drinking water. Then to improve microbial safety, the reliability of a real-time bacteriological counter coupled with an online dialysis membrane-based pre-treatment system was evaluated. Lastly, we developed a nanofiltration membrane-based pre-treatment system for continuously analyzing the concentrations of bromate ions in treated wastewater.

For many drinking water utilities, predicting odor occurrence in drinking water sources is a major challenge. *Pseudanabaena* sp. was found to be responsible for odor peak at low level concentration in lake water. It can be used as a surrogate indicator for 2-methylisoborneol (2-MIB) concentration in lake water. The fluorescence emitted by chlorophyll was relatively weak and uniform throughout the cells for cyanobacteria like *Pseudanabaena* sp., whereas other algae such as diatoms and green algae showed highly variable auto-fluorescence intensity in their cells. This difference of fluorescence intensity allowed us to discriminate cyanobacteria from all other algae. Among cyanobacteria, the length and width of *Pseudanabaena* sp. were unique; thus, dimensions and fluorescence intensity were the criteria selected to recognize only *Pseudanabaena* sp. among algae. The developed auto-counting method was successfully validated. Manually and automatically counted *Pseudanabaena* sp. in lake water samples were highly correlated. Although the developed method can overestimate *Pseudanabaena* sp. counts due to the presence of other similar-sized algae, this facile method permits frequent on-site analysis by water treatment plant workers without analytical skills. Providing early warnings of potential 2-MIB occurrence enables the drinking water treatment plants to take suitable precautionary countermeasures.

Real-time bacteriological counting technology is capable of providing an online profile of bacterial removal during the water treatment process, and can enhance the safety of water. However, dissolved organic compounds present in treated wastewater and freshwaters have strong autofluorescence, interfering with the analysis by masking the weak auto-fluorescence emitted from bacteria. Then the reliability of real-time bacteriological counter coupled with an online dialysis membrane-based pre-treatment system was evaluated for continuous monitoring bacterial counts in sand filter effluents of a full-scale drinking water treatment plant. The pre-treatment system, which included anion exchange resins for dialysate regeneration, successfully achieved the stable attenuation of background interfering substances (humic acids) during 19 d. The real-time bacteriological counter equipped with the pre-treatment system provided a continuous profile of bacterial counts in the sand filter effluent ($0.2–2.5\times10^4$ counts/mL). The online analysis identified different timing of concentration peaks between particle and bacterial counts after backwashing. In addition to bacterial monitoring, the versatility of the real-time monitoring system was also manually analyzed. Bacterial community analysis revealed that Proteobacteria, Planctomycetes, and Cyanobacteria were the dominating phyla, which was the same as expected according to previous studies. Further, total bacterial counts determined by fluorescence microscopy and SYBR® Green I staining was found to be an indicator of online-monitored bacterial counts. The results indicated the potential of the real-time bacteriological counter for providing an early warning of filter failures.

Continuous monitoring of bromate ions, a disinfection by-product of the ozonation of wastewater, may improve the safety of recycled water for potable use. A recently developed elemental analyzer can determine bromate ion concentrations online. However, dissolved organics present in wastewater interfere with the detection of bromate ions. The aim of this study was to develop a nanofiltration (NF) membrane-based pre-treatment system to remove the interfering substances present in treated wastewater prior to the online analysis. The NF pre-treatment system was optimized to ensure the removal of the interfering substances from the membrane bioreactor (MBR)-treated wastewater without altering the bromate ion concentration. We determined a permeate flux of 1 L/m^2 h and a feed temperature of 35 °C as optimal pre-treatment conditions for online analysis. Furthermore, the continuous monitoring of MBR-treated wastewater, containing different bromate ion concentrations (0–12 μg/L), for three days revealed a strong correlation between the concentrations determined using the online analyzer and liquid chromatography coupled with tandem mass spectrometry. Thus, this study demonstrates the potential utility of the online bromate ion analyzer coupled with NF pre-treatment system to monitor the rate of bromate ion formation during ozonation.