Is There a Fluorescent Disinfection Residual Following UV Treatment of Drinking Water?

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Abstract: Ultraviolet (UV) irradiation is a cost-effective disinfection process commonly used prior to chemical disinfection in order to inactivate resistant microorganisms to chemical disinfectants. The irradiated UV light is absorbed not only by microorganisms, but also by the dissolved organic matter (DOM) pool present in the water, leading to changes in DOM molecular structures and optical properties. In this study, changes in optical properties, particularly fluorescence, were studied upon the UV irradiation at 254 nm. The intensities of fluorescence peaks changed in linear fashion by increasing UV dose in the levels of irradiation (< 180 mJ/cm^2) typically used for drinking water disinfection.

Keywords: UV disinfection- dissolved organic matter- Fluorescence spectroscopy

Ultraviolet (UV) irradiation is increasingly used as a primary disinfection process to inactivate the pathogenic microorganisms which are resistance to chlor(amin)ation such as *Giardia lamblia* cysts and *cryptosporidium.* The inactivation of microorganisms by UV is the results of damaged nucleic acid of the cell or virus upon the absorption of UV light within the germicidal wavelength range (UV-C: 240-280 nm) (Hijnen, Beerendonk, & Medema, 2006). In addition to the effect of UV disinfection on the growth and reproducibility of pathogenic microorganism, applying UV disinfection prior to chemical disinfection reduces the required dose of disinfectant (EPA, 1999).

The performance of UV disinfection is assessed by its efficiency to inactivate pathogenic microorganism (Lyon, Cory, & Weinberg, 2014). Opposite to chlor(amin)ation, UV disinfection does not leave any chemical residual, therefore, there is no mean to continuously monitor the performance of the process. Thus, verification of UV system to check if it provides the required UV dose to achieve desired log inactivation for target pathogens is essential for UV disinfection process. The theoretical UV dose is calculated by multiplying the intensity of the UV light and residence time of water inside the UV chamber. Due to complexity of the reactor's hydraulic and water trajectory, the irradiation time and intensity varies at different points. Moreover, aging the UV sensors installed inside the UV chamber causes imprecise measurement of UV intensity (EPA, 1999). Therefore, the light dose applied by UV systems should be validated in treatment plants. There are validation standards based on biodosimetry (EPA, 2011) which is time consuming and requires shutting down the UV system. Thus, there is a need for a fast and easy method for monitoring the UV dose applied during the disinfection process.

Absorption of photons by dissolved organic matter (DOM) in water may lead to changes in the construction of DOM. The degree to which the structure of organic matter modifies upon light absorption depends on both the characteristics of UV irradiation, including wavelength and applied dose and characteristics of organic matter in water including the composition and concentration. The influence of UV irradiation on organic matter composition at the dose level applied for disinfection process has been reported (Lyon et al., 2014), however not quantified due to the subtle changes occurring in DOM composition upon low doses of UV irradiation.

Fluorescence spectroscopy is a fast and sensitive technique providing information about the composition and concentration of DOM pool in aquatic system. Although, fluorescence spectroscopy has been vastly used to study the reactivity of DOM with the disinfectant during chlor(am)ination and predict the BDPs formation, its sensitivity to detect the subtle changes to DOM optical properties due to UV irradiation within doses applied during disinfection is unknown. If there is a relationship between the changes in DOM fluorescence and UV dose, it could be used as a proxy for the UV dose and ultimately enable us to monitor the performance of UV disinfection.

In the current study, fluorescence spectroscopy was used to measure changes in DOM optical properties due to UV irradiation at 254 nm, which is the typical germicidal wavelength applied during disinfection. The irradiation experiments were performed using a mercury UV light source on the drinking water samples collected before UV disinfection process (after filtration) from different treatment plants in Sweden. Linear relationships were observed between the intensities of fluorescence peaks and UV dose at the level normally used for drinking water disinfection (< 180 mJ/cm^2). The linear relationship between the ratios of two fluorescence peaks (Ex/Em: 400/500 and 320/420 nm) and the UV dose is shown in Figure 1. This suggests that DOM fluorescence is a potential proxy of the UV dose applied during disinfection. Tracking the effect of UV irradiation on DOM optical properties could help us to predict disinfection effectiveness on microorganisms.

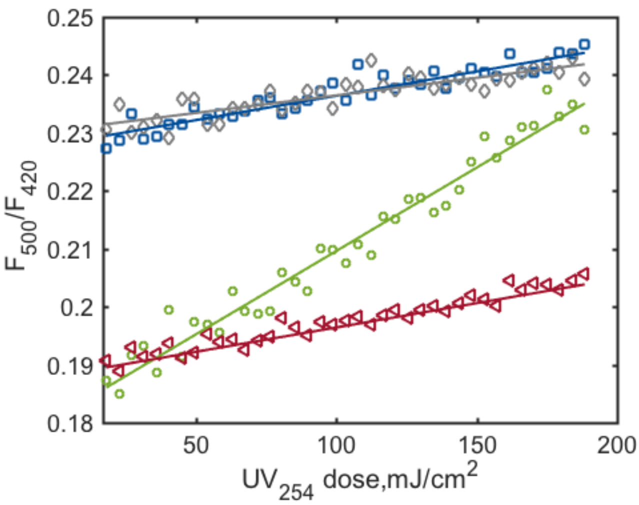

Figure 1. Changes in the ratios of raw fluorescence intensities (RU) at two specific wavelength pairs at low UV_{254} doses. F_{500}: (Ex/Em: 400/500 nm) / F_{420} (Ex/Em: 320/420 nm). Results are shown for drinking water samples collected from four treatment plants: Alelyckan (green circle), Sydvatten (blue square), Norrvatten (red triangle), Mölndal (grey diamond). R^2 values are: 0.92, 0.88, 0.94 and 0.74, respectively.

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