Ultraviolet Microfluidic treatment of Colored and Fluorescent Dissolved Organic Matter

R. Lopes[1,2, †], H. Schütte[1], M. L. Miranda[2,3], S. Gassmann[1], O. Zielinski[2]

[1]Jade University of Applied Sciences, Department of Engineering, Wilhelmshaven, Germany
[2]Carl von Ossietzky Oldenburg University, ICBM, Wilhelmshaven, Germany
[3]Air and Water Quality Laboratory, University of Panama, 0824 Panama, Republic of Panama
† **Corresponding Author**: raquel.lopes@jade-hs.de

Abstract

Using microfluidic systems to address the optical properties of dissolved organic matter (DOM) offers new ways for investigating its interactions with the environment. Here, we present a microfluidic system which applies ultraviolet light (UV) under controlled temperatures to treat DOM samples. As a substantial part of dissolved organic carbon both in fresh and coastal waters colored dissolved organic matter (CDOM) has a strong influence on the subsea optical conditions. Through selected absorption of lower wavelengths it limits light availability for photosynthesis, at the same time protecting from harmful UV irradiation. A fraction of CDOM that emits photons of different wavelengths is called fluorescent dissolved organic matter (FDOM), and can be used as a tracer of DOM changes (Miranda, et al., 2018; Zielinski & Watson, 2013). CDOM / FDOM typical composition includes lignin, humic and fulvic acids, proteins and amino acids residues. However, molecular weight and composition can differ accordingly with the geographical location, local development of human activities and industries (Coble, 2007; Miranda et al. 2016).

UV radiation and temperature are two factors affecting CDOM and FDOM alike. UV radiation is present in the sun, where only 50% of UVA (315 nm to 400 nm) and 10% of UVB (298 nm to 315 nm) pass through the ozone layer and interact with CDOM in the water column, causing an effect known as photo-bleaching. This process involves CDOM decomposition and production of carbon dioxide as well as several small organic molecules, the latter as a potential carbon source for microbes (Gaughan, 2017; Zielinski & Watson, 2013). In addition, the increase of temperature is known to decreases the intensity in FDOM fluorescence as a result of quenching (Downing et al. 2012; Coble, 2007).

Microfluidic systems are a technology that offers many advantages, such as high resolution and sensitivity, low costs and short analysis time due to the use of small samples (Whitesides, 2006). Gassmann and his colleagues 2015 created a microfluidic system with the intend of treating the sample with temperature gradients, using two temperature zones with a range from 4ºC to 20ºC for the cold zone and 20ºC to 90ºC for the hot zone, so that the sample would cycle between zones in a user determined time and cycles. Herein we utilized this system and adapted it to integrate an UV LED illumination as an additional treatment.

The UV microfluidic system uses a micro milled channel using a UV transmitting PMMA bonded to a PMMA film. This is then glued to a printed circuited board (PCB), which is the connection to the electronic elements. The LED board has two UV-LEDs with different wavelengths, 340 nm and 280 nm, creating two zones, UVA zone and UVB zone, respectively. The LED board is positioned on top of the channel connect to the PCB with pin heads as shown in the right panel of Fig. 1. The PCB is connected to other electrical components where LEDs can be switched on or off individually and temperature values can be controlled in both zones from 4ºC to 90ºC, independently. The PCB has two temperature sensors to ensure the right temperature is being applied by the Peltier Elements, which are incorporated in milled pockets to decrease the heat resistance. An external syringe pump is connected to a user interface. The latter controls the time in each zone and the number of cycles.

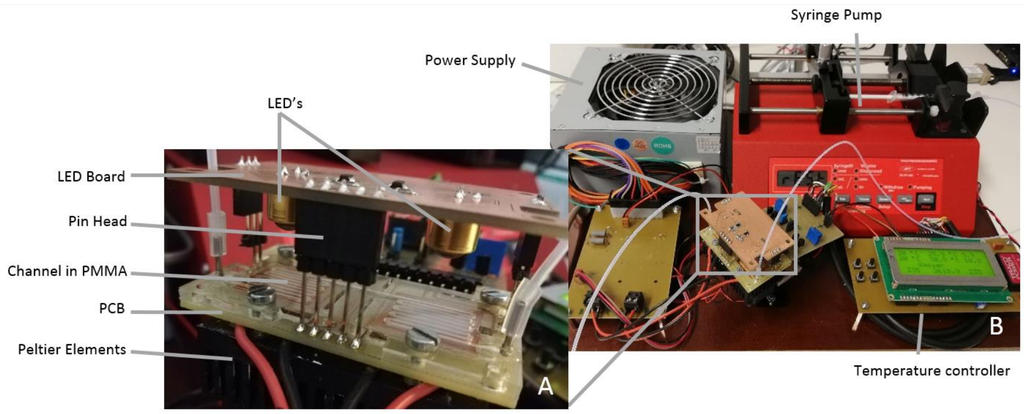

Fig. 1–A) Close up of the microfluidic chip with the LED board; B) Microfluidic System

After the treatment of natural water samples from Jade Bay (southern North Sea), data acquired for the absorbance (Shimadzu UV 2700) and fluorescence (Perkin Elmer LS55) were analyzed with drEEMs / PARAFAC (Murphy et al., 2013) to investigate the effect of the UV irradiation on the DOM optical active components. We aim to understand the difference between the individual treatments and the combined effect of UVA and UVB on the sample, while temperature is controlled to avoid heating from the LEDs. The overall aim of this research is to study the changes caused by UV radiation on CDOM and FDOM properties. The microfluidic system was designed to create controlled, highly reproducible conditions while reducing the time needed for the transformation of DOM as caused by UV radiation, helping to understand the CO2 production process from photo oxidation.

References :

Coble, P. (2007). Marine Optical Biogeochemistry : The Chemistry of Ocean Color. Florida: American Chemical Society.

Downing, B., Pellerin, P., Bergamaschi, B., Saraceno, J., & Kraus, T. (2012). Seeing the light: The effects of particles, dissolved materials, and temperature on in situ measurements of DOM fluorescence in rivers and streams. Limnology and Oceonography: Methods.

Gassmann, S., Trozjuk, A., Singhal, J., Schuette, H., Miranda, M. L., & Zielinski, O. (2015). PCB based micro fluidic system for thermal cycling of seawater samples. 2015 IEEE International Conference on Industrial Technology (ICIT). Seville, Spain: IEEE.

Gaughan, R. (2017, April 25). What Percent of UV Does the Ozone Absorb? Retrieved from Sciencing: https://sciencing.com/percent-uv-ozone-absorb-20509.html

Miranda, M. L., Mustaffa, N. I., Robinson, T. B., Stolle, C., Ribas-Ribas, M., Wurl, O., & Zienlinski, O. (2018). Influence of solar radiation on biogeochemical parameters and fluorescent dissolved organic matter (FDOM) in the sea surface microlayer of the southerncoastal North Sea. Elem Sci Anth 6:15.

Miranda, M., Trojzuck, A., Voss, D., Gassmann, S., & Zielinski, O. (2016). Spectroscopic evidence of anthropogenic compounds extraction from polymers by fluorescent dissolved organic matter in natural water. Journal of the European Optical Society - Rapid Publications.

Murphy, K. R., Stedmon, C. A., Graeber, D., & Bro, R. (2013). Fluorescence spectroscopy and multi-way techniques. PARAFAC. Anal. Methods.

Whitesides, G. M. (2006). The Origins and the future of microfluidics. NATURE, 368-373.

Zielinski, O., & Watson, J. (2013). Subsea optics and imaging. Cambridge: Woodhead Publishing limited.