Introduction of a Mini-Fluidic Photoreaction System

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UV photoreactions (photochemical and photobiological) have been widely used for chemical synthesis, pollutants degradation, and water/wastewater disinfection. Being different from conventional chemical reactions, the determination of kinetic parameters for photoreactions needs an accurate measurement of UV fluence rate (FR) and a supply of fluences over a broad range. At present, bench-scale photoreactions are commonly performed using a quasi-collimated beam apparatus (CBA). The CBA can produce a relatively uniform FR over the surface of a Petri dish, which can be measured easily with a UV radiometer. Water samples are exposed to various fluences through varying the exposure time to obtain the kinetic parameters of photoreactions. The CBA is usually equipped with a low-pressure (LP) mercury vapor lamp, which produces an FR ranging from 0.01 to 0.50 mW/cm2; however, this range is much different from that in a practical LP UV reactor (i.e., 3–30 mW/cm2). Thus, there are inevitable errors for kinetic parameters determined in a CBA.

This study, inspired by the micro-fluidic device idea [1,2], has developed a mini-fluidic photoreaction system (MFPS) for bench-scale photochemical and photobiological experiments. A 105 W LP high-output UV lamp (with a quartz sleeve of 23 mm o.d.) was housed in the center of an annular quartz reactor (> 90% of the UV transmittance of quartz). A polytetrafluoroethylene (PTFE) tube (about 75% of UV transmittance, 2 mm i.d.) was coiled around the outer surface of the annular quartz reactor. Water sample was continuously pumped through the PTFE tube using a peristaltic pump for UV exposure. Based on the flow rate of water sample and the UV-exposed length of the PTFE tube, the total exposure time could be readily calculated. To obtain various FR values in the tube, the annular quartz reactor was fabricated specially to have several segments with different diameters for the tube to coil around. A micro-fluorescent silica detector (MFSD) [3,4], inserted into a short PTFE tube, was placed close to the reactor surface for accurate FR measurements. This detector has a 360-degree response to FR and a maximum measurement error of 3%. In addition, an adjustable ballast was utilized to tune the lamp output so as to export a desired FR. The preset fluence was equal to the product between the FR (measured by the MFSD) and the exposure time (calculated from the sample flow rate and the exposed tube length).

Photochemical experiments were conducted with the MFPS. KI/KIO3 actinometer was chosen to validate the preset fluences through measuring the 352 nm absorbance [5]. Three FR values were tested including 24, 4.60, and 0.44 mW/cm2. At a fixed FR, the exposure time was varied by adjusting the exposed tube length and the sample flow rate to achieve the preset fluencies (2.0, 3.7, 4.8 and 6.0 mJ/cm2). The results showed that the KI/KIO3 actinometer had almost the same response for three different FRs applied, which demonstrated that the MFPS could provide accurately measured and practical FRs for photochemical and photobiological experiments.

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