A novel method to control biofouling on the surface of membrane filters using UV irradiation through optical fibers

Name: Doo Hyun Chung (dchung@hmc.edu), Harvey Mudd College
Advisors: Professor Jaehong Kim, Dr. Pyung Kyu Park, Department of Civil and Environmental Engineering, Georgia Institute of Technology
HMC Liaison: Professor Nancy Lape, Department of Engineering, Harvey Mudd College

Abstract

Membrane processes such as microfiltration, ultrafiltration, nanofiltration and reverse osmosis have been popular subject for researchers interested in water filtration system. One of the main problems with such membrane system is biofouling, which is caused by deposition or growth of microorganisms on membrane surface. One solution to this problem, as it has been used for many years now, is chlorination. However, it has a number of side effects including over chlorination, odor problems, and formation of highly carcinogenic disinfection by-products [1-3]. As an alternative solution to biofouling, UV irradiation has been used to clean the membrane system. However, it is difficult to accomplish complete disinfection with normal UV source because UV cannot be irradiated onto every part of membrane. This research focuses on UV disinfection using optical fibers, which allow the UV ray to be delivered to any site on membrane.

Research

GE has been developing membrane water filtration system for applications in developing world. Professor Kim's lab was funded to evaluate the performance of GE's membrane unit under varying water quality conditions. The student will focus on understanding the biofouling process and developing a novel way to mitigate membrane fouling. More specifically, the student will use UV irradiation process with optical fibers to control membrane biofouling, and explore the optimal configuration and operating conditions based on cell deactivation or growth retardation, water productivity through membrane filtration, and equipment and operation costs.

A schematic diagram of a membrane-UV irradiation system is shown in Fig. 1. Microfilatration or ultrafiltration membranes of hollow fiber types are used. Optical fibers are placed among the

membrane fibers as Fig. 2.

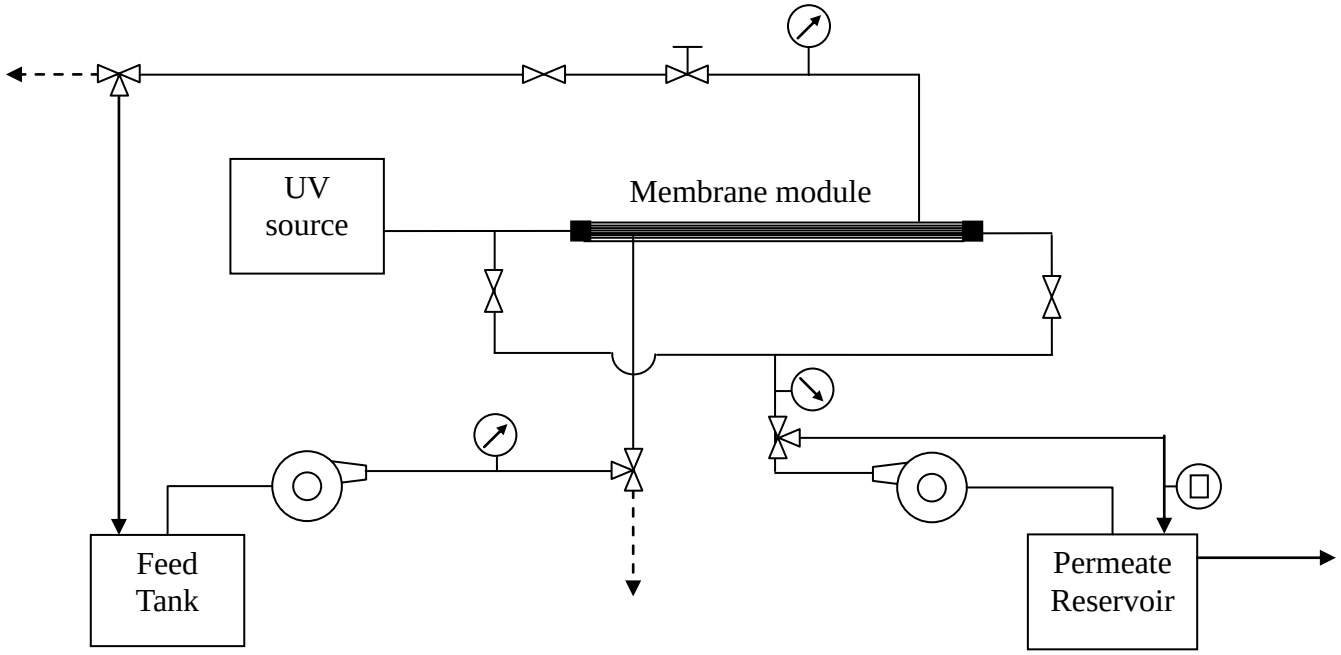

Fig. 1. A schematic diagram of a lab-scale membrane-UV irradiation system.

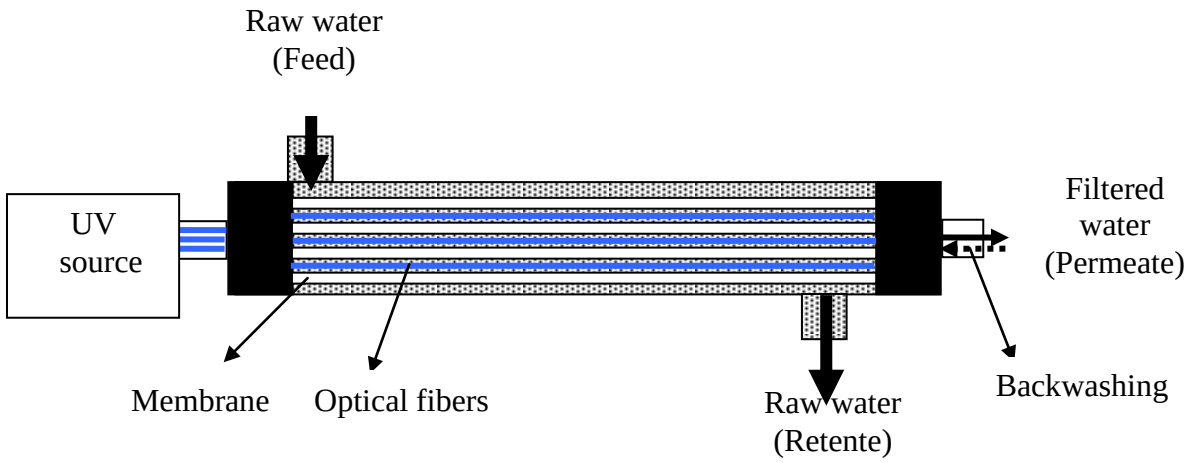

Fig. 2. A hollow fiber membrane module equipped with UV irradiation

Experiments will be performed in these manners:

i) *Comparison of biofouling with and without UV irradiation* – During filtration of microorganisms such as E. coli with and without UV irradiation, permeability (water productivity) will be monitored by measuring permeate flow rate. After filtration, degree of biofouing will be investigated by cell counting or cell activity test for cells in retentate and

deposited on membrane surface.

ii) *Comparison of cell detachment efficiency during backwashing of membrane* – Backwashing by inversely pumping permeate to membrane is usually adapted to remove foulant deposited on membrane surface. During this process, detachment of microorganisms deposited on membrane surface will be tested by cell counting for backwashed water.

iii) *Comparison of irradiation methods* – The efficiency of biofouing control will be checked up for intermittent irradiation, different UV source powers, and irradiation from one end *vs*. both ends of optical fibers.

Environmental Significance

There have been many warnings for scarcity of fresh water resources around the world and many studies have focused on improving the cost and efficiency of water filtration system. This research is one of the few that are exploring this relatively unveiled field of optical fiber as a means to deliver the UV ray. With any luck, this research can take the water filtration system to whole another level by restricting biofouling without chlorination. \

Educational Value

After reading a science article on diminishing water resources last summer, the student has developed an interest in this field of engineering to fight the global water-deficiency problem. Especially, this area of research provides rich contexts for the student as his own native country of Korea is predicted to experience one of the more severe water scarcity problems in the future. As someone who has been away from home for 6 years to study abroad, the student now feels he has found something that he can even remotely contribute to his home country. Although the student plans to study chemical engineering while in college, it is still undecided what specific fields the student would like to pursue. This research will be a wonderful opportunity for the student to decide whether this field of curing water problem is the right choice or not.

Feasibility

The research will start on May 18, 2009 and will continue until August 7, 2009 (exactly 12 weeks). During his stay in Atlanta, the student will stay in dormitory room on Georgia Tech's campus with access to most of the school's facilities including the Daniel Laboratory Building,

school library, as well as the recreation center. On daily basis, research will start at 9 am and will end by 6 pm although there may be special occasions where the student will have to stay longer. The research will conclude with a formal paper and two presentations which will be delivered at Georgia Tech in August and at Harvey Mudd in September.

Professor Jaehong Kim, an expert on membrane filtration for water treatment, will direct the overall process of the research while the student will be put under direct supervision of Dr. Pyung Kyu Park, a postdoctoral researcher in Professor Kim's research group. Membrane systems and facilities are already in use in Professor Kim's lab, so all the necessary equipments are ready for use by the student.

Tentative Schedule

Week 1: Literature research/reading, Research begins
Week 2-3: Comparison of biofouling with and without UV irradiation
Week 4: Progress Report, Write-up of the first third of research
Week 5-7: Comparison of cell detachment efficiency during backwashing of membrane
Week 8: Progress Report, Write-up of the second third of research
Week 9-11: Comparison of irradiation methods
Week 12: Completion of paper, Presentation at Georgia Tech

The tentative schedule is formulated by student's discretion based on three different parts of the research. This schedule by no means represents the actual agenda planned by the research advisor.

Proposed Budget

Salary – $4000 (Harvey Mudd pay scale for 10 weeks)
Travel – $200 (Airfare from Ontario to Atlanta)
Room and Board on Georgia Tech campus– $1000

References

[1] N. Pozos, K. Scow, S. Wuertz, and J. Darby, UV disinfection in a model distribution system: biofilm growth and microbial community, Water Research 38 (13) (2004) 3083-3091.

[2] S. W. Krasner, H. S. Weinberg, S. D. Richardson, S. J. Pastor, R. Chinn, M. J. Sclimenti, G. D. Onstad, and A. D. Thruston, Occurrence of a new generation of disinfection byproducts, Environmental Science & Technology 40 (23) (2006) 7175-7185.
[3] X. R. Zhang, and R. A. Minear, Formation, adsorption and separation of high molecular weight disinfection byproducts resulting from chlorination of aquatic humic substances, Water Research 40 (2) (2006) 221-230.