UV Treatment: A Solution for Small Community Water Supplies?

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Introduction

In December 2014, the authors started an international collaborative research program entitled "Innovative UV Technologies for the Removal of Emerging Contaminants and Sustainable Water Supplies in Small Communities." Drs. Oguma and Mohseni respectively serve as principal investigators (PIs) for the Japanese and Canadian teams in this three-year project, which is supported by the Japan Science and Technology Agency (JST) and the Natural Sciences and Engineering Research Council of Canada (NSERC).

Several institutions in both countries are participating in the project – Japanese team members come from the University of Tokyo, National Institute of Public Health and Hokkaido University, while the Canadian team includes experts from the University of British Columbia, École Polytechnique de Montréal and Dalhousie University. This research collaboration builds on the work of the RES'EAU-WaterNET Strategic Network in Canada, which is a multi-disciplinary program funded by NSERC with partners from industry, communities, government and NGOs, and which focuses on the development of affordable solutions to the drinking water challenges faced by small and rural and aboriginal communities (SRCs).

The need for, and potential utility of, such collaboration is illustrated in Figure 1. Japan and Canada share common challenges stemming from limitations in financial and human resources that hinder efforts to ensure the provision of safe drinking water in SRCs in an effective and sustainable manner. The use of UV, with its great potential for applications in small community settings, is growing in Japan following the enforcement of the UV disinfection guideline in 2007 (Figure 2). Canada's extensive experience in the application of UV disinfection and advanced oxidation will be of great value to Japanese researchers and the communities they serve, as they strive to advance the use of UV technology in various applications. Meanwhile, North America has in recent years been facing the growing problem of eutrophication and harmful algal blooms in shallow lakes and reservoirs. On these matters, Japan's deep expertise in algal bloom monitoring and the routine treatment of taste and odor (T&O) compounds in drinking water may be valuable for Canada. As such, the research strengths and expertise of both countries are complementary, leading to mutual benefit and a win-win relationship in collaboration. Team members of both countries have

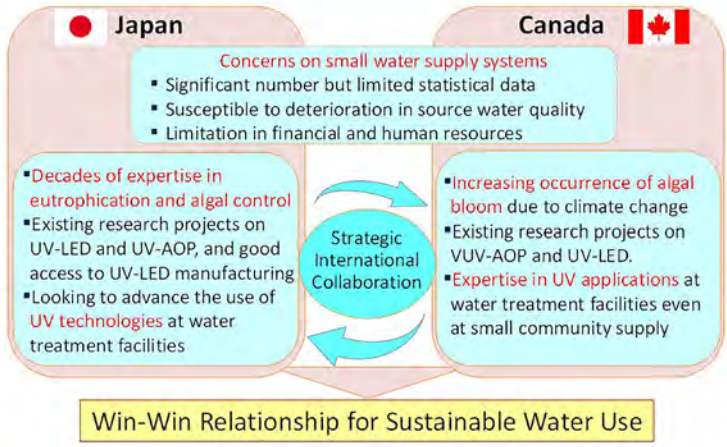

Figure 1. Scope of collaboration.

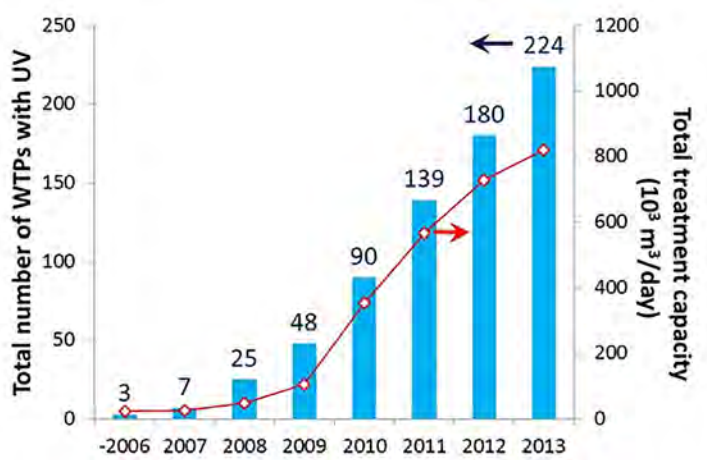

Figure 2. Water treatment facilities adopting UV disinfection in Japan (Modified from Japan Water Research Center, 2013).

ongoing research projects focusing on UV-based technologies, which is a great accelerator to promote collaboration.

Challenges in Japan

According the Ministry of Health, Labor and Welfare (MHLW), over 95% of people in Japan having connection to a water supply are served by large public water utilities with populations of 5,001 or more. Meanwhile, based on the number of facilities, small public water supplies (about 6,100 facilities) and private water supplies (about 8,100 facilities) account for roughly 90%

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of the total water supply systems in Japan. It should be noted that these statistics are for facilities serving a population of 101 or more; that is, those serving 100 people or less do not appear in the data. Our estimation suggests that over three million people in Japan are served by these "invisible" facilities.

Small water systems commonly use nearby streams or groundwater as the source, with chlorination. Over the past 30 years, water quality incidents in Japan with negative health impacts have mostly been associated with microbial contamination (Kishida et al., 2015). Waterborne diseases caused by pathogens in water have been reported almost every year for decades, and only 4% of such incidents occurred at large public water supply systems (serving pop. ≥5,001). Namely, the remaining portion of incidents leading to negative health impacts has occurred at small water systems, particularly at very small water supply systems serving a population of 100 or less. Hence, it is evident there is a clear and urgent social need in Japan for effective and robust water disinfection technologies that work reliably in small water settings.

The population in Japan has been decreasing since 2008 and the society has been aging very rapidly. These phenomena can have negative consequences on water utilities, such as a decrease in water sales revenue, lower economic efficiency arising from lower water demand density, limited human resources and less skillful engineers, and the presence of more sensitive customers. Moreover, climate change is an emerging threat to water utilities, and adaptation measures require additional cost. These difficulties are particularly hard for small water supply utilities with significant human and financial limitations.

Challenges in Canada

Approximately 80% of Canadians live in urban areas and enjoy a relatively stress-free relationship with their water supply and treatment systems. However, a multitude of factors make providing even basic services much more difficult for SRCs. In March 2015, the Council of Canadians (Council of Canadians, 2015) reported nearly 1838 water advisories in SRCs in Canada. This includes 169 advisories in 126 First Nations communities, out of nearly 600 First Nations communities across the country. These advisories are generally intended to be a precautionary measure in the public health tool kit, ensuring the public is protected from exposure to harmful waterborne pathogens. However, given that some advisories have been in place for years, it is apparent that they are used as substitute for proper disinfection and treatment.

While the risk of microbiological contamination is still a primary concern and the impetus for boil water advisories in many small and remote communities, disinfection by-products (DBPs), seasonal algal toxins and T&O compounds also pose significant risks to public health and represent major issues to overcome. Indeed, eutrophication of shallow lakes is a key emerging issue in Canada affecting the quality of drinking water sources of many SRCs. A combination of climate change, population growth and evolving land use activities have resulted in algal and cyanobacterial bloom occurrences, raising a serious concern for public health and safety due to the increased detection of cyanotoxins in the impacted waters. Tackling the issues of cyanotoxins and T&O compounds for small water systems can be quite challenging, given the fact that many such systems are at a comparative disadvantage due to their size (e.g., limited financial and human resources), and often due to their remote location.

UV Technology as a Potential Solution

Challenges in Japan and Canada clearly indicate the need to explore technologies suitable for small water systems in terms of reliability, robustness, feasibility and sustainability. The goals of this Japan-Canada research collaboration include, but are not limited to, the application of UV light emitting diodes (UV LEDs) for water disinfection at small facilities and/or point-of-use systems, as well as the UV-based advanced oxidation (UV-AOP) process for decomposing emerging micro pollutants, such as cyanotoxins and T&O compounds.

Such UV-based technologies will be evaluated in comparison with other relevant unit processes, such as chlorination (for disinfection) and ozone or activated carbon adsorption (for T&O control), and the final outcome will include technical data required for the design, implementation and operation of the technologies in small community settings.

Past and Upcoming Activities

This research collaboration was kicked off with a workshop at the University of Tokyo in January 2015, followed by a special session at the 10th International Symposium on Water Supply Technology in Kobe, Japan, in July 2015. At the Kobe symposium, more than 70 international participants from academia, industries and water utilities joined in the discussion and information sharing. Moreover, team members have joined site visits at small water systems in Japan and in Canada (Figure 3), resulting in a deeper understanding of the issues and opportunities at hand.

A special session on the application of UV in small water systems will be held at the IUVA World Congress 2016 in Vancouver. Needless to say, small water supply systems are of concern in many other countries. We are very much looking forward to having many international participants with diverse

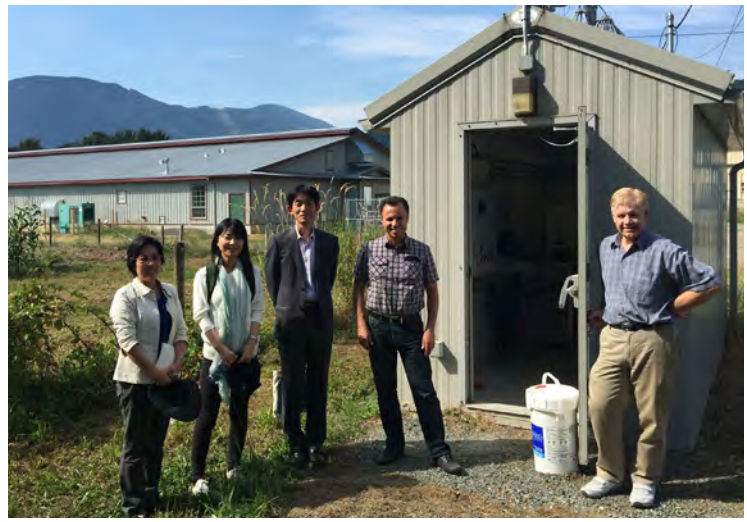

Figure 3. From left, visits to small water treatment systems in Japan (Yabu, Hyogo) and in Canada (Agassiz, British Columbia).

backgrounds to share and bridge our knowledge for a better future for all nations facing similar challenges.

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Author biographies

Dr. Kumiko Oguma is an associate professor at the University of Tokyo. She has been working on UV research for over 15 years, particularly on UV disinfection and DNA repair issues. Application of UV light emitting diodes (UV-LEDs) to water treatment is one of her recent research activities. She serves as one of the Board Members of IUVA, and a technical committee of IUVA. She can be reached at oguma@env.t.u-tokyo.ac.jp.

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