Evaluation of Disinfection Byproduct Formation during Potable Reuse Treatment

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1. Introduction

In 2012, California became the first state to recognize the human right to water. Under Assembly Bill 685, California declared that "every human being has the right to safe, clean, affordable, and accessible water" (Cal. Water code § 106.3(A)). To meet this ambitious goal, California must be prepared for a variety of setbacks in the coming century, most notably continued population growth, urbanization in semi-arid/arid regions, and shifts in hydrological patterns due to climate change (Fuller, 2010). To counteract these challenges, California must be proactive in pursuing new technology and infrastructure that is capable of generating potable water from new sources.

2. Background

One example of this pursuit is potable reuse, which involves the treatment of wastewater into potable water. This process is accomplished at advanced wastewater treatment facilities (AWTFs), which use a combination of advanced unit processes to remove and inactivate a variety of contaminants and pathogens. The most prevalent treatment train within AWTFs, also known as full advanced treatment (FAT), includes the coupling of microfiltration (MF), reverse osmosis (RO), and advanced oxidation processes (AOP). Alternative (Ozone based) treatment trains are less commonly employed within AWTFs, and largely limited to inland communities where disposal of brine, generated in RO, is a limiting factor (Gerrity, 2013).

Historically, the most pressing question about the viability of potable reuse has been the capability of AWTFs to remove pharmaceuticals and personal care products, found in elevated levels within wastewater. This perspective has shifted over the last few years as recent research has focused on chemical compounds formed during the water treatment process, such as disinfection byproducts (DBPs), which pose a greater risk to human health, with concentrations orders of magnitude closer to levels of human health concern (Council, N. R., 2012). Additionally, the regulation behind potable reuse is largely archaic, as it only targets select species of DBPs, leaving a number of DBPs unregulated that have been measured at more toxic concentrations (Zeng, 2016).

Moving forward with potable reuse, a deeper understanding of the potential human health risk associated with advanced wastewater treatment is necessary. Our project had two main goals. First we compared the toxicity of DBPs found in water generated through potable reuse to conventional drinking water. Secondly we examined the formation and removal of DBPs at each stage in the treatment train, for all AWTFs in our project, to better understand where DBPs are generated and removed.

3. Methods

To accomplish these goals, we analyzed water samples from six different AWTFs (Singapore, Aurora, UOSA, HSRD, Windhoek, and Gwinnett). Effluent water samples were collected at each stage in the treatment train and an additional sample was collected from the region's conventional drinking water source. Each sample was examined for 35 different DBPs that fall under five chemical categories: nitrosamines, haloacetic acid, trihalomethanes, bromate, and aldehydes. Each of these DBP categories required an individualized extraction method, outlined by the USEPA (US EPA Method 551.1, 552.3, and 521), to increase the DBP concentrations within the sample. DBP concentrations were then quantified through analysis by gas chromatography – mass spectrometry or ion chromatography (bromate only). To facilitate comparison between all 35 DBPs, the relative toxicity was calculated for each DBP based on their associated toxic potency. This was carried out by dividing the concentrations by concentrations determined in toxicological assays to be associated with adverse health effects, a more in depth explanation can be found in prior research publications (Chuang, 2017).

Image 1: Singapore Event 1 Reverse Osmosis UFC Sample

The exact same process was carried out on a second set of samples, UFC samples, which included the additional injection of a disinfection agent (Free Chlorine or monochloramine). This was done to promote the full formation of DBPs within the samples, to more accurately emulate the introduction of treated effluent into the distribution system.

4. Results and Discussion

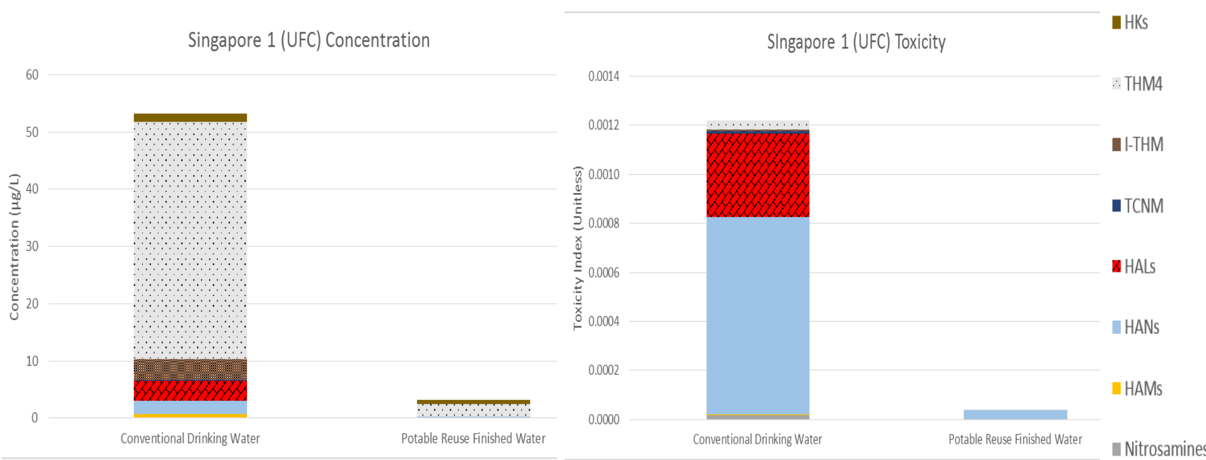

Figure 1: compares potable reuse finished water to conventional drinking water, by looking at the cumulative concentration (left) and cumulative toxicity (right).

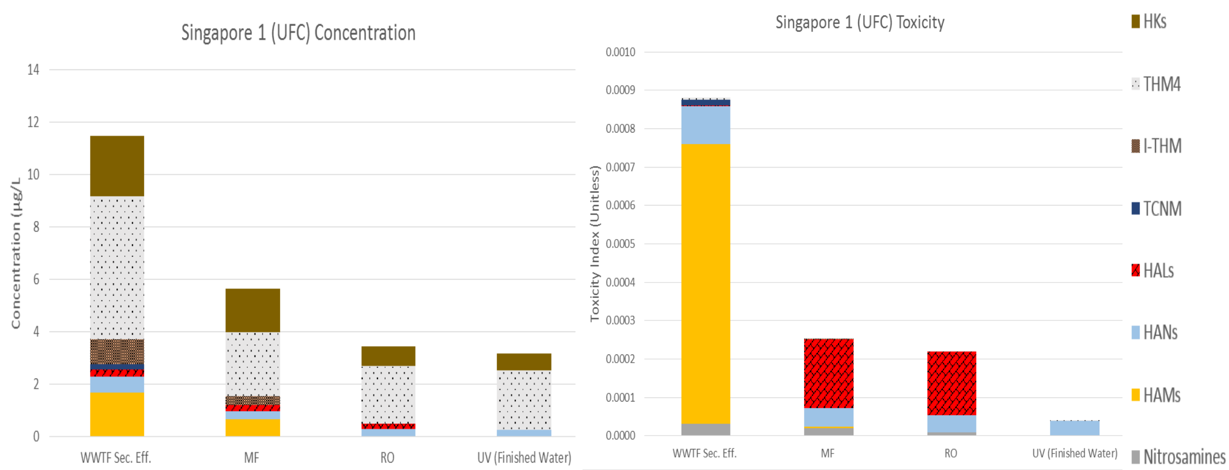

Figure 2: exams how the cumulative concentration (left) and cumulative toxicity (right) levels fall/rise through each stage in the Singapore AWTF treatment train.

Our early results, in figure 1, support the notion that there is no increased risk to human health by ingesting potable reuse finished water as a substitute to conventional drinking water, seeing that cumulative concentration and cumulative toxicity levels are both lower. In figure 2, the two graphs display decreasing levels of DBP cumulative concentration and cumulative toxicity, through each stage in the treatment train. This indicates that some of the DBPs originally in the water are removed with each additional advanced unit process.

Looking at the results as a whole, figure 1 and 2, it is interesting to see that some of the DBPs that dominate in concentration (THMs) are not a large contributor when it comes to toxicity. Instead, a select few of the DBPs that appear at trace levels are the ones that end up dominating the cumulative toxicity (HALs, HANs & HAMs). This insight can potentially serve as a tool for future potable reuse regulation, directing attention toward specific DBPs that are most harmful to human health.

5. **<u>Future Work</u>**

Moving forward, samples will continue to be delivered and analyzed into early 2018 for the 6 AWTFs. Once all samples are processed, more general conclusions will be drawn leading to an official publication of the projects entire scope. A deeper understanding of DBPs is just one step in furthering the viability of potable reuse; however, additional research will need to be conducted looking at other areas of concern: pathogen inactivation, pharmaceuticals and personal care products, and endocrine disrupting compounds.

Even with a strong base of knowledge, potable reuse still faces other major hurdles. Non-technical constraints in the form of financial cost and public acceptance must be overcome as well. These factors must largely be championed by political leadership, in accordance with scientist and engineers, through public outreach and education.

6. References

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