Oxidation and Biological Removal of Emerging Contaminants from Drinking Water in Singapore

Stream

The Industrial Doctorate Centre for the Water Sector

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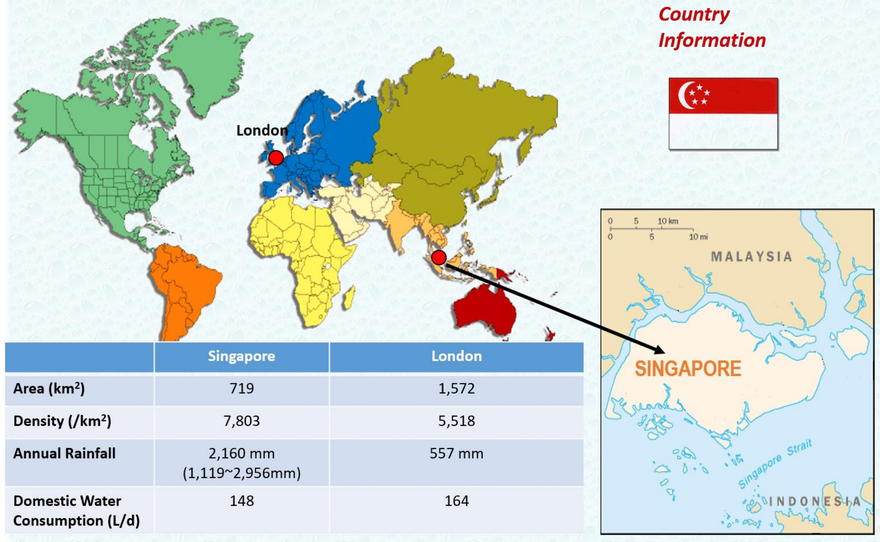
Background



Country Information

	Singapore	London
Area (km²)	719	1,572
Density (/km²)	7,803	5,518
Annual Rainfall	2,160 mm (1,119~2,956mm)	557 mm
Domestic Water Consumption (L/d)	148	164

Singapore's Four "National Taps"

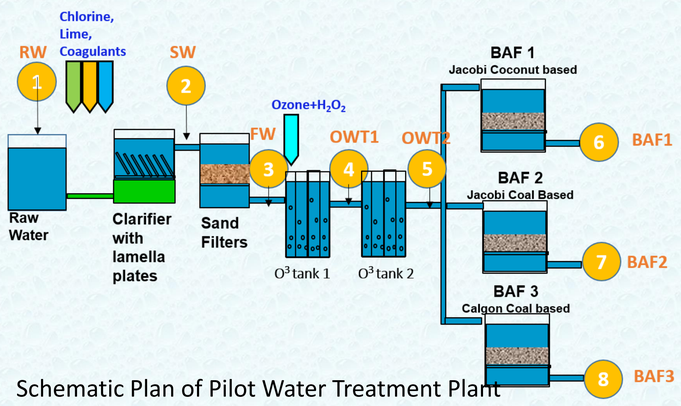
- Raw water from highly urbanized local catchment area and foreign agricultural catchment in Malaysia with potential risk of deterioration.
- PUB's Waterworks are being upgraded from conventional treatment to Ozone and Biological Activated Carbon (BAC) process which could potentially be developed to Ozone based Advanced Oxidation Process (AOP) such as Ozone-H_2O_2 Process.
- PUB mission is to supply "Good Water": high quality, safe to drink directly from tap.

Aim

To establish the contaminant removal, transformations and treatment envelops for selected potential pollutants of the raw water sources as well as disinfection by-products formations using the pilot water treatment plant which is similar to the full-scale plants.

Objectives

- Identify existing and potential contaminants in the raw water sources;
- Define the operational limits for different target compounds for Ozone and Ozone based Advanced Oxidation Processes (AOP);
- Understand the transformation of background organics and formation of disinfection by-products formation.



Schematic Plan of Pilot Water Treatment Plant

Methodology

Identify Potential Contaminants
- PUB Water Quality Monitoring Data;
- Published Water Quality Studies;

Pilot Plant and Lab Experiments
- Simulated challenges by spiking contaminants (MIB, Geosmin and Pesticides) in actual raw water;
- Pilot Plant test with Lab scale testing;
- Variation of Operation conditions (O_3, H_2O_2 dosages);

Analysis &Discussions
- Treatment Performance: Contaminant Removal;
- Disinfection By-Products (DBPs)forming potential removal;
- Factors impacting contaminant removal and DBPs formation potential.

Expected Outcomes
- Contribution to Sponsor: Future Readiness-Action plan and optimization strategies for PUB's full-scale plant;
- Scientific Contributions: -Impact of controllable variables of operation; -Transformations of background organics to DBPs FP.

Current Results

Identify Potential Contaminants

- Comprehensive routine monitoring regime in place by PUB from source to tap (300+ parameters such as heavy metal, Pesticides, Pharmaceuticals, Bacteria, etc.) ;
- No current concerns for emerging contaminants in raw water for both Singapore catchment and Johor River Catchment;
- Potential risk of contaminants such as pesticides, taste & odour compounds and pharmaceuticals in raw water:
  - "2nd Tap" source from agricultural catchment in Malaysia.
  - -Local highly urbanized water catchment.

Published Water Quality Studies on Other Water Catchments in Malaysia

	Category	Detected Compounds	Catchment	Year of Study	Reference
1	Organochlorine Pesticides	BHC (Lindane), Chlordane, Aldrin, Dieldrin, DDT, DDD, DDE, Endrin, Heptachlor,Methoxychlor,Endosulfan,Endosulfan Sulphate	Sembrong Lake Catchment	2016	Zati Sharip et al.
2	Pesticides, Alkylphenols	Lindane, Diazinon, Heptachlor, Chlorpyrifos, DDE, Endosulfan, Dieldrin, Endosulfan Sulphate, DDT, Bisphenol A, Alkylphenols		2000& 2001	BLL Tan et al.
	PCBs	PCBs	Selangor River Catchment	2009	Nobumitsu Sakai et al.
	Organochlorine Pesticides, Plasticisers	HCB, Lindane, Chlordane, Diedrin, DDD, DDT,Endrin, Mirex, Bisphenol A, PAEs, DEHP, DBP, DEP,DMP,BBP,DOP		2008&2009	Veerasingam Armugam Santhi et al.
	Organochlorine and Organophosphate Pestcides	Lindane, Heptachlor,Endosulfan, Dieldrin, Endosulfan Sulfate, DDE, DDT, Chlorpyrifos, Diazinon		2002&2003	Kok Hoong Leong et al.
3	DDTs and DEHP (plasticizers)	DDT, DEHP	Rivers in Selangor state	2008&2009	Veerasingam Armugam Santhi et al.
	Pesticides, Alkylphenols	Alkylphenols, Bisphenol A, Chlorpyrifos, Lindane	Other Rivers in Selangor state	2001 & 2002	BLL Tan et al.
4	Bisphenol A	Bisphenol A	Langat River Basin	2008&2009	Veerasingam Armugam Santhi et al.
	Organophosphorous Pesticide	Quinaphos, Diazinon, Chlorpyrifos,		2015	Sze Yee Wee et al.
	Estrogenic Compounds	E2, E3, EE2		2015	Sarva Mangala Praveena et al.

Seasonal variation of organochlorine pesticides in other agricultural catchment with similar land use.

Sembrong Lake, Malaysia

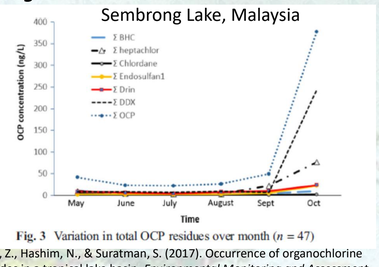


Fig. 3 Variation in total OCP residues over month (n = 47)

Sharip, Z., Hashim, N., & Suratman, S. (2017). Occurrence of organochlorine pesticides in a tropical lake basin. *Environmental Monitoring and Assessment*, *189*(11). https://doi.org/10.1007/s10661-017-6274-y

Local Highly Urbanized Catchment Areas

Baseline of Ozone Treatment (without contaminant spike)

This is similar to the current operation conditions of the full-scale plant which maintains residual Ozone at around 0.3 mg/L to meet the requirement of disinfection.

It will be used as baseline to compare with experiments with H_2O_2 dosing as well as contaminants spiking at the later part of the project.

Figure 1 Total Organic Carbon (TOC) Removal

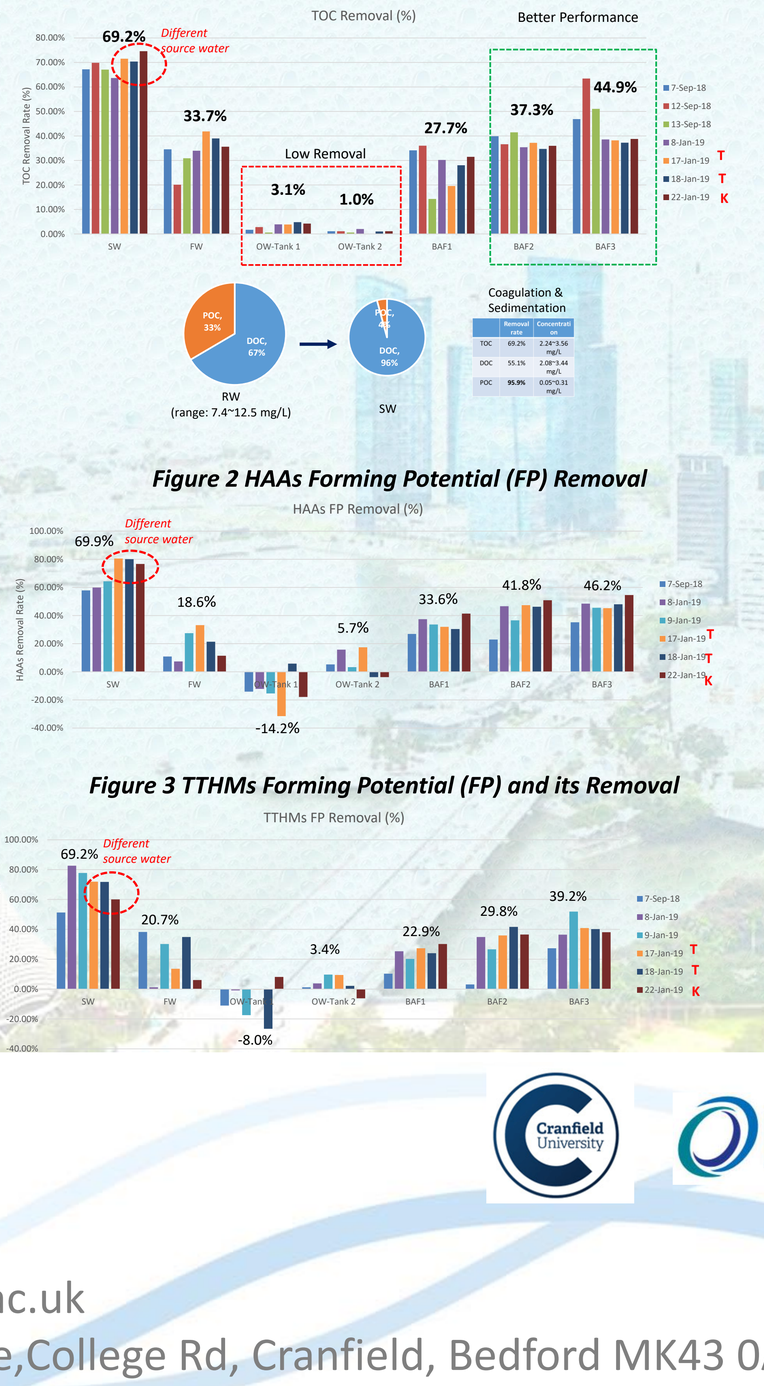
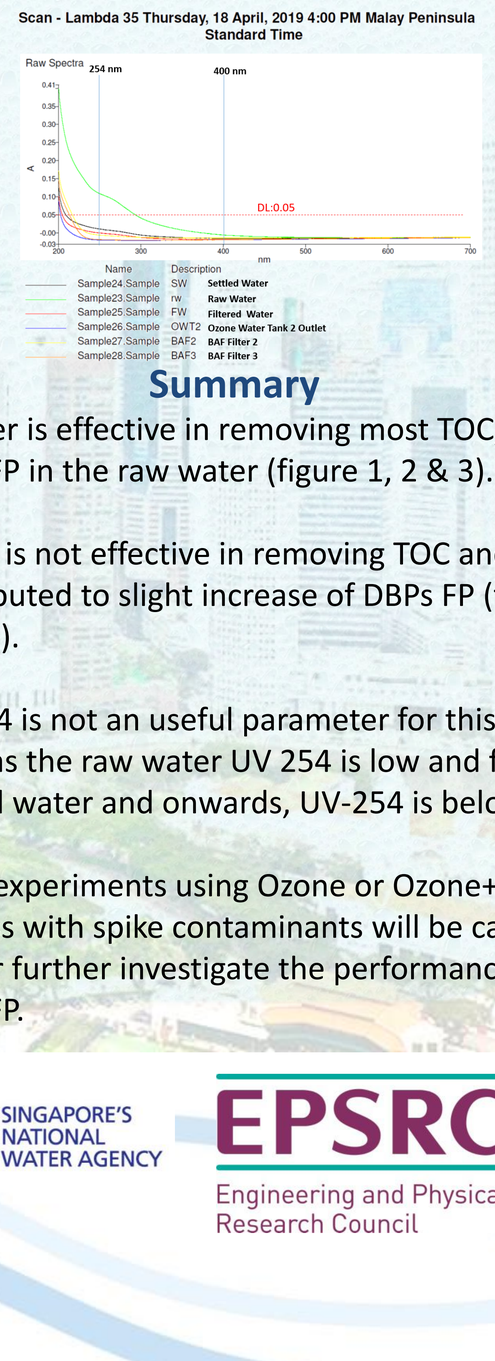


Figure 2 HAAs Forming Potential (FP) Removal

Figure 3 TTHMs Forming Potential (FP) and its Removal

Figure 4 UV Scan of Pilot Plant Samples



Summary

- Clarifier is effective in removing most TOC, and DBPs FP in the raw water (figure 1, 2 & 3).
- Ozone is not effective in removing TOC and it contributed to slight increase of DBPs FP (figure 1,2 &3).
- UV-254 is not an useful parameter for this pilot plant as the raw water UV 254 is low and from settled water and onwards, UV-254 is below DL.
- More experiments using Ozone or Ozone+H_2O_2 process with spike contaminants will be carried out for further investigate the performance and DBPs FP.

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