Alternative oxidants in seawater industrial cooling towers for biofouling control: Effect of organics

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JCMEF 26-27 Apr 2017

Background

Seawater cooling towers

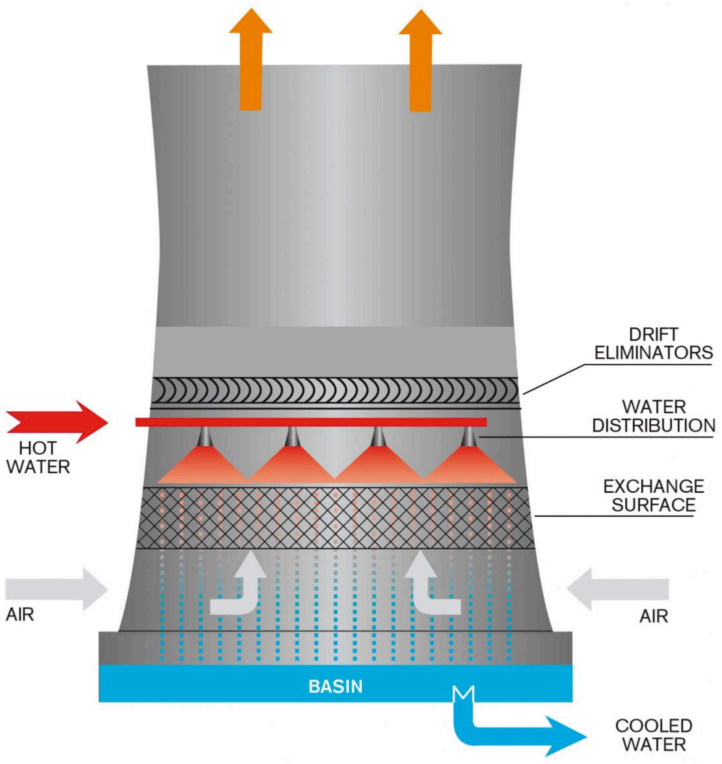
Current practice

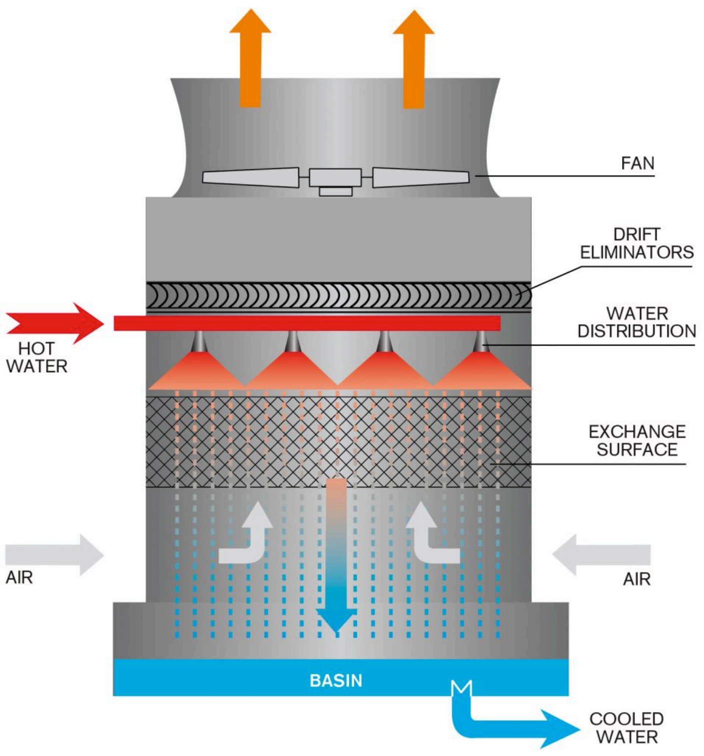
Challenges

Bench Scale

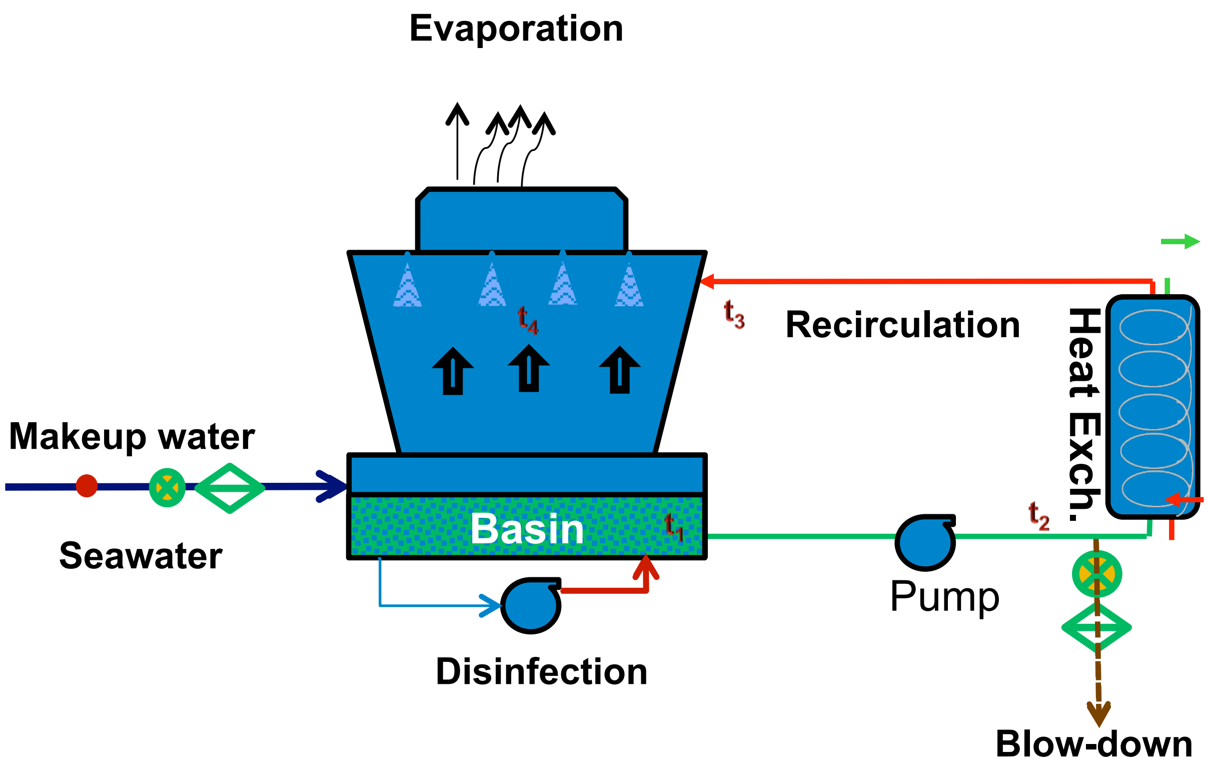
Pilot Scale

Cooling Towers



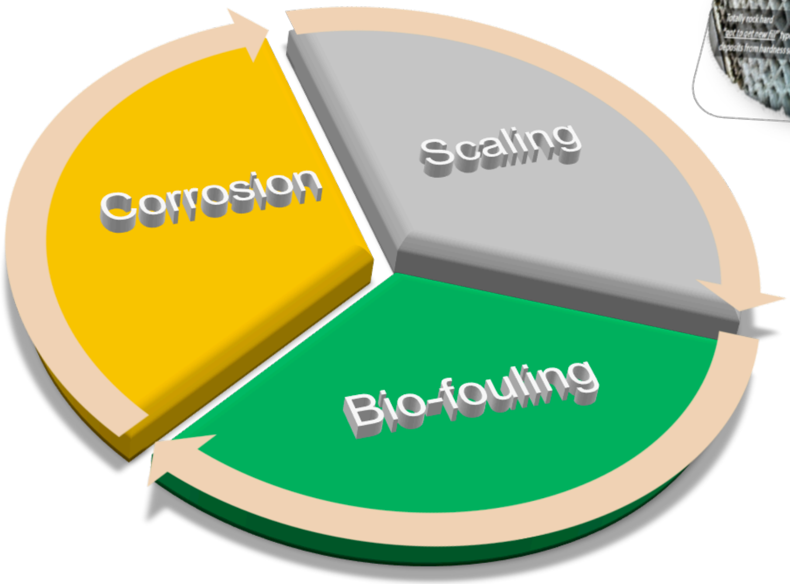


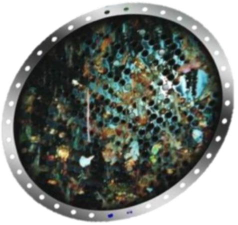
Seawater Cooling Towers



- **Behavior of oxidants in seawater**
- **Disinfection efficacy the seawater**
- **Impact of disinfectant** to corrosion, scaling, DBPs, etc.
- **Discharge limits** meeting regulations

Cooling Tower Operational Issues



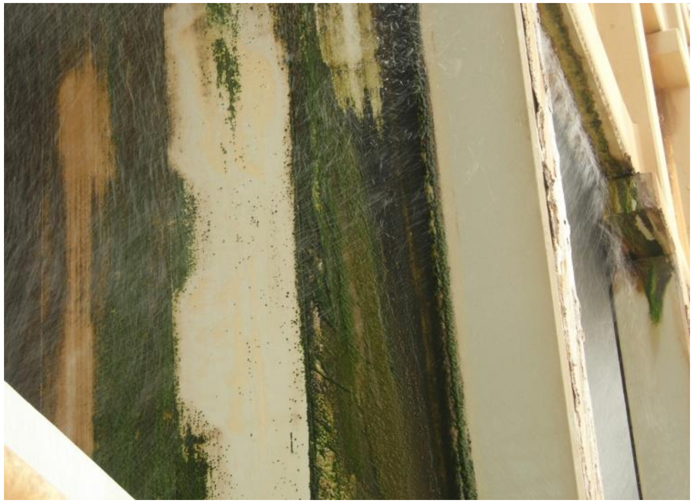


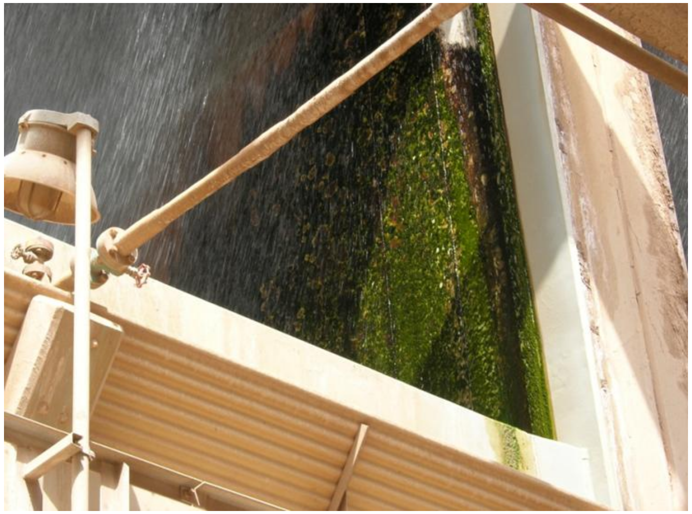
Bio-fouling

- ✓ Open surface
- ✓ Packing and filler materials
- ✓ Direct exposure to ambient air and sunlight
- ✓ Concentration of nutrients

Types of biofouling that exist in cooling towers

Microorganisms	**Impact/on/cooling/tower/system**
Algae	• Provide a nutrient source for bacterial growth. • Deposit on surface contributes to localized corrosion • Process. • Loosened deposits can block and foul pipe work and other • Heat exchange surfaces.
Fungi	• Proliferate to high number and foul heat exchanger Surfaces.
Bacteria	• Some types of pathogenic bacteria such as Legionella may cause health hazards. • Sulphate reducing bacteria can reduce sulphate to corrosive hydrogen sulphide. • Cathodic depolarization by removal! of hydrogen from the cathodic portion of corrosion cell.

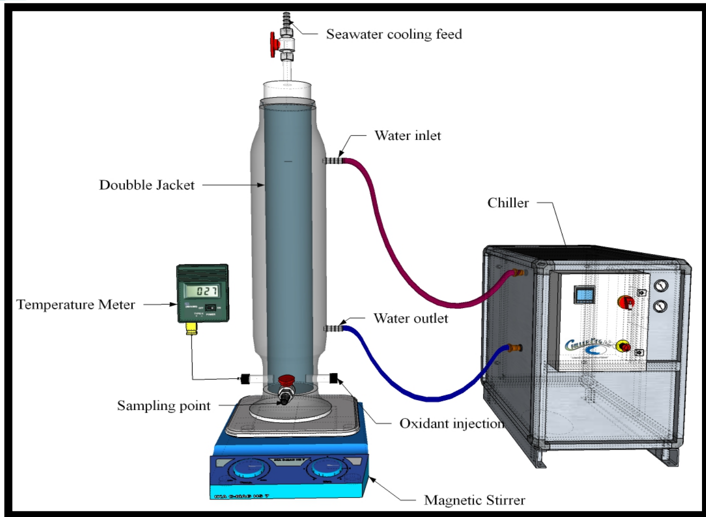


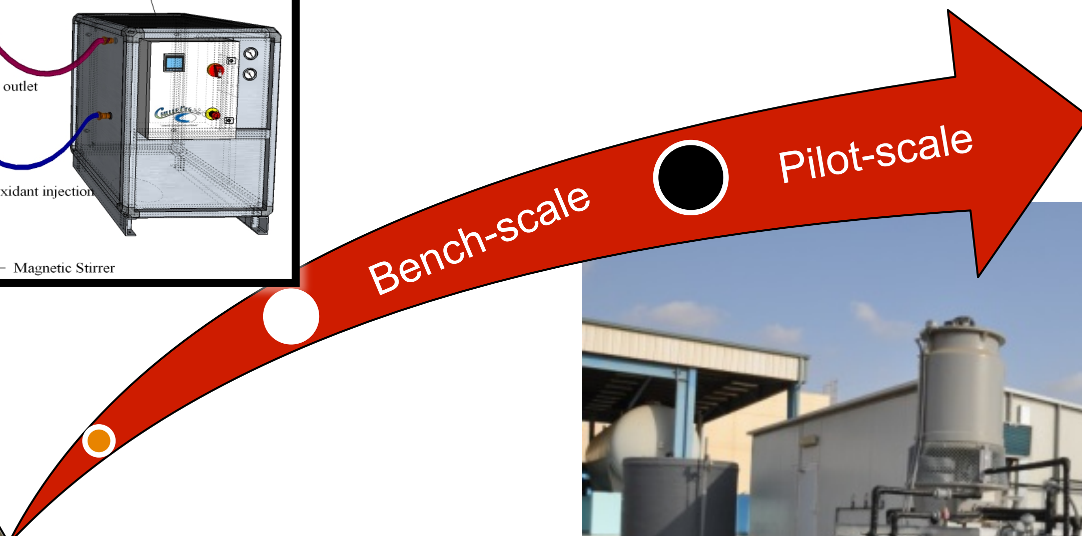


Bhatia,A.,*Cooling(Water(Problems(and(Solutions*.

Brankevich, G.J.e.a., *Biofouling and corrosion in coastal power-plan cooling systems.* Technol. Soc. J. , 1990. **24**: p. 20.

Alternative oxidants treatment seawater cooling towers





Seawater characteristics

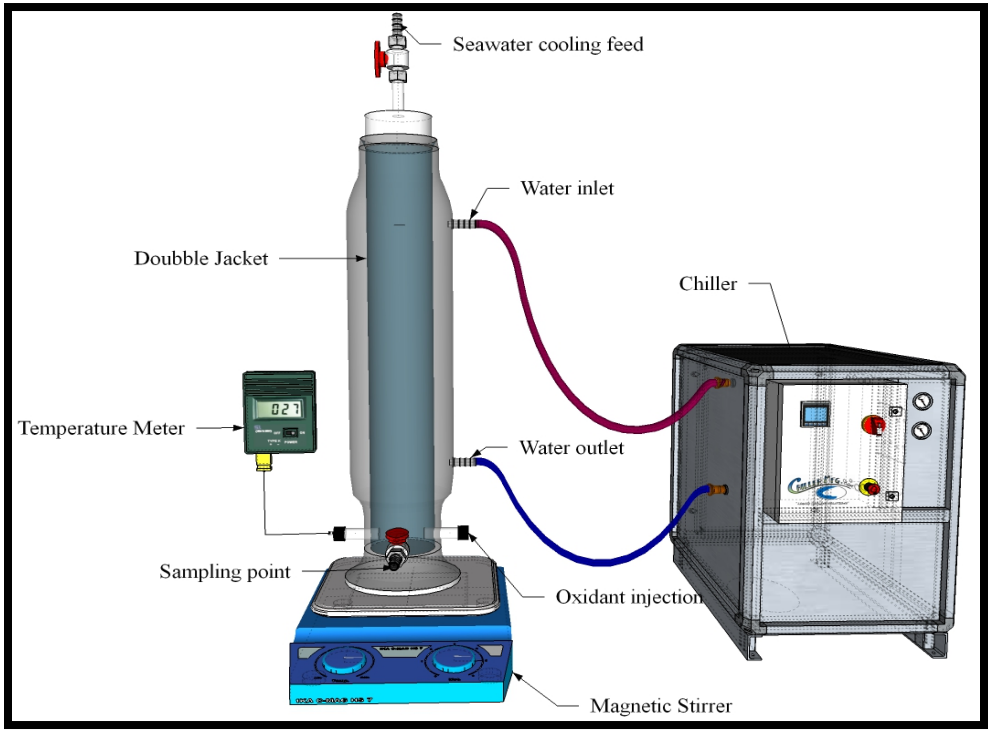
Parameter	Results	Parameter	Results
pH (SU)	8.13	Cadmium (mg/l)	0.00001295
Temperature (oC)	26.4	Chromium (mg/l)	0.001749
TDS (mg/l)	38,000	Copper (mg/l)	0.00005235
Conductivity (mS/cm)	60.0	Lead (mg/l)	0.00001902
Turbidity (NTU)	5.34	Lithium (mg/l)	0.03207
ORP (mV)	147	Manganese (mg/l)	0.001541
Total Alkalinity (mg/l as CaCO3)	120	Molybdenum (mg/l)	0.0001625
Total Hardness (mg/l as CaCO3)	7,500	Nickel (mg/l)	0.01628
Mg Hardness (mg/l as CaCO3)	6,300	Selenium (mg/l)	0.03042
Ca Hardness (mg/l as CaCO3)	1,200	Silver (mg/l)	ND
DOC (mg/l)	1.101	Strontium (mg/l)	5.314
UVA254 (1/cm)	0.016	Uranium (mg/l)	0.0006162
SUVA (L/mg-m)	1.4	Vanadium (mg/l)	0.0007
Bromide (mg/l)	71.0	Cadmium (mg/l)	0.00001295
Chloride (mg/l)	23,624	Chromium (mg/l)	0.001749
Fluoride (mg/l)	1.3	Total Iron (mg/l)	0.02
Nitrite as NO2- (mg/l)	0.0047	Boron (mg/l)	4.6
Ortho-P as PO4-3 (mg/l)	0.1	Sulfate (mg/l)	2,650

Bench Scale

- To evaluate different COC, Temperature and Dosage for each oxidant
- To determine the residue after 10 min decay (discharge limit)
- Study on By-product and Biological growth after disinfection

Method

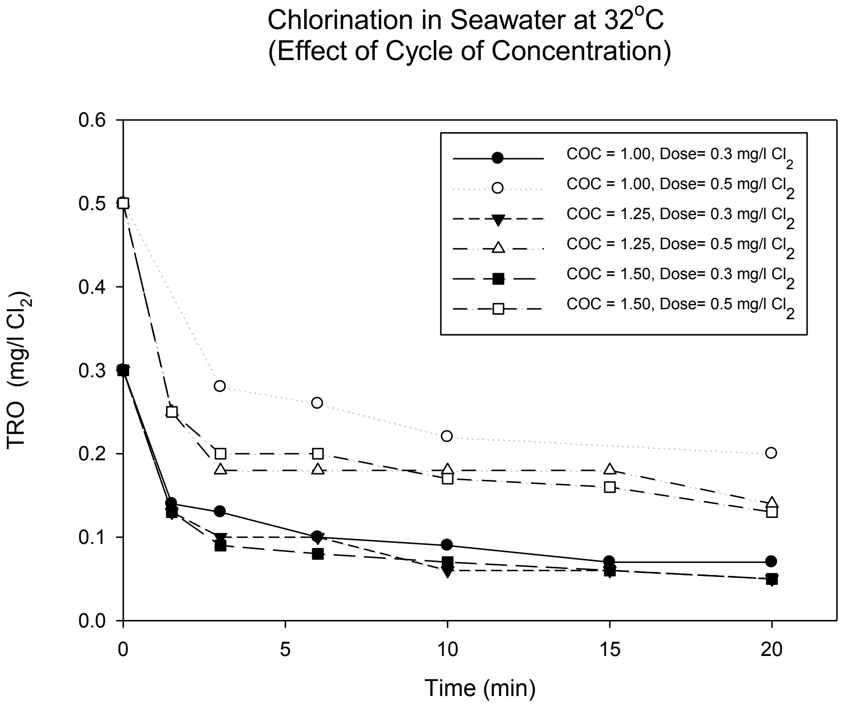
- ✓ Total Residual Oxidant (TRO)
- ✓ Cycle of concentration (COC)
- ✓ Temperatures

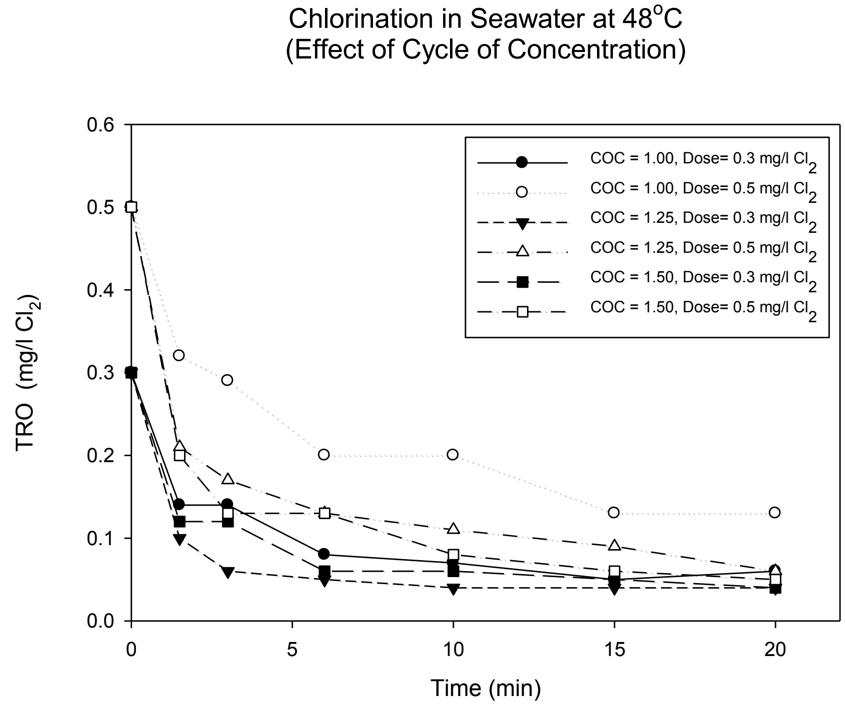


WDRC, KAUST SABIC project (bench scale)

Bench Scale results

The Effect of Cycle of Concentration (COC) on Oxidant demands





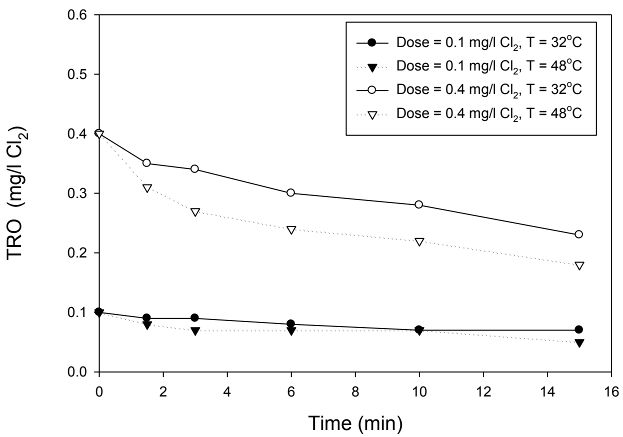
The overall impacts of COC for all three oxidants and types were found to be very much using chorine as an illustration (as other disinfects behaviors were similar).

WDRC, KAUST SABIC project (bench scale)

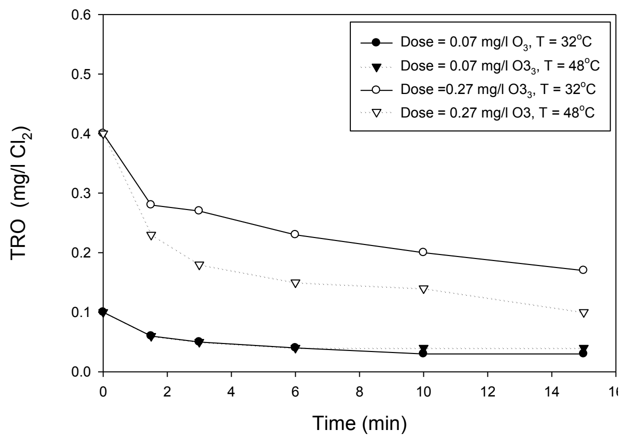
Bench Scale results

The Effect of Temperature on Oxidant Demands

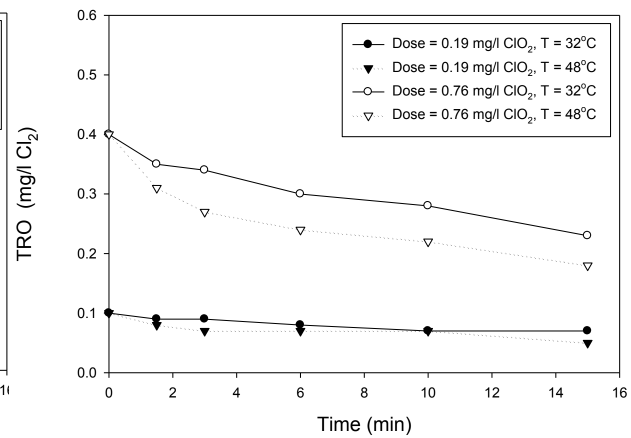
Chlorination Seawater
(Effect of Temperature at COC = 1.20)



Ozonation in Seawater
(Effect of Temperature at COC = 1.20)



Chlorine Dioxide in Seawater
(Effect of Temperature at COC = 1.20)

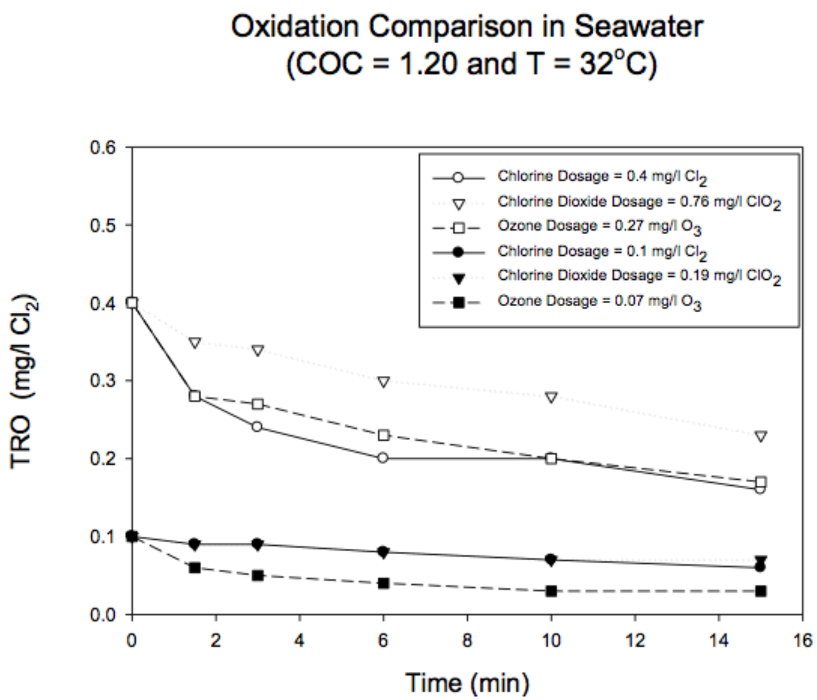


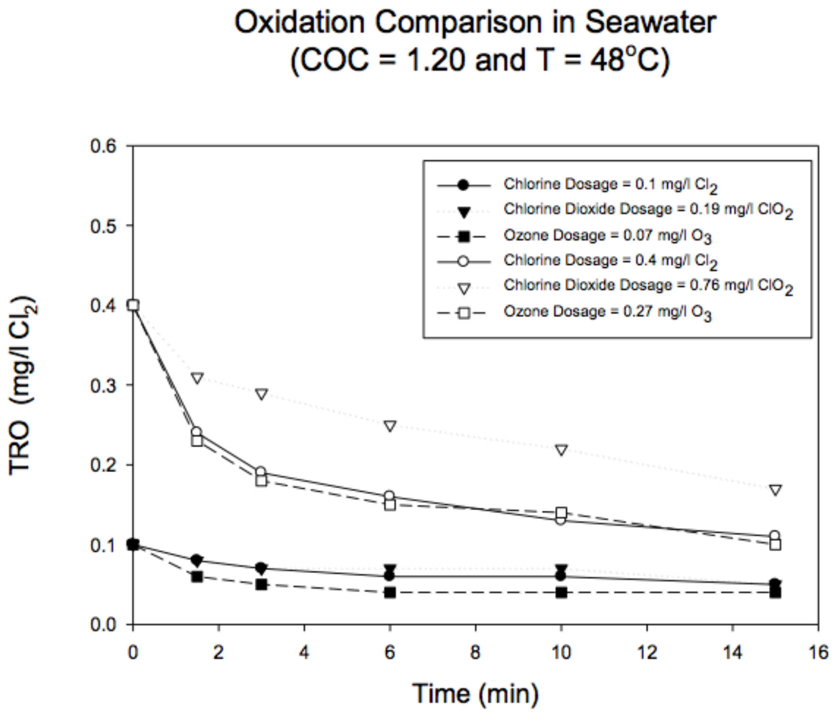
Different dosages and temperatures (32°C and 48°C) at constant COC of 1.2.

WDRC, KAUST SABIC project (bench scale)

Bench Scale results

Comparison of Total Residual Oxidants (TRO) between the oxidants



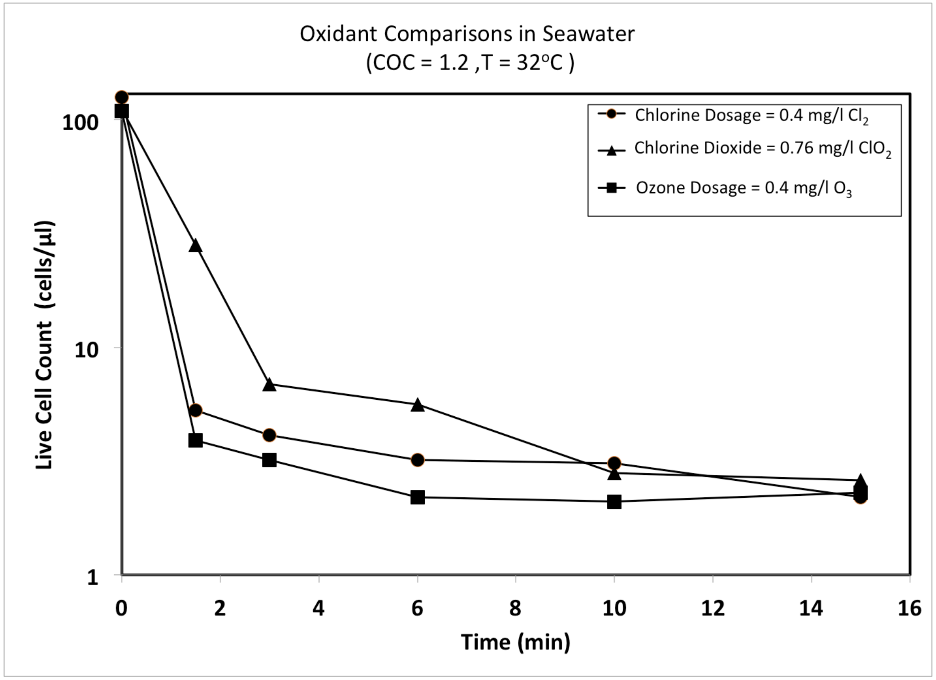


Total Residual Oxidant decay comparison for chlorine, ozone and chlorine dioxide at 32°C and 48°C.

WDRC, KAUST SABIC project (bench scale)

Bench Scale results

Microbial Analyses Due to Oxidants - Viable Cell count

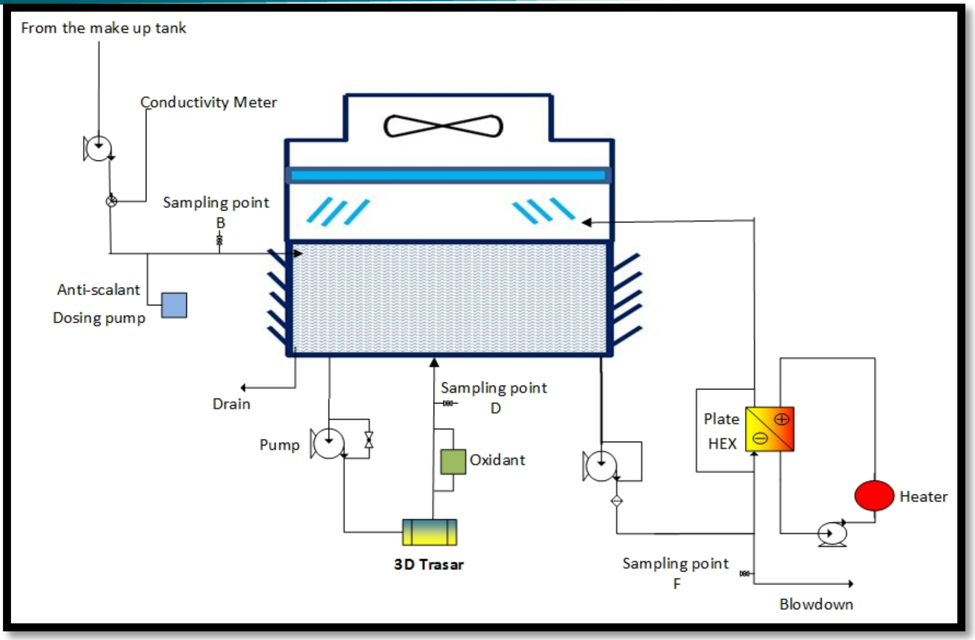


Oxidant	Dosage (mg/l Cl_2)	Temperature	
		32.0°C	48.0°C
Chlorine	0.1	34.3	25.2
Ozone	0.1 (0.07 mg/l O_3)	56.0	24.5
Chlorine Dioxide	0.1 (0.19 mg/l ClO_2)	19.2	8.1
Chlorine	0.4	2.8	2.5
Ozone	0.4 (0.27 mg/l O_3)	2.1	1.5
Chlorine Dioxide	0.4 (0.76 mg/l ClO_2)	2.8	1.8

- ✓ Oxidant is demanded when the seawater is concentrated (at higher COC).
- ✓ Comparison between the oxidants chlorine dioxide has a higher TRO values than chlorine and ozone.
- ✓ As for viable cell counts, chlorine dioxide also yielded higher disinfection rate at very low oxidant dosage.
- ✓ Finally the bench scale study is assisting for pilot scale.

WDRC, KAUST SABIC project (bench scale)

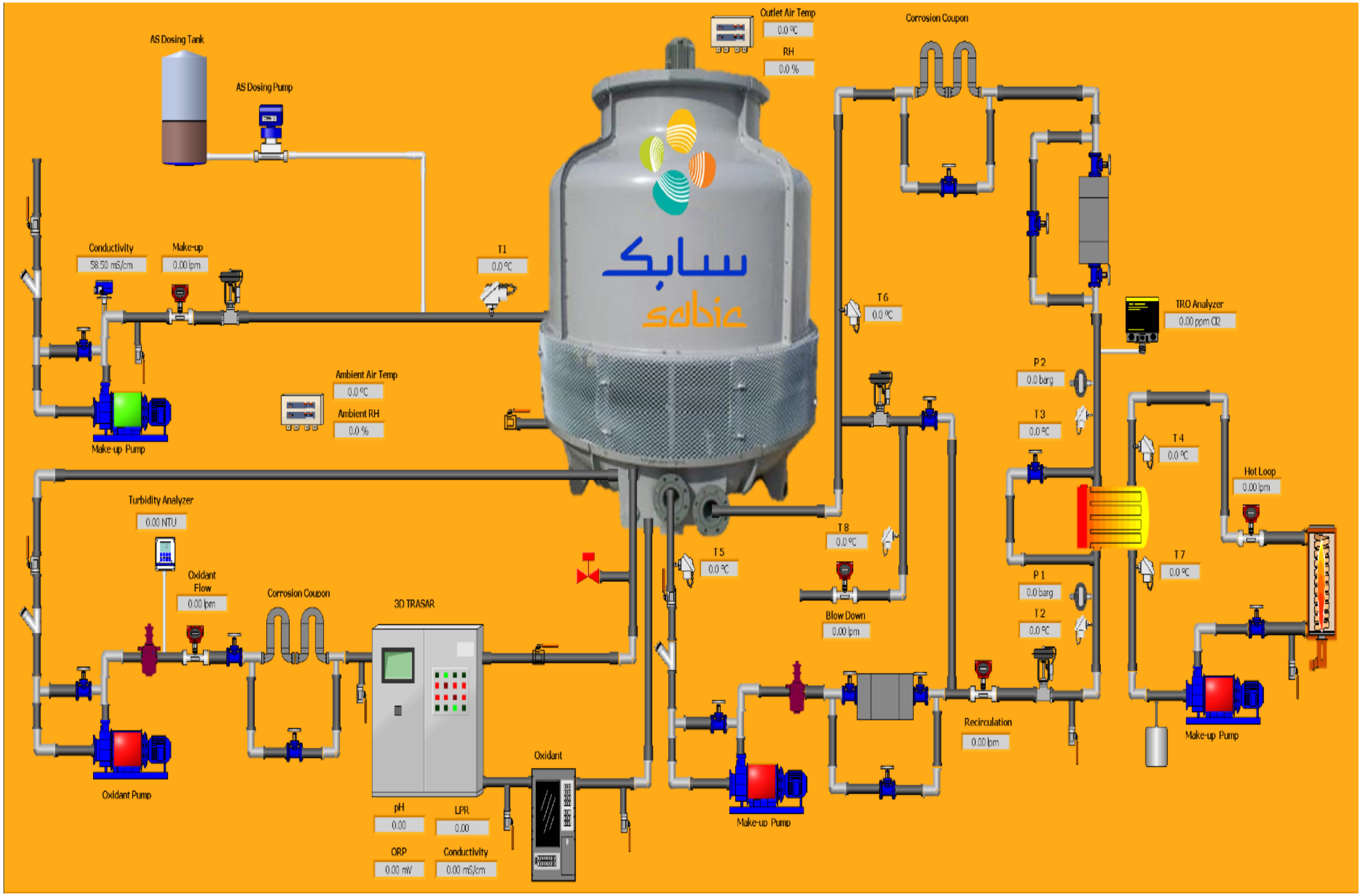
Pilot Scale



Test No	Test Program	Duration (days)	Remarks
1	Cooling Tower (CT) operation without treatment (No oxidation)	40	- COC =1.2. - Disinfectant switched off. - Anti-scalant dosing on. - Organics spike (Me OH).
2	CT operation with Oxidant Treatment (Oxidation)	30	- COC =1.2. - Disinfectant switched on. - Anti-scalant dosing on. - TRO = 0.2 ppm at blowdown (as Cl_2). - Organics spike (Me OH).

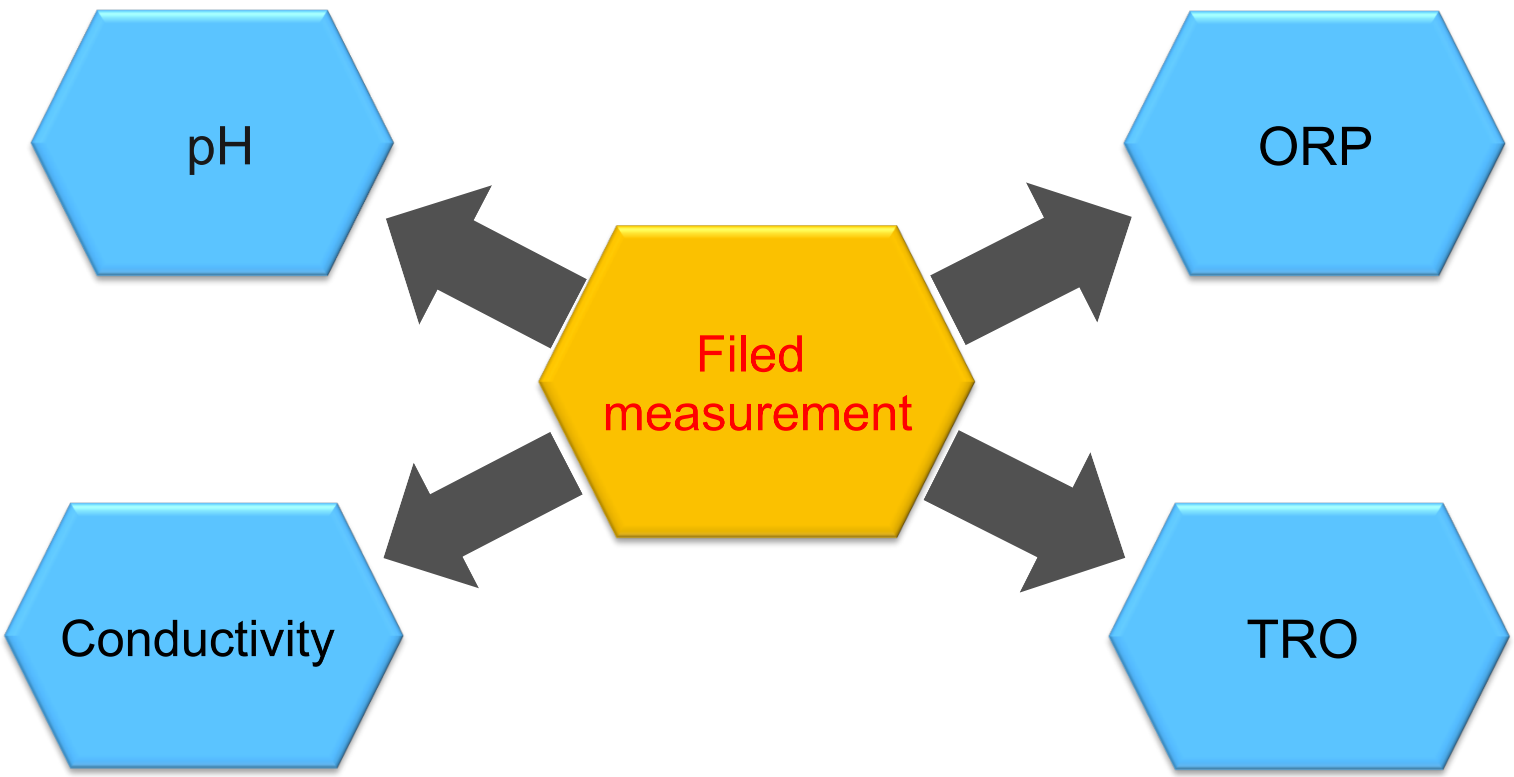
Pilot Scale

Graphical User interface with Real Time Data Acquisition and Logic Control

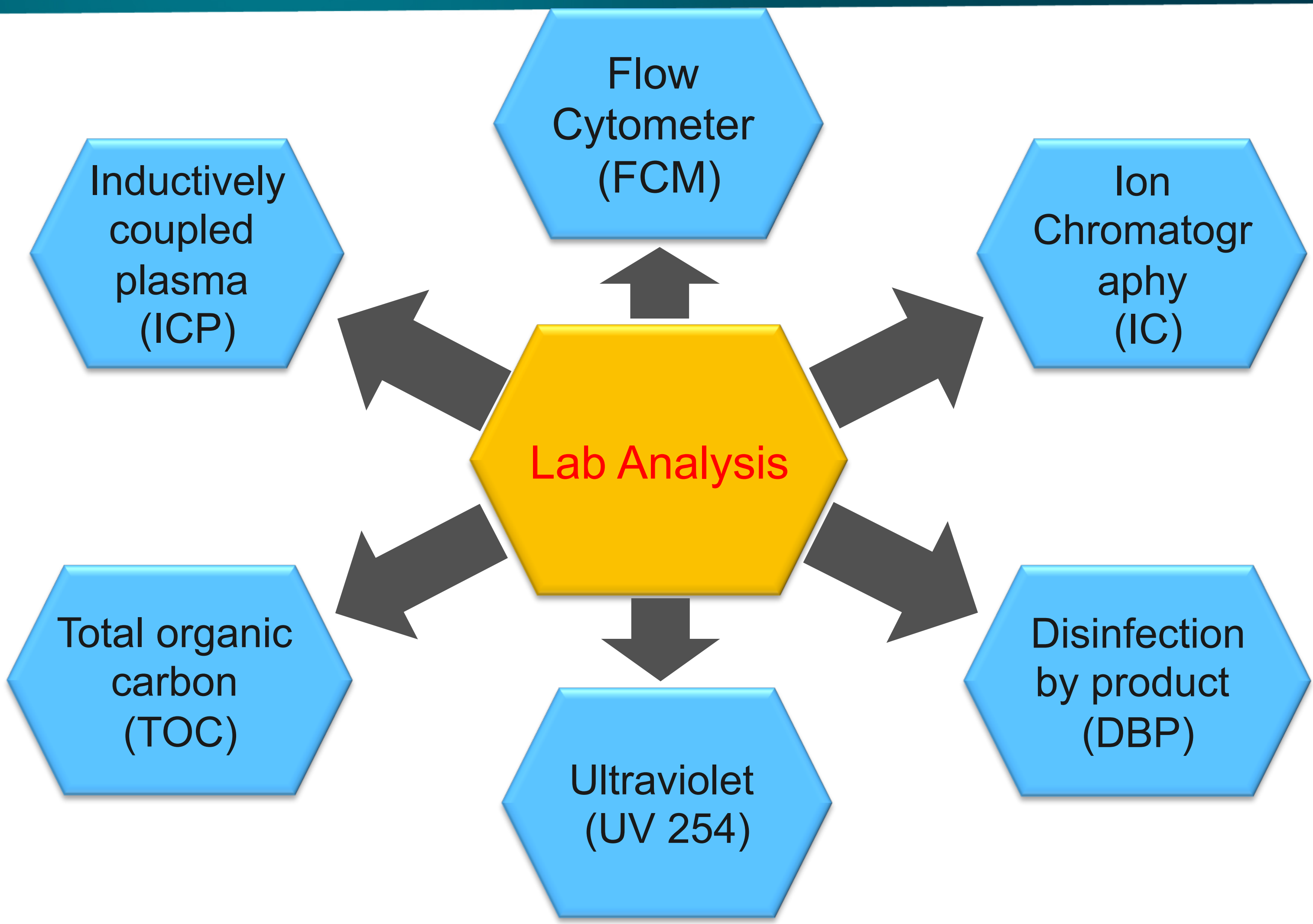


Pilot Scale

Methodology

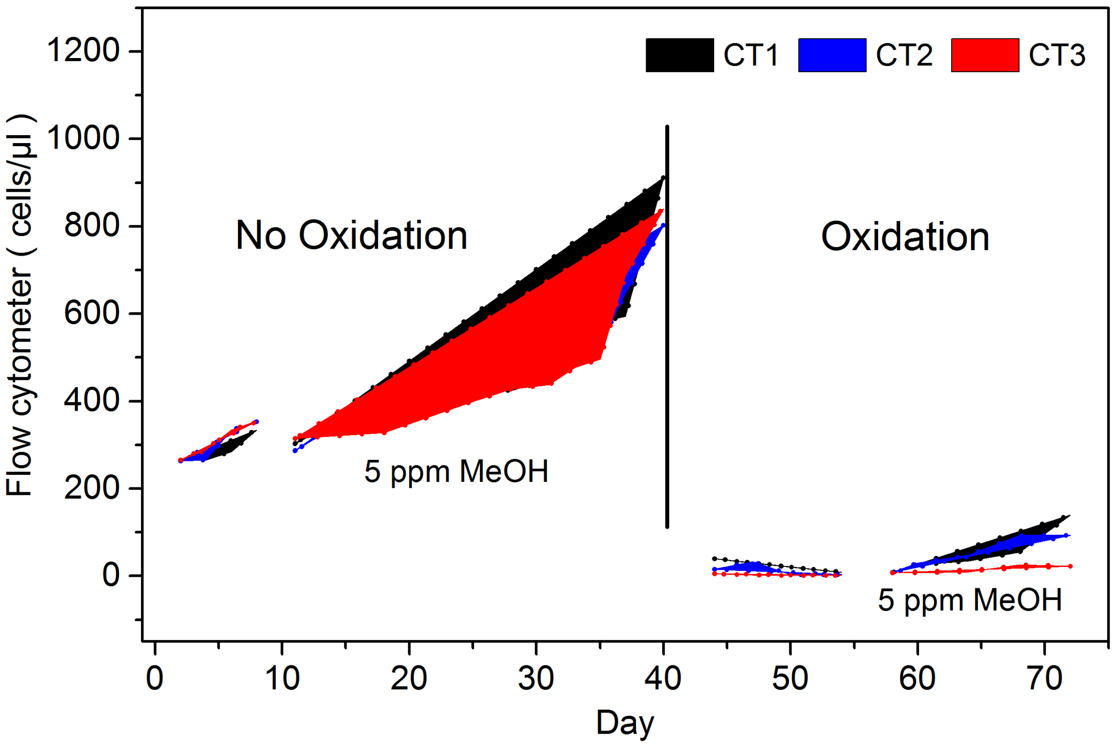


Methodology



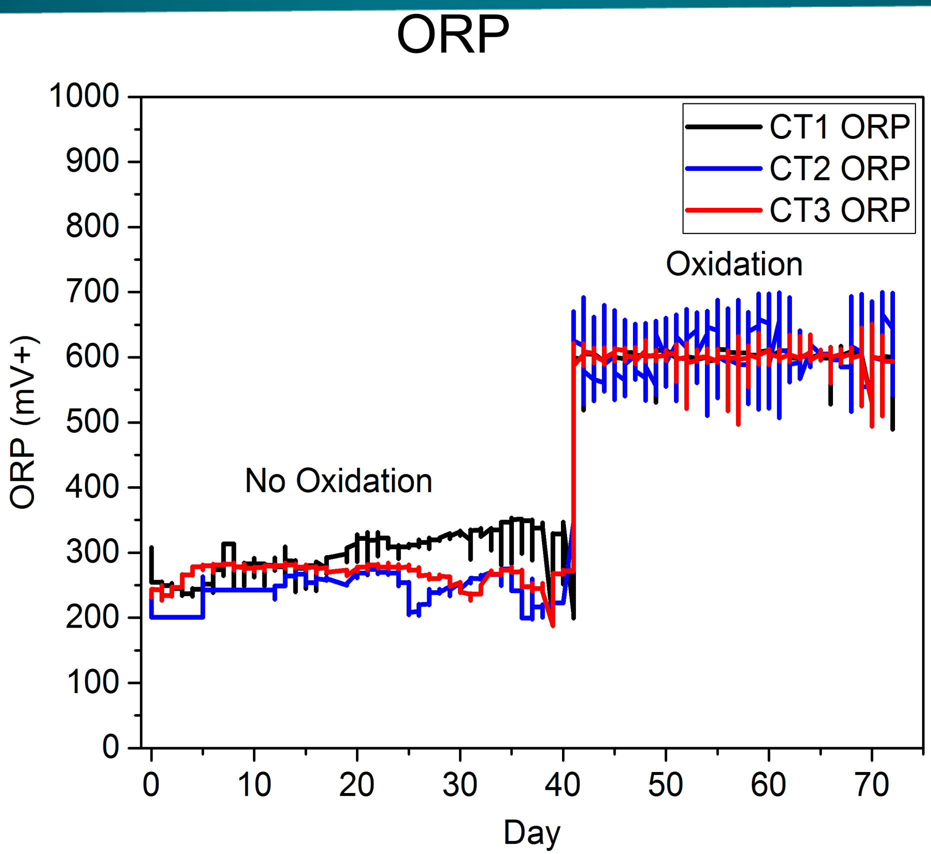
Pilot scale results

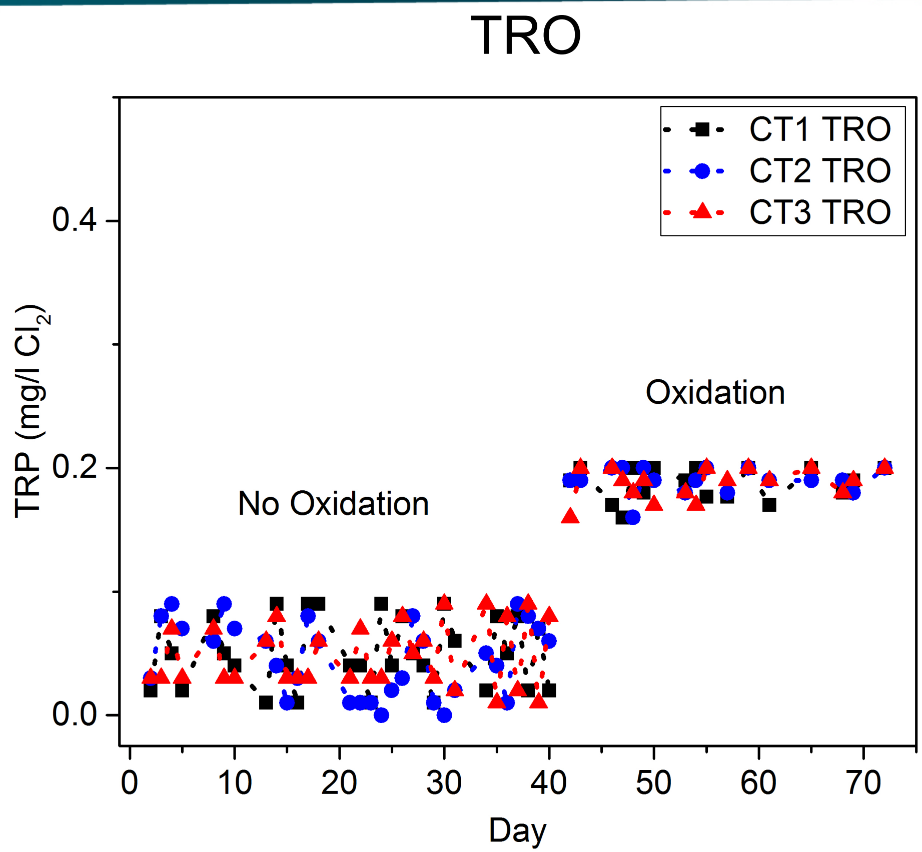
Biological growth



Biological growth was observed within the few days after organic (MeOH) addition.

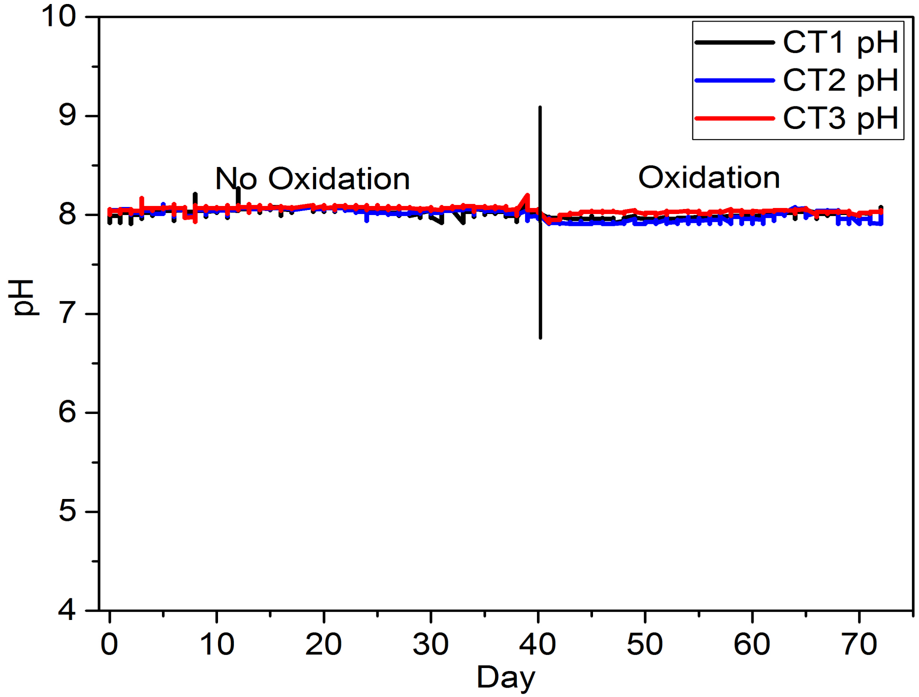
Effect of oxidation





Set point = +600 mV; equivalent to TRO of 0.2 ppm

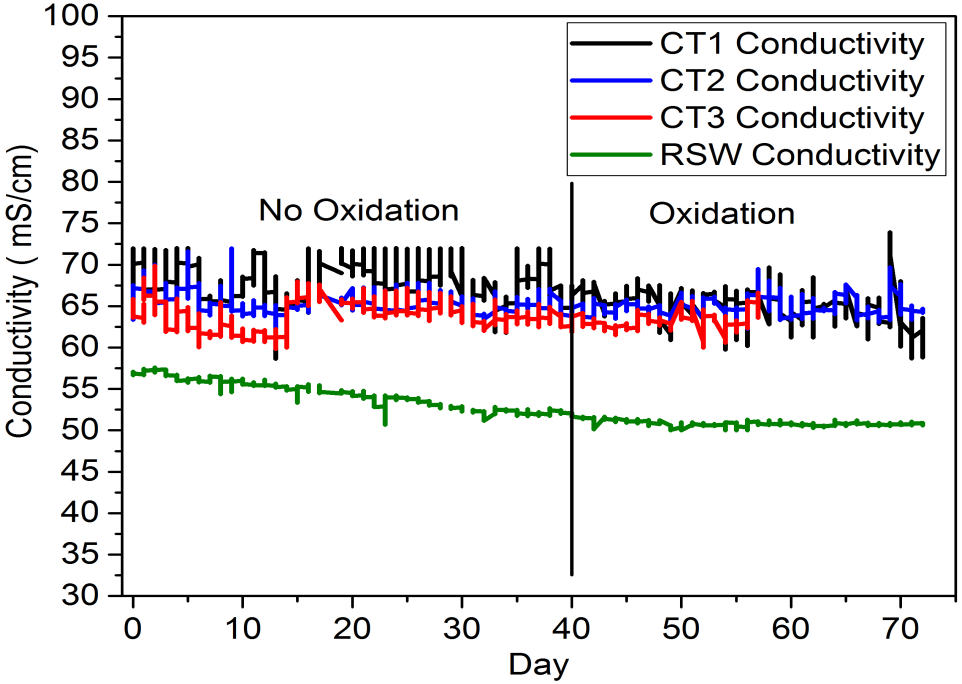
Bench Scale results



No pH change over the 70d and maintained at 8.0

COC = 1.2

All CTs show a similar conductivity average value of 65 mS/cm at CT basins



Disinfection byproducts (DBPs)

DBPs		Unit	CT1	CT2	CT3
Bromate ($NaBrO_3$)		ppb	3	0.8	114
Chlorite (ClO^{2-})		ppb	5	5	4
Chlorate (ClO^{3-})		ppb	57	5	4
TTHMs	Trichloromethane ($CHCl_3$)	ppb	57	1	58
	Tribromomethane ($CHBr_3$)	ppb	48	0	50
	Dibromochloromethane ($CHBr_2Cl$)	ppb	106	0	48
	Bromodichloromethane ($CHBrCl_2$)	ppb	48	2	211

Conclusions

- Higher biological growth was noted at higher concentration of methanol dose, this is due to increase the organic carbon.
- Ozone and Chlorine dioxide disinfectants were an effective in keeping the microbial growth to the minimum than, chlorination.
- Ozone are effective in inactivating 97 % microorganisms, and this is followed by chlorine dioxide at 91%, whilst the conventional chlorine dosing has only 84% reduction in bioactivities.
- Among the disinfectants, Chlorine dioxide was found less DPBs formed than, ozone and chlorination.

On going research

- Testing a new seawater anti-scalant (non-phosphorus based) at Higher cycles of concentrations (COCs).

- Collaboration project with Computational Bioscience Research Center on biofouling characterization (DNA) on seawater by using a standers coupon of (C1010).

- Nutrients removal from seawater to minimize biofouling and prevent algae and bacteria growth in seawater cooling tower by using AC biofilter.

Acknowledgement

We gratefully acknowledge the financial support from SABIC (Research Project: Alternative Treatment of Seawater Cooling Tower Using Ozone Microbubbles and Chlorine Dioxide)


Thank You