Effect of UV treatment on formation of disinfection by-products in chlorinated seawater swimming pools

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INNOVATIONS AND APPLICATIONS 2

Effect of UV treatment on formation of disinfection by-products in chlorinated seawater swimming pools

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Abstract

A laboratory scale study has been conducted to analyse the effect of UV irradiation on the formation of several DBPs in seawater pools. The pool samples were collected from three indoor public seawater pools and exposed to two different UV doses and then chlorinated in dark for 24 h. In this study, effect on the formation of various volatile disinfection by-products e.g. trihalomethanes (THM), haloacetonitriles (HAN) and haloacetic acids (HAA), were observed in laboratory experiments using medium pressure UV treatment after post-UV chlorination. Results showed that post-UV chlorine demand was increased, dose dependently, with UV treatment. Results also indicated that post-UV chlorination induced formation of several DBPs. However, the formation of HAAs were decreased significantly, dose dependently, with post-UV chlorination which could also mean that HAAs decomposition might occur due to heat from UV exposure. Furthermore, the breakage of HAAs molecules into smaller molecules would also mean that they resulted an increase in THMs. Overall, the formation of HAAs were decreased but the formation of THMs and HANs were increased with post-UV chlorination. There is need to standardize the application of UV system in the seawater pool.

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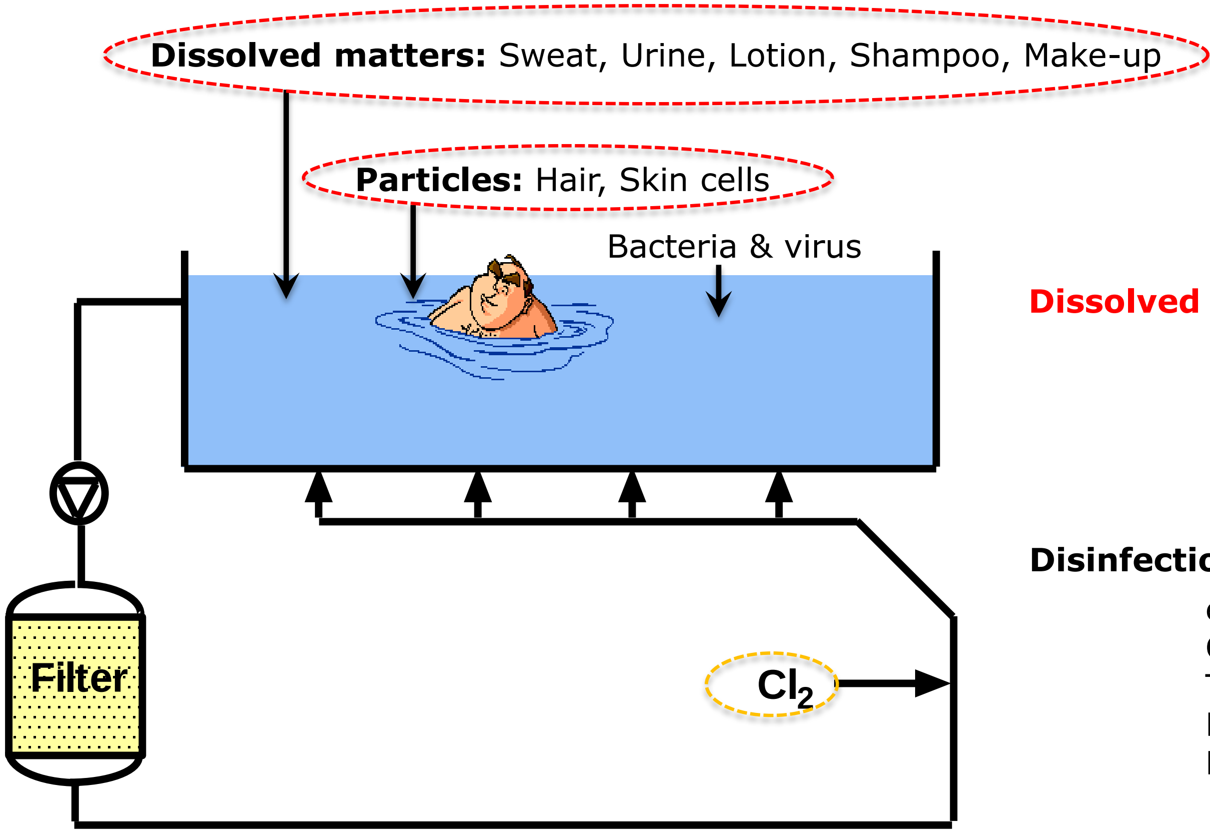
USA

Disinfection By-Products



Dissolved Organic Carbon (DOC)
+
Chlorine

↓

Disinfection By-Products (DBPs)

e.g.
Chloramines
Trihalomethanes
Haloacetonitriles
Haloacetic acids

Seawater Pools
Brominated DBPs

Skin conditions & wounds

Hay fever & sinus issues

Meditation & relaxation

Composition of seawater (mg/L)

Source: Water Condition & purification, 2005

	Typical Seawater	Eastern Mediterranean	Arabian Gulf at Kuwait	Red Sea at Jeddah
Chloride (Cl^-)	18.980	21.200	23.000	22.219
Sodium (Na^+)	10.556	11.800	15.850	14.255
Sulfate (SO_4^{2-})	2.649	2.950	3.200	3.078
Magnesium (Mg^{2+})	1.262	1.403	1.765	742
Calcium (Ca^{2+})	400	423	500	225
Potassium (K^+)	380	463	460	210
Bicarbonate(HCO_3^-)	140	-	142	146
Strontium (Sr^{2+})	13	-	-	-
Bromide (Br^-)	65	155	80	72
Borate (BO_3^{3-})	26	72	-	-
Total dissolved solids (TDS)	**34.483**	**38.600**	**45.000**	**41.000**

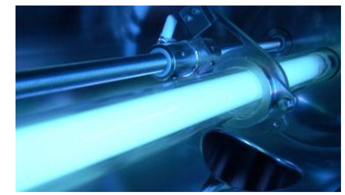
$$HOCl + Br^- \rightarrow HOBr + Cl^-$$

$$HOBr + DM \rightarrow Br\text{-}DBPs$$

Seawater pools disinfection resulted in brominated DBPs

Approach
Emerging treatment technologies

UV treatment



Particles → DOC + chlorine → DBPs

Can UV treatment be effective to remove the DBPs?

Approach
DBPs

Group	Compound	Abbreviation
THMs	Chloroform Bromodichloromethane Dibromochloromethane Bromoform	TCM BDCM DBC TBM
HANs	Dichloroacetonitrile Bromochloroacetanotile	DCAN BCAN
Misc. DBPs	Trichloronitromethane Dichloropropanone Trichloropropanone	TCnitro DCprop TCprop
HAAs	Bromochloroacetic acid Dibromoacetic acid Tribromoacetic acid Dibromochloroacetic acid	BCAA DBAA TBAA DBCAA

Approach
Toxicity estimation

- Calculated for water samples by:

$$Toxicity = \sum \frac{C_i}{EC_{50,i}}$$

EC_{50} taken from Plewa et al. 2008

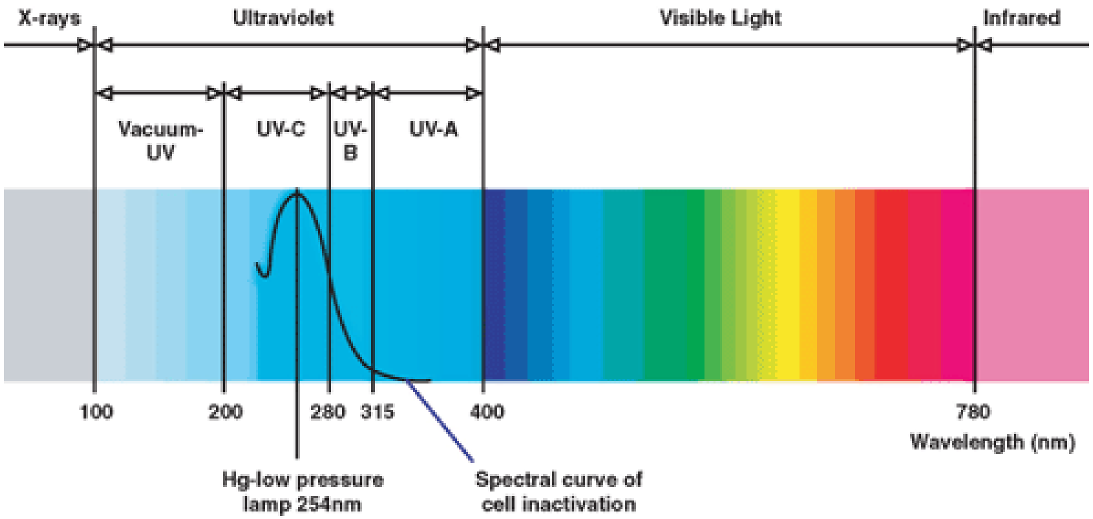
- The toxicity of the different groups

Haloacetonitriles (HANs) > Haloacetic acids (HAAs) > Trihalomethanes (THMs)

Hansen et al., (2012)

UV light

- UV light is short waved, high energy electromagnetic irradiation



Drinking water

- Low pressure UV is used for bacteria control

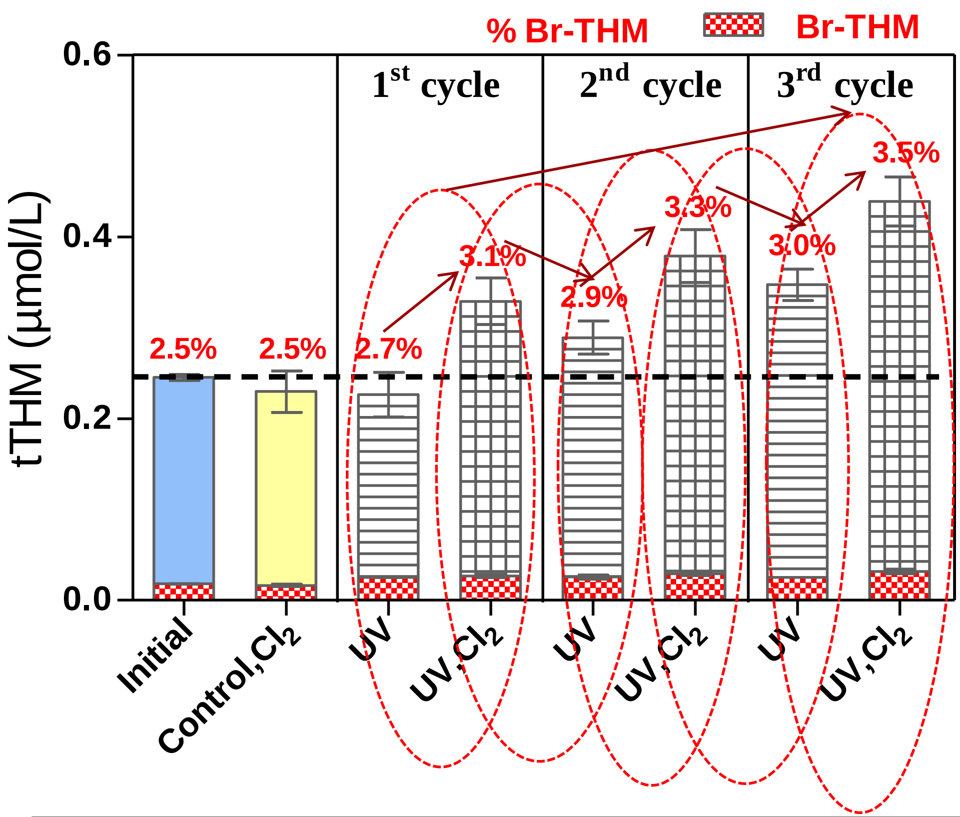
Swimming pools

- Medium pressure UV is used for combined chlorine control

UV photolysis

Freshwater pools

Total Trihalomethane

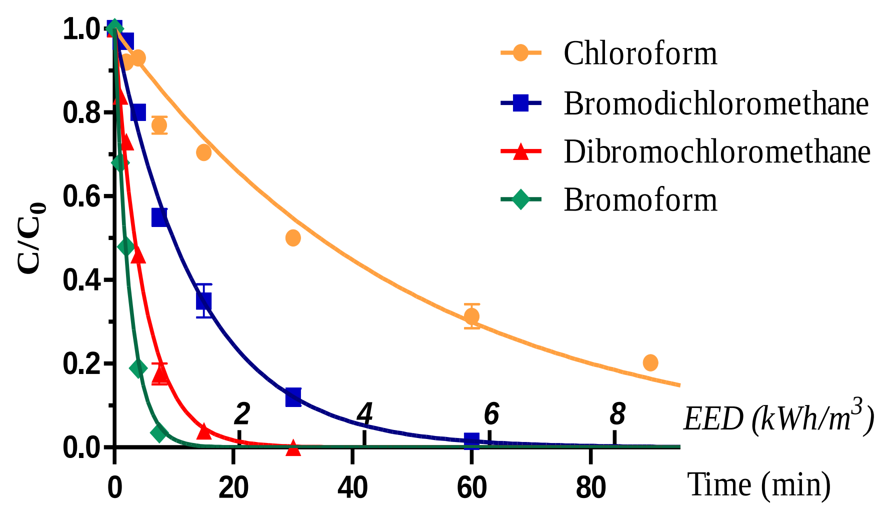


UV treatment followed by Cl_2 → increased Br-THM

UV treatment → decreased Br-THM

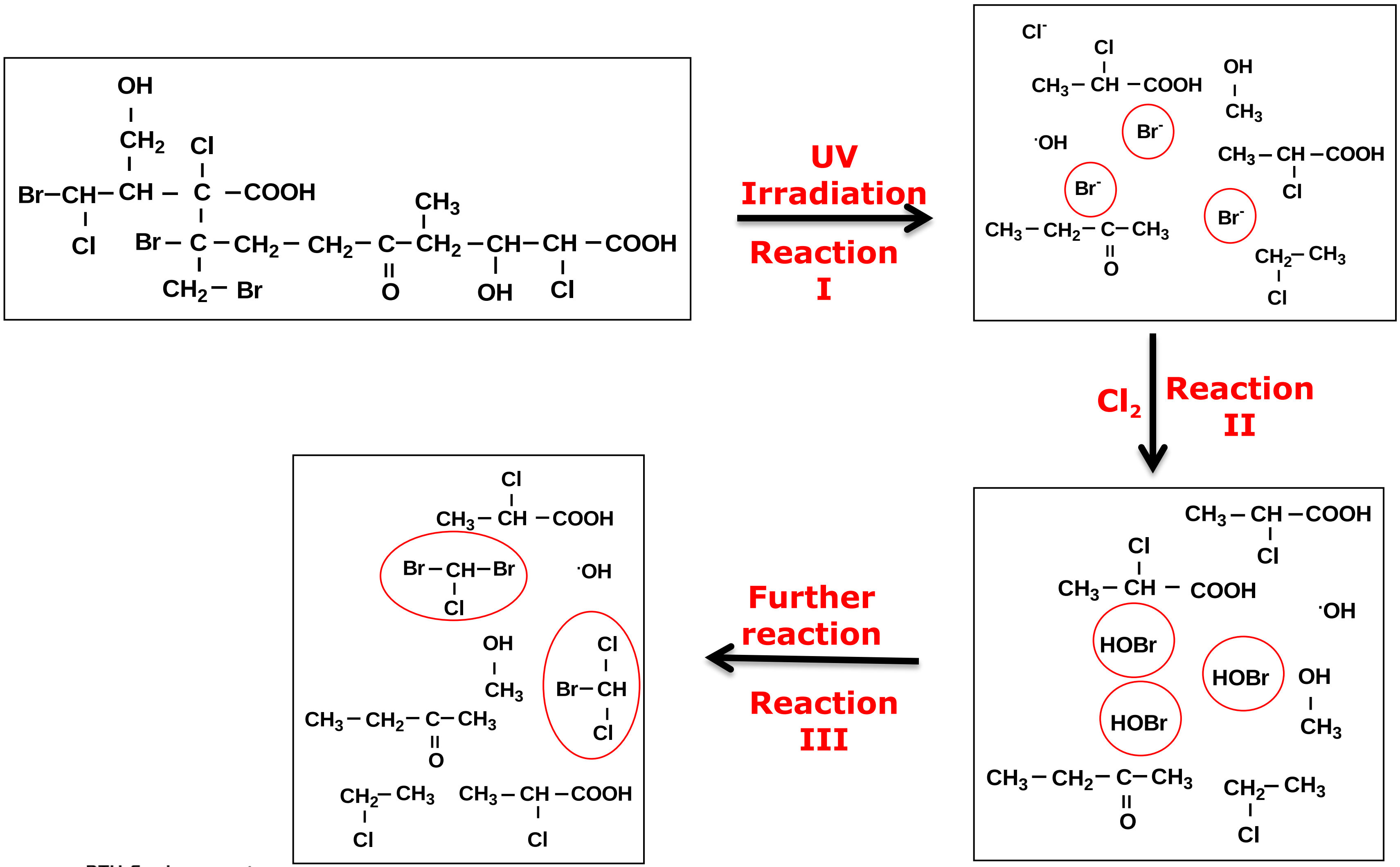
UV photolysis

Hansen et al., (2013)



- Increased bromine substitution → increasing UV photolysis

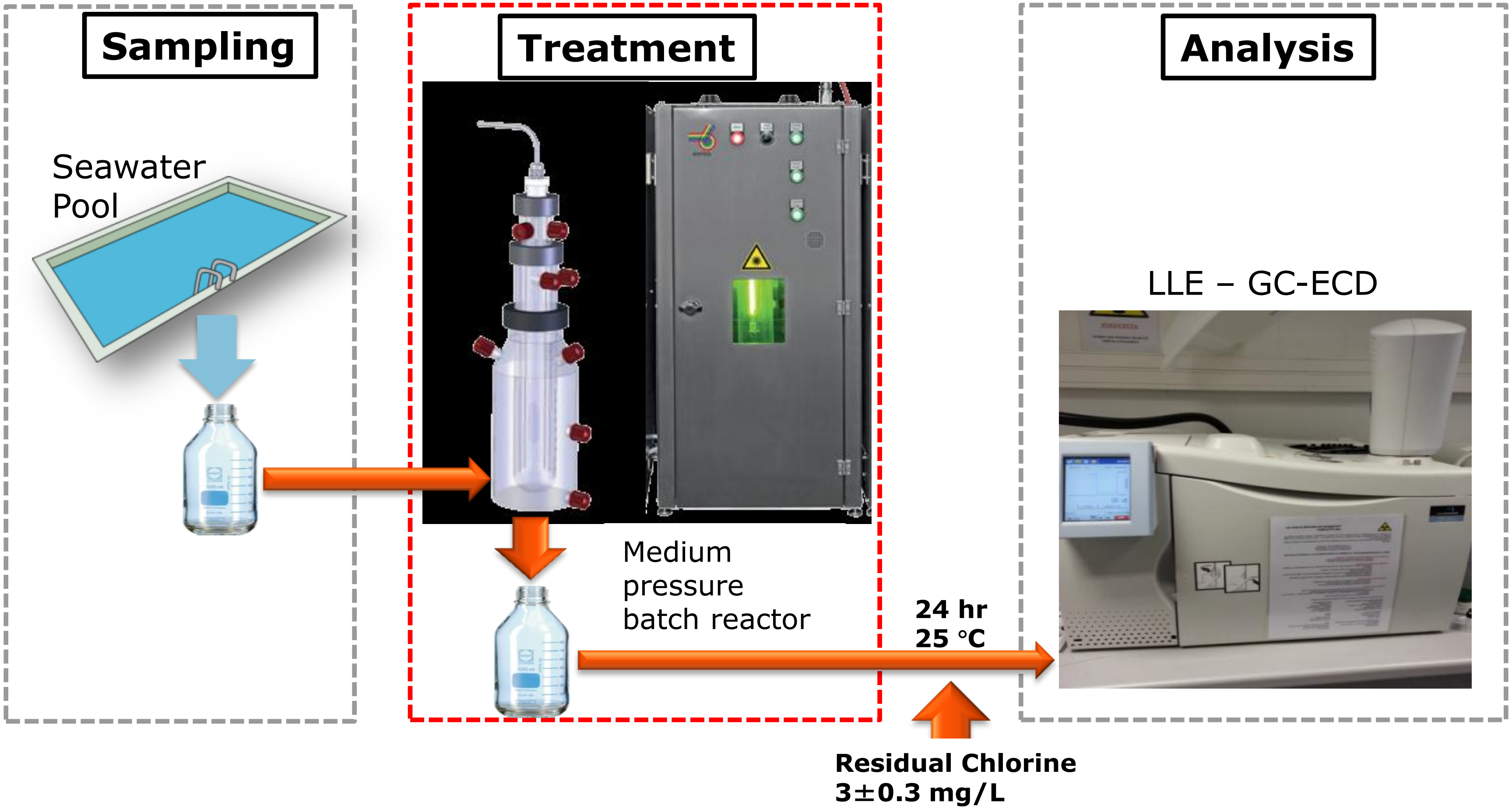
Br-Cl-DBP Formation Theory



Spiliotopoulou et al., (2015)

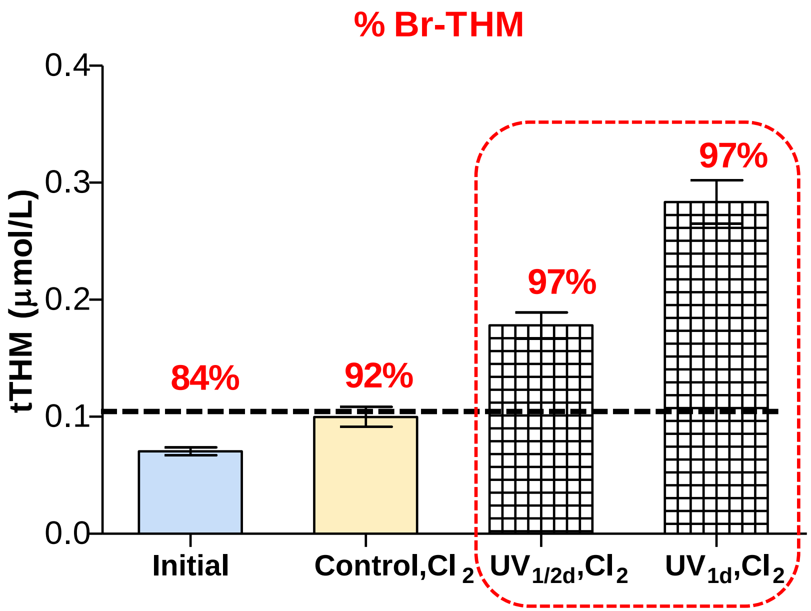
FRANCE
ATLANTIC OCEAN
SLOVENIA
CROATIA
Ligurian Sea
Gulf of Lion
ITALY
Adriatic Sea
Corsica
Bosphorus
Strait of Otranto
ALBANIA
SPAIN
Balearic Sea
Sardinia
Tyrrhenian Sea
Thracian Sea
Sea of Marmara
PORTUGAL
Balearic Islands
GREECE
Dardanelles
TURKEY
Aegean Sea
MEDITERRANEAN
Sicily
Ionian Sea
Sea of Sicily
Strait of Messina
Myrtoan Sea
Gulf of Antalya
Strait of Gibraltar
Alboran Sea
SEA
MALTA
Sea of Crete
Crete
Cyprus
Gulf of Gabès
ALGERIA
Libyan Sea
Levantine Sea
TUNISIA
MOROCCO
Gulf of Sidra
LIBYA
EGYPT

Experimental setup



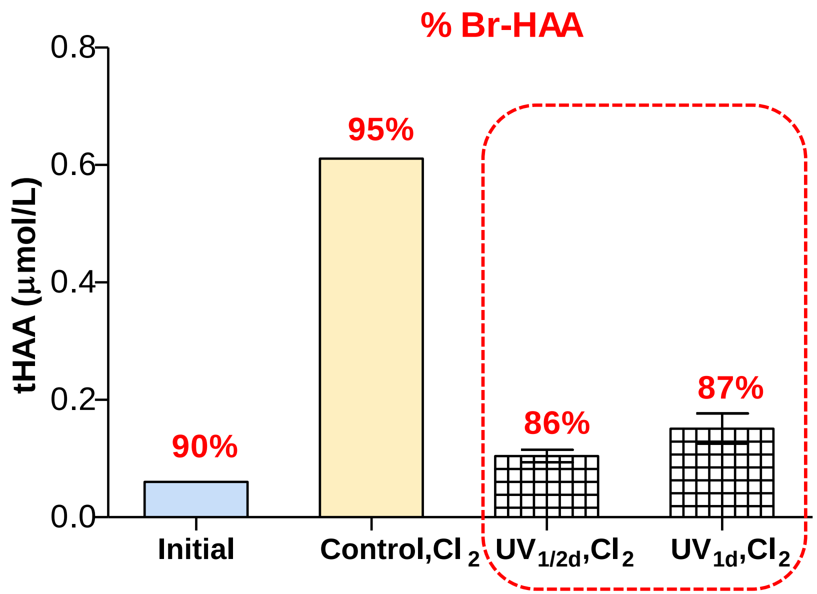
UV in seawater pools
Results

Total Trihalomethane



- UV treatment followed by Cl_2 → increased total THM

Total Haloacetic acid

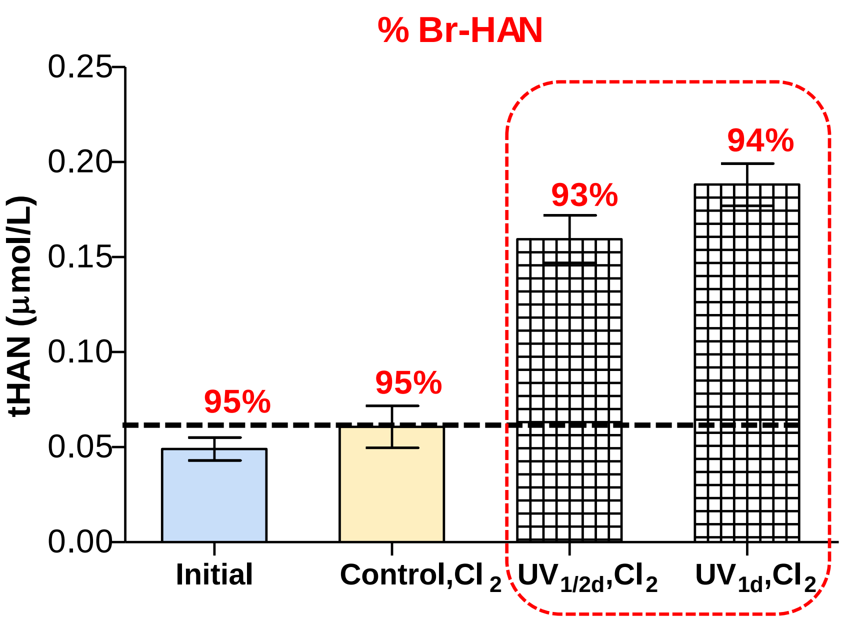


- UV treatment followed by Cl_2 → decreased total HAA

UV in seawater pools

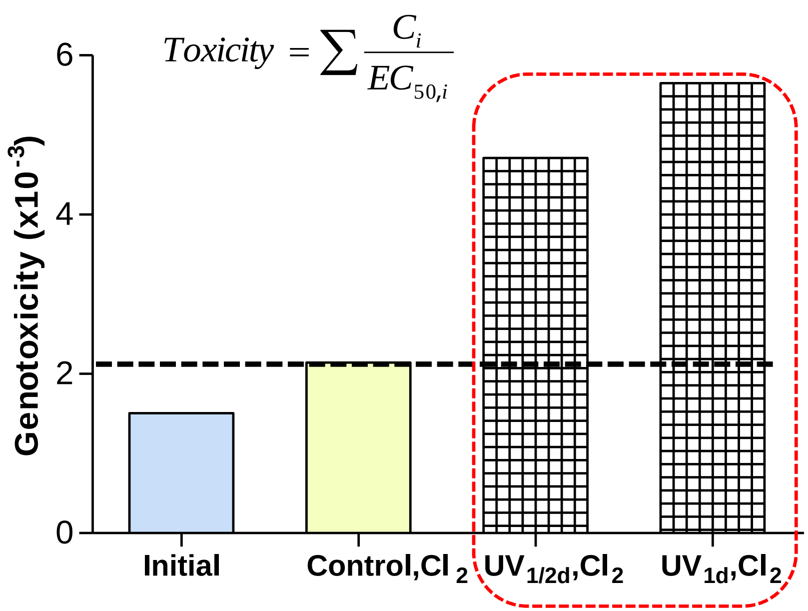
Results

Total Haloacetonitriles



- UV treatment followed by Cl_2 → increased total HAN

Genotoxicity



- UV treatment followed by Cl_2 → increased toxicity

Future work

Seawater pools

- Repeated treatment investigations for seawater pools

Thanks for your attention!