Babak Rajaeian

PhD candidate
Department of Civil Engineering

The Effect of Natural Organic Matter on Bromide Removal from Drinking Water Using Silver-Impregnated Activated Carbon (SIAC)

Supervisors:

A/Prof Anna Heitz (*Department of Civil Engineering*)

A/Prof Cynthia Joll (*Curtin Water Quality Research Centre*)

Dr Sébastien Allard (*Curtin Water Quality Research Centre*)

About Myself…

Research question?

Why do we need to remove **bromide** from drinking water sources???

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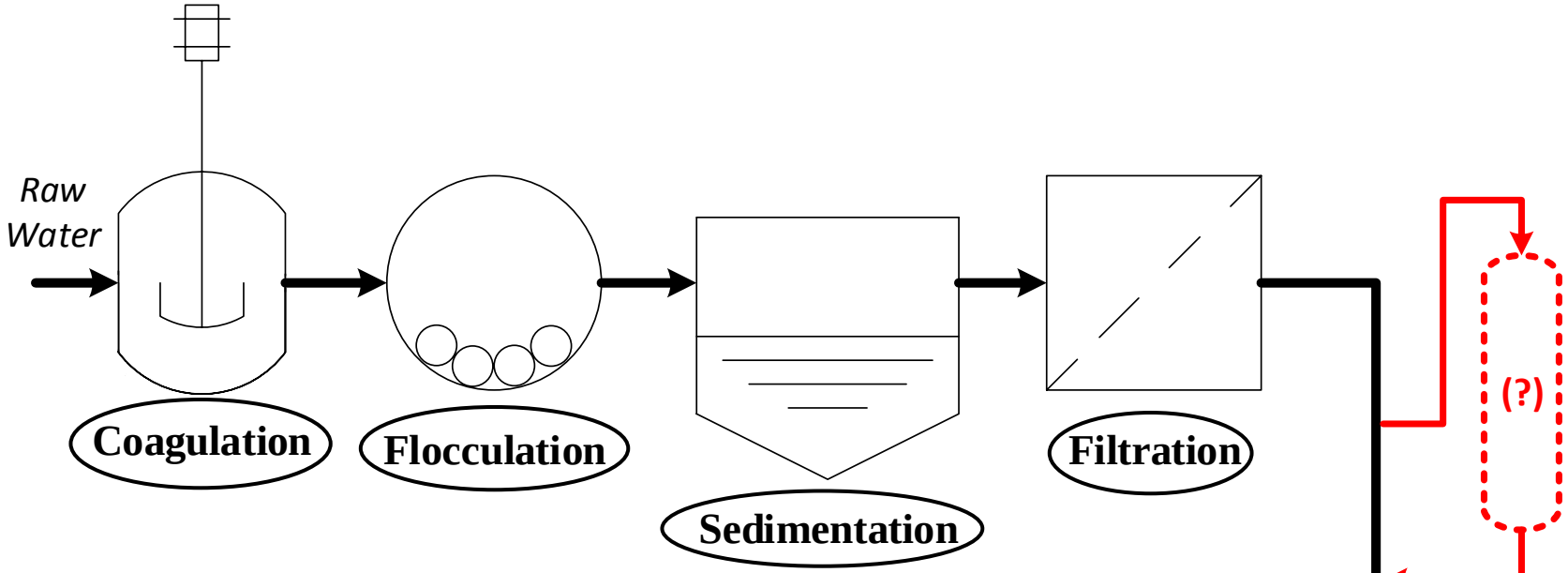
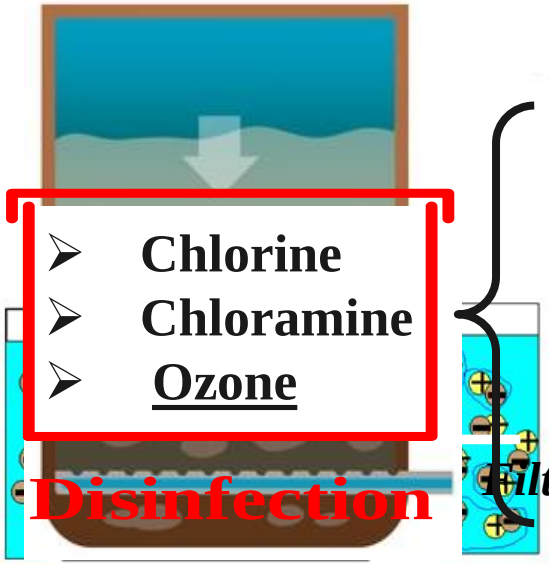
Industry Knowledge Gap





1) Carcinogenic { **Bromate**, **Br-DBPs**, **N-DBPs**
2) **Discoloured** water
3) **Taste** and **odour** issues
4) Exacerbated disinfectant decay (*Minimised disinfectant residuals*)

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Challenges in Western Australia (WA)

Sample	[Br] (µg/L)	[DOC] (mgC/L)
North-West Coastal GW	8455	0.8
Great Southern SW1	847	10.2
South-East GW	754	1.2
North-West SW	448	4.3
South-West SW	400	3.5
Perth Metro GWTP raw water	743	7.6
Mid-West E GW bore	1460	0.6
Goldfields GW bore 1	977	0.8
Goldfields GW bore 2	1385	1.2
Goldfields GW bore 3	817	0.7
Goldfields GW bore 4	868	0.9
Goldfields GW bore 5	717	0.9
Perth South Coastal GW bore 1	1483	1
Perth South Coastal GW bore 2	479	2.6
Perth South Coastal GW bore 3	1307	1.2
Great Southern SW2	561	16.2
Mid-West W GW bore 1	2249	0.5
Mid-West W GW bore 2	1908	0.4
Mid-West W GW bore 3	2807	0.6
Perth Northern GW bore	567	2.2
Perth Metro artesian GW	2261	1

(E = eastern; GW = groundwater; GWTP = groundwater treatment plant; SW= surface water; W = western).

(Gruchlik et al., Water, 2015)

https://www.watercorporation.com.au/water-supply/our-water-sources?pid=res-wss-np-spw

[Br] < 50 µg/L — **Low**
(Gillogly et al., AWWA Research Foundation, 2001)

76 µg/L < [Br] < 540 µg/L — **Moderate to High**
(Boyer and Singer, Water Research, 2005)

[Br] > 700 µg/L — **Very high**
(Hansson et al., Water Research, 1987)

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Current Methods for the Bromide Removal

Membrane

- ❑ Reverse osmosis
- ❑ Nanofiltration

- × Susceptible to fouling
- × High **energy** consumption
- × Short **lifespan**
- × **Costly** pre-treatment processes
- × **NOT selective** and **overtreats** water

Electrochemical

- ❑ Electrolysis
- ❑ Capacitive deionization (CDI)
- ❑ Membrane capacitive deionization (MCDI)

- × High capital **cost**
- × High **energy** consumption

- × **NOT selective** and **overtreats** water

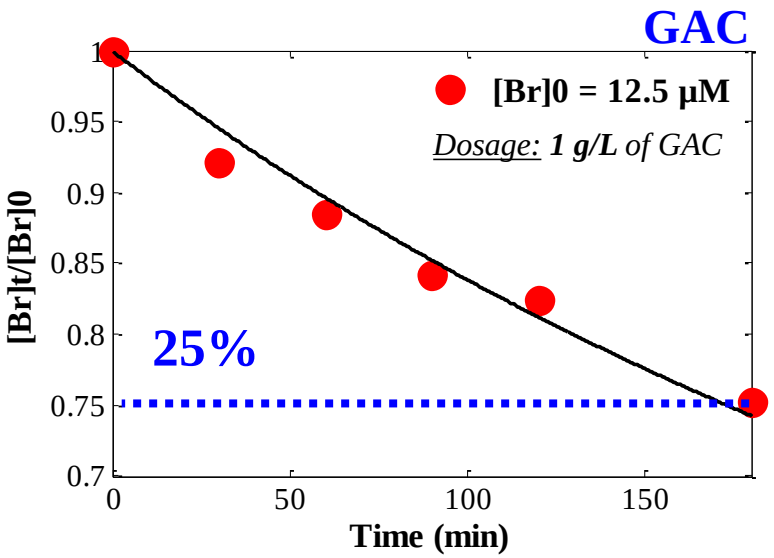
Adsorption

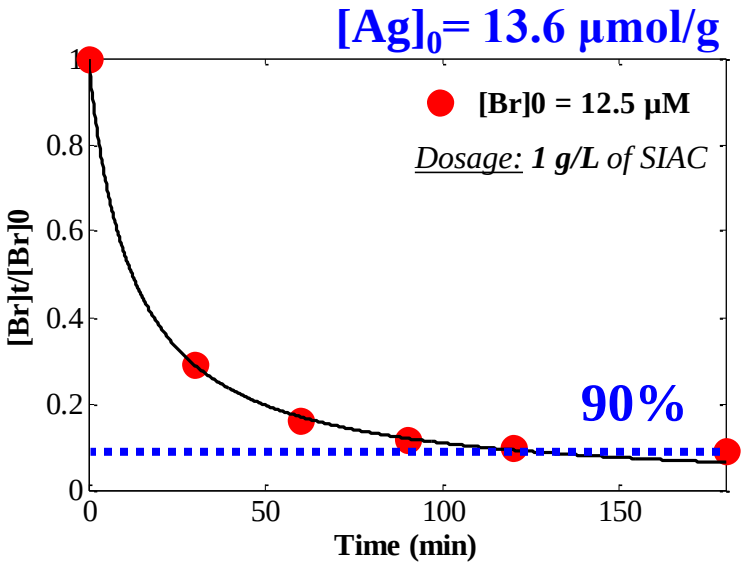
- ❑ Aluminium coagulation
- ❑ Ion-exchange resins
- ❑ **Activated carbon (GAC)**

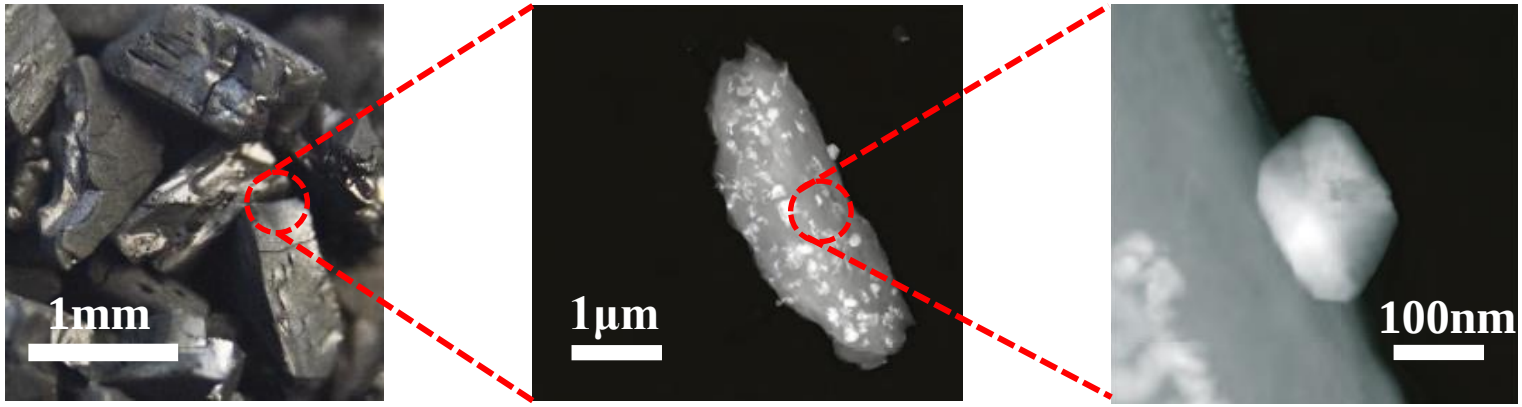
- ✓ Ease of application and **low-cost**

- × **NOT selective** and **overtreats** water

Silver-Impregnated Activated Carbon







Nowack et al. ES & T (2010)

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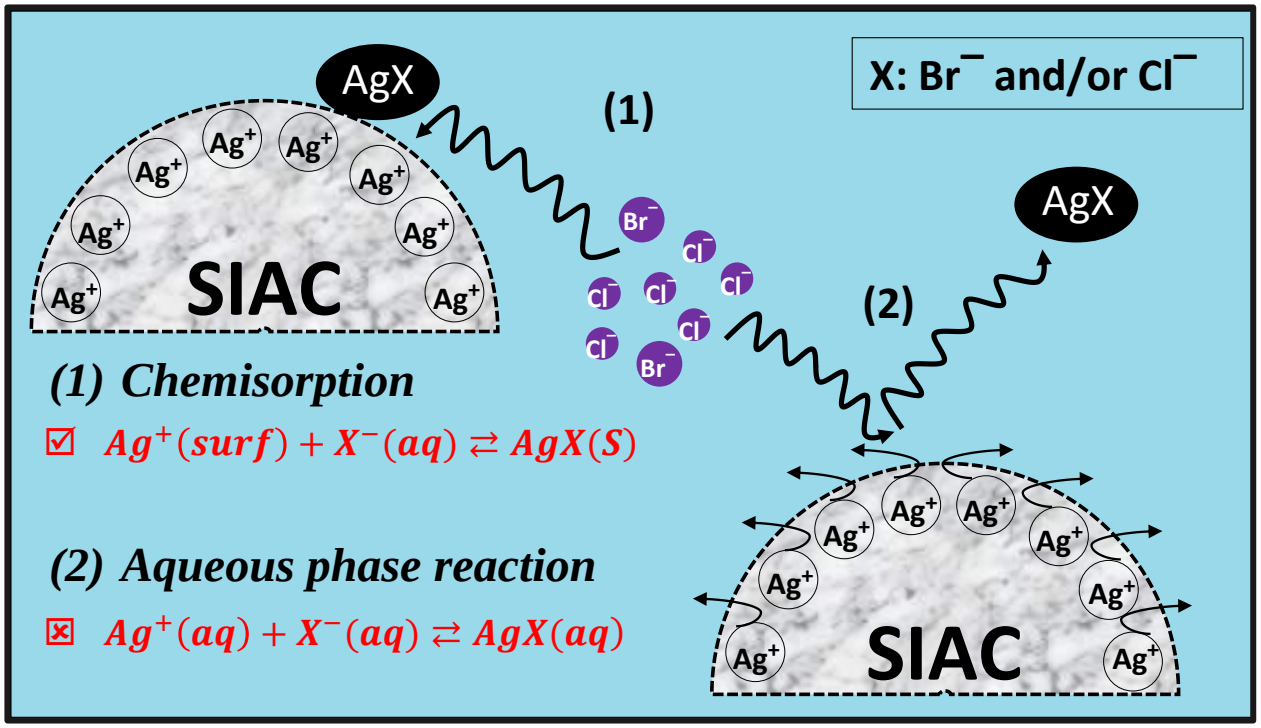
Br^- Removal Mechanisms

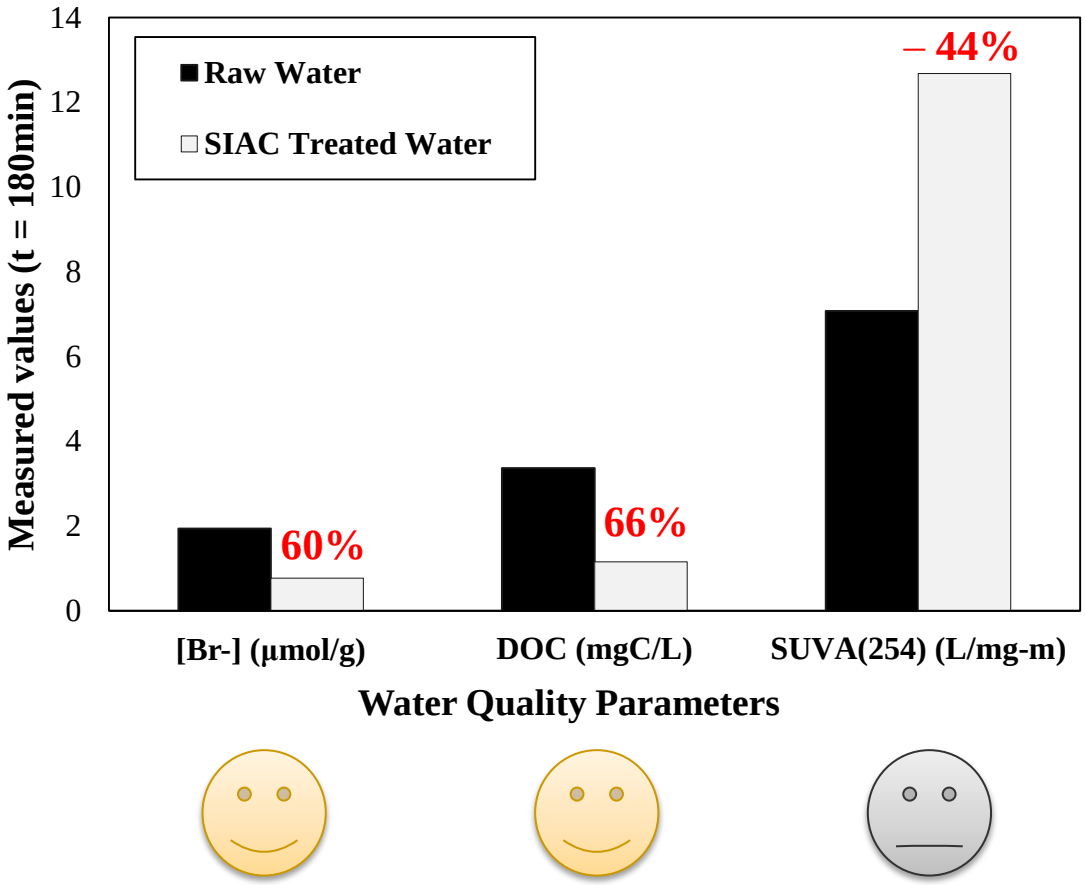


$$Ag^+ + Cl^-(aq) \rightleftarrows AgClK_{sp} = 2.8 \times 10^{-10}$$

$$Ag^+ + Br^-(aq) \rightleftarrows AgBrK_{sp} = 5.2 \times 10^{-13}$$

$$AgCl + Br^-(aq) \rightleftarrows AgBr \text{ (Anion exchange of } Cl^- \text{ for } Br^-)$$

A Groundwater Sample From a Bore in Western Australia



	Initial values
Chloride (mg/L)	43
Bromide (µg/L)	155
Iodide (µg/L)	5
DOC (mgC/L)	3.37
$UV_{254\ (nm)}$	0.238
SUVA (L/mg-m)	7.08
pH	7.1

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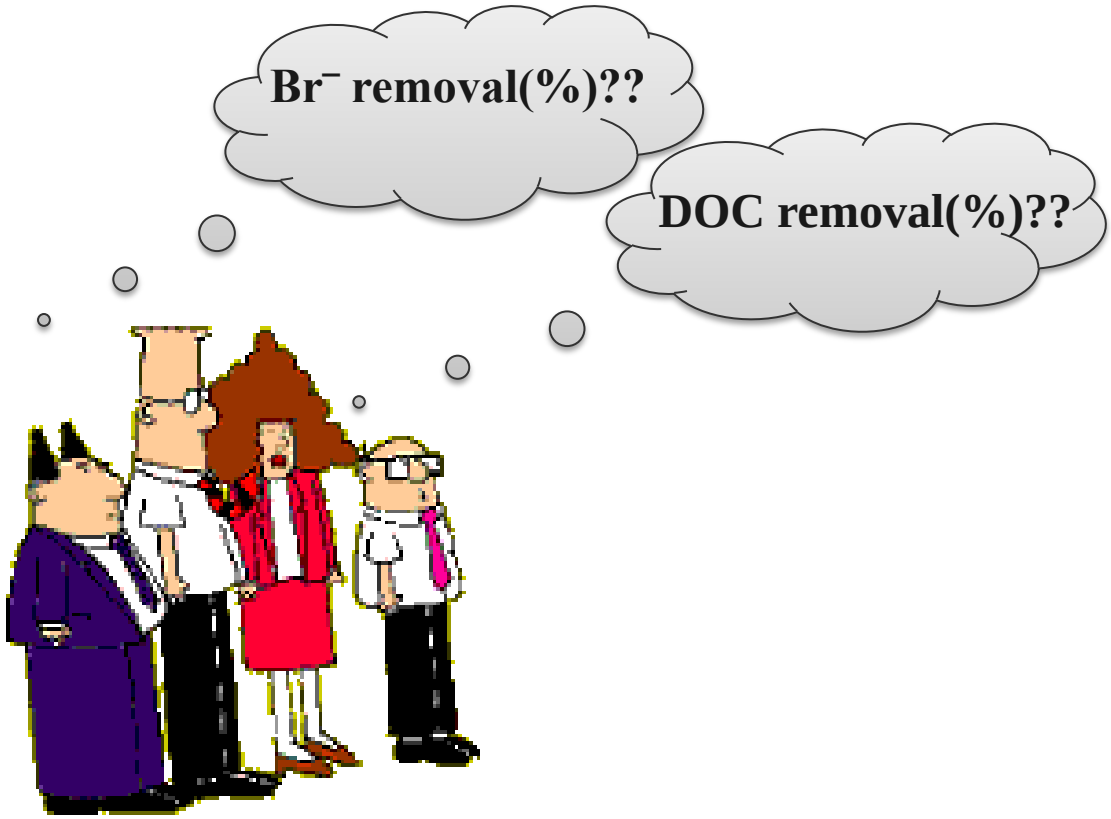
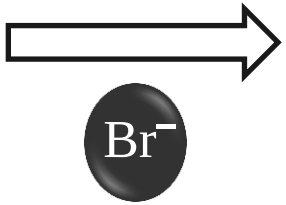
Research Gap!!



NOM Character



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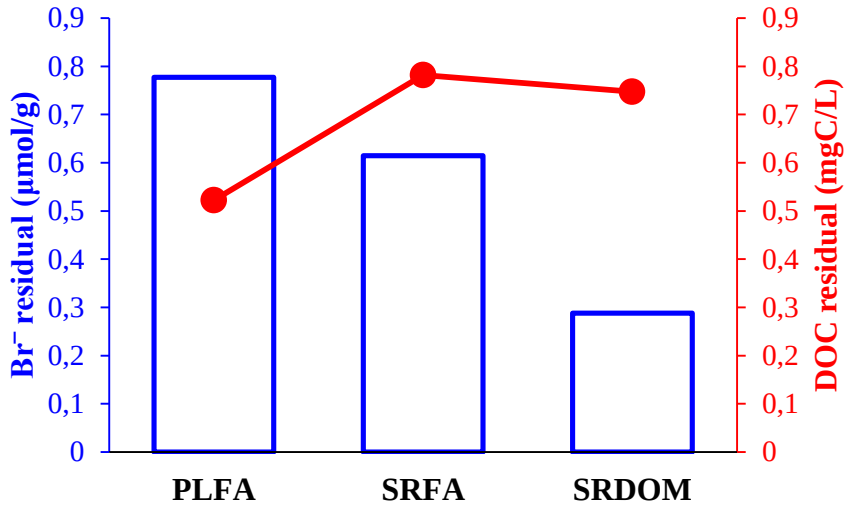
SIAC Treatment of Selected NOM Isolates



$[Br]_0$= 12.5 µM

$[DOC]_0$= 1 mgC/L

***Dosage:** 2 g/L of SIAC*

NOM isolate type	M_w	$SUVA_{254}$	C		O (w/w) %	N (w/w) %	S (w/w) %
			Aromatic (%)	Aliphatic (%)			
Pony Lake Fulvic Acid (PLFA) - 1R109F	1200 – 1400	2.51	12	61	31.38	6.51	3.03
Suwannee River NOM (SRDOM) - 2R101N	2190	3.84	24	33	41.48	1.27	1.78
Suwannee River Fulvic Acid (SRFA) - 2S101F	2290 – 2310	5.16	23	27	42.98	0.67	0.46

Elemental Compositions and Stable Isotopic Ratios of IHSS Samples http://www.humicsubstances.org/elements.html (accessed Mar 10, 2017).

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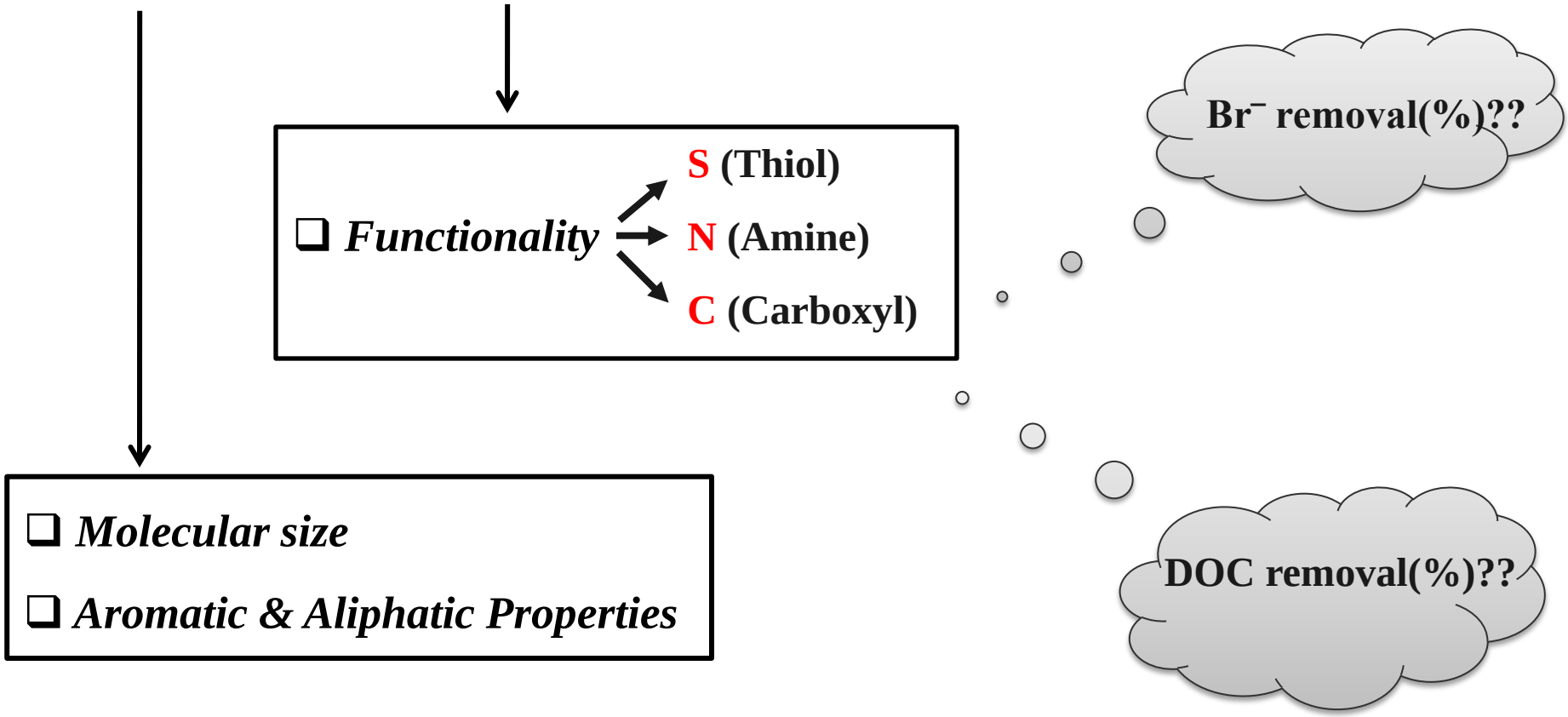
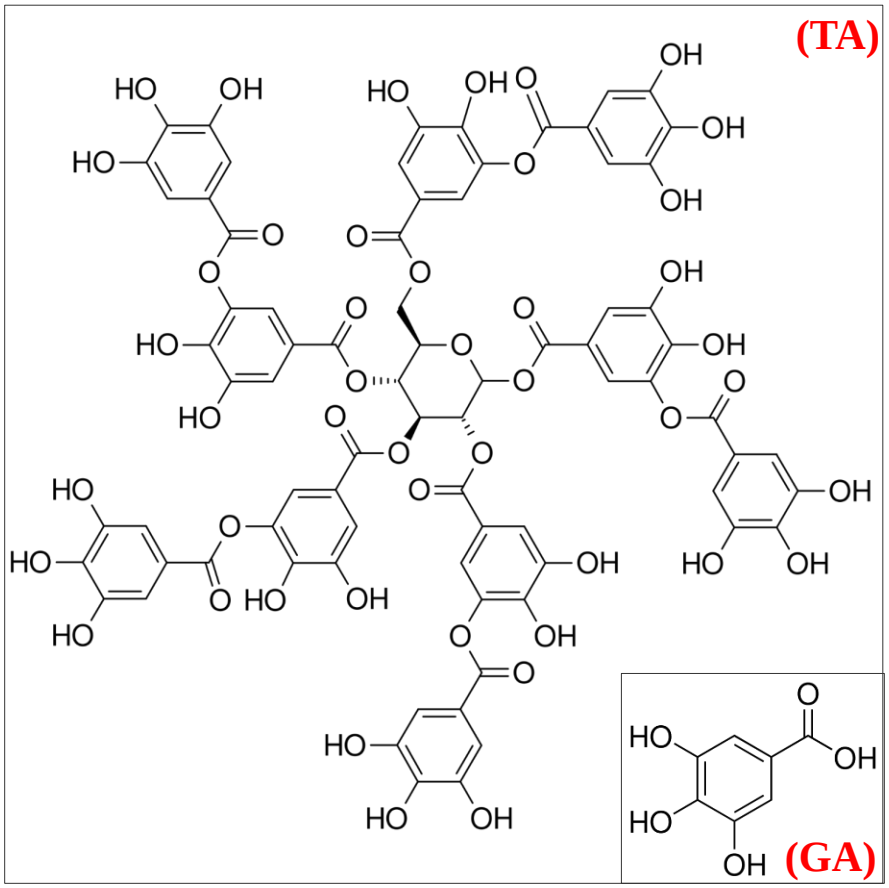
Take-home Message...

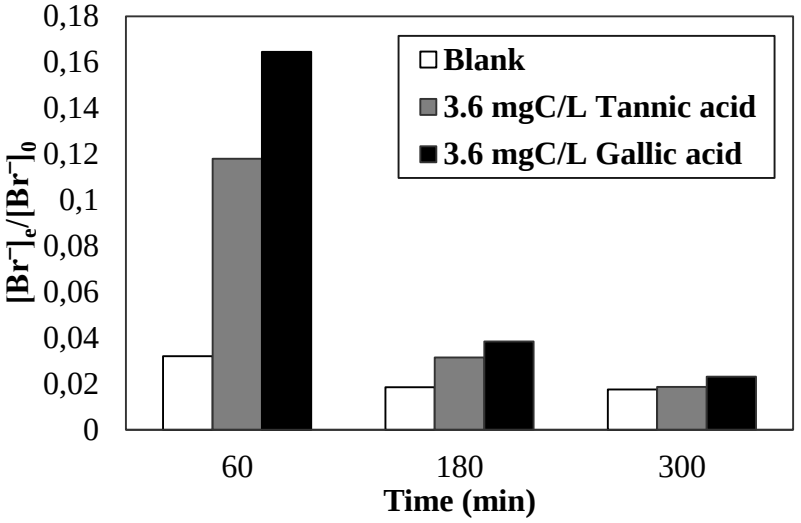
Physical **and** ***Chemical*** **characteristics of NOM**

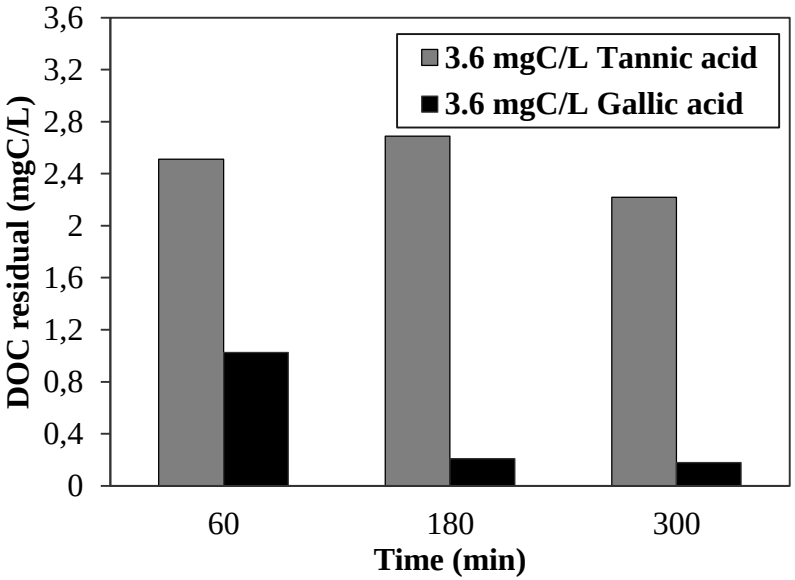


NOM model compounds (Size effect)



Compound	Molecular Weight	Molecular Diameter
Tannic acid (TA)	1701.2 g/mol	1.6 nm
Gallic acid (GA)	170.12 g/mol	0.57 nm





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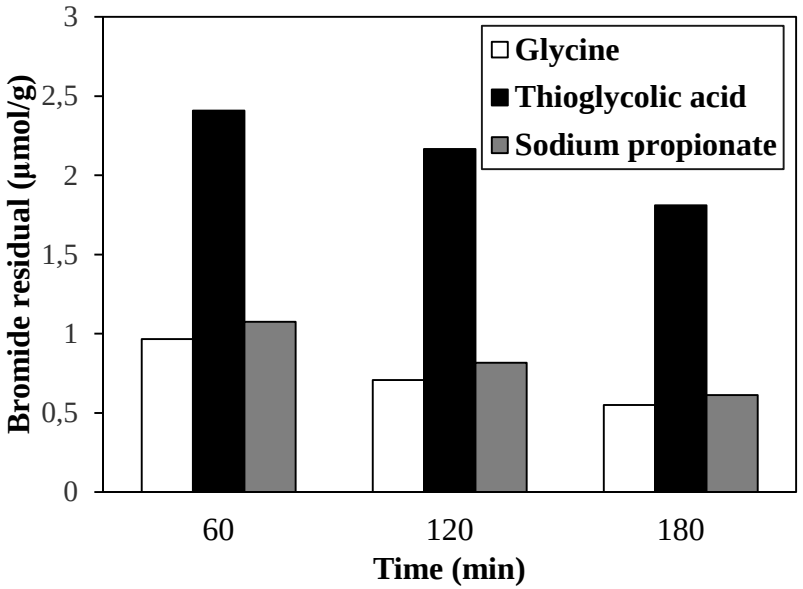
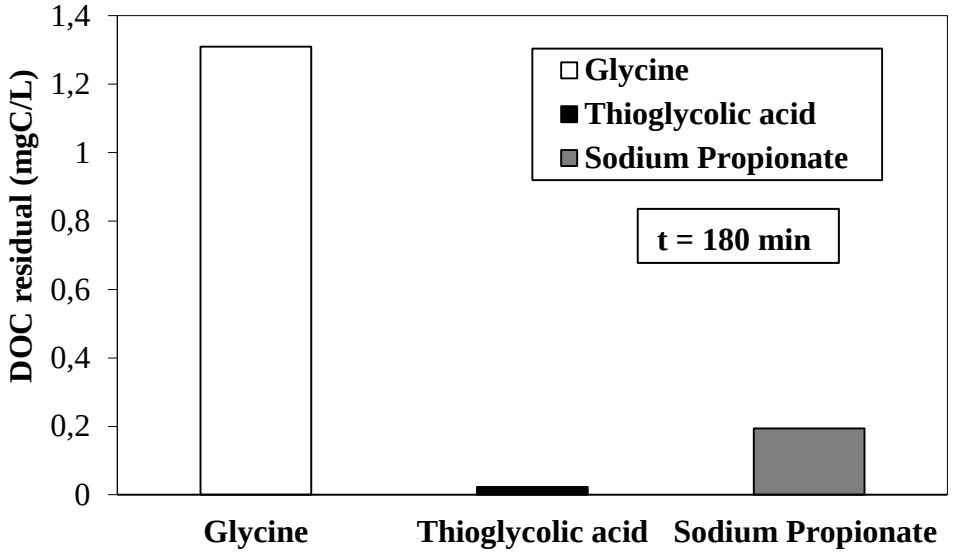
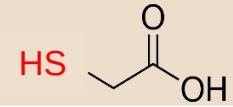
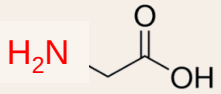
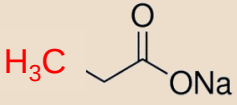
NOM model compounds (Functionality effect)





Compound	Molecular structure	Molecular weight	Binding Sites for Ag^+
Thioglycolic acid		92.1 g/mol	Carboxylic acid, Thiol
Glycine		75.1 g/mol	Carboxylic acid, Amino acid
Sodium propionate		96.1 g/mol	Carboxylic acid

- *$[Br]_0$= 12.5 µM*
- *$[DOC]_0$= 1.4 mgC/L*
- ***Dosage:** 2 g/L of SIAC*

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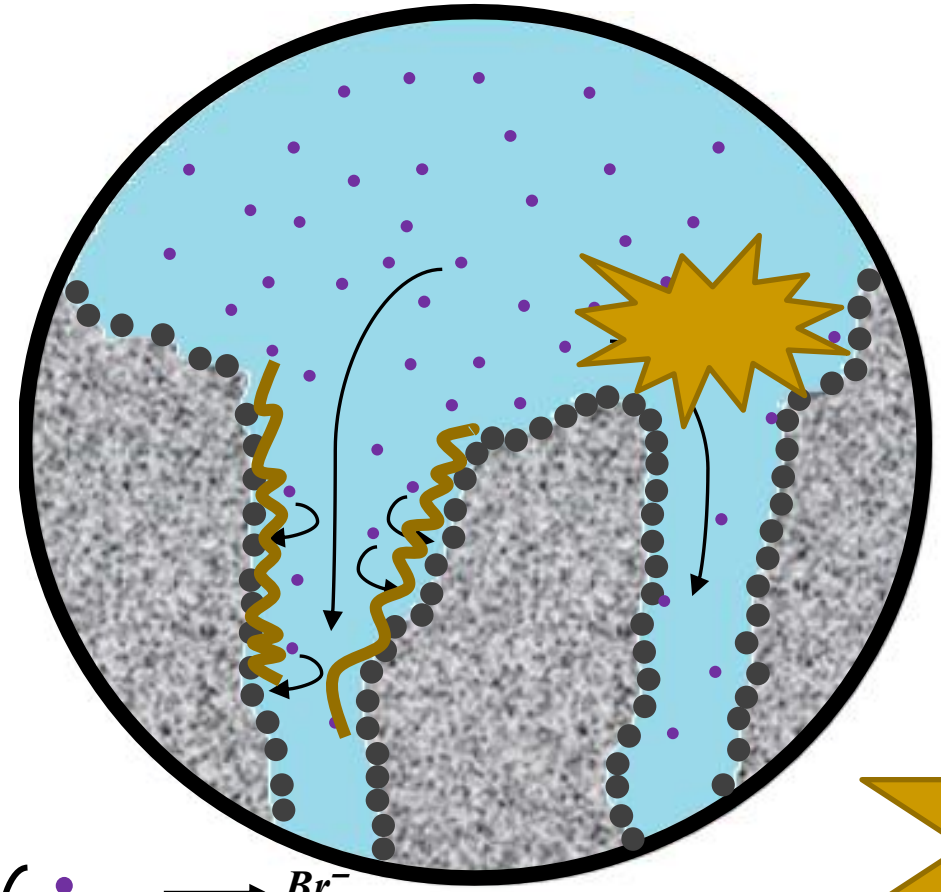
How the NOM Interferes...



Physical interactions

- **Pore Blockage**

Higher M_w NOM Fraction and higher Aromaticity

Chemical interactions

- **Site Competition** *(Ag-NOM complexation)*

Higher Aliphatic Fractions

Future work

Total concentration of Br-DBPs (AOBr)??

- ***Br⁻***
- ***Ag⁺***
- ***High-SUVA NOM***
- ***Low-SUVA NOM***

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Summary

Who benefits…

- ✓ **Academia**
- ✓ **Industry**

- ☑ New **mechanistic knowledge**
- ☑ **Retrofitable** to existing water treatment system
- ☑ **Cost-effective** quality water in remote locations
- ☑ Improves consumer perception (**tastes and odours**)
- ☑ Minimises **Br-DBPs**
- ☑ Minimises **discoloured water** events
- ☑ Improves **risk management** for water utilities
- ☑ Facilitates **Ozone** application→(Long-Term)

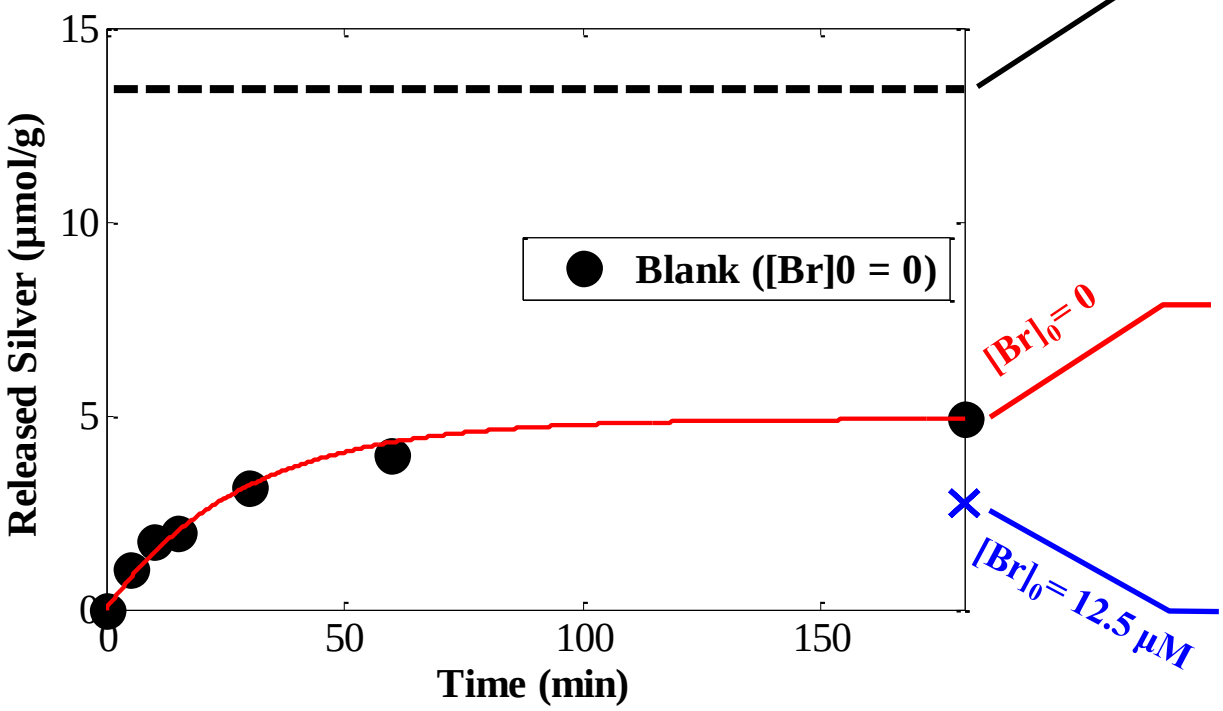
Vettakollen, Oslo, Norway

THANK YOU

QUESTIONS and COMMENTS

21/06/2017

Silver Leaching



$[Ag]_0$ = 13.6 µmol/g

$[Ag]_{t=180\ min}$ = 5.8 µmol/g

$[Ag]_{t=180\ min}$ = 3.5 µmol/g

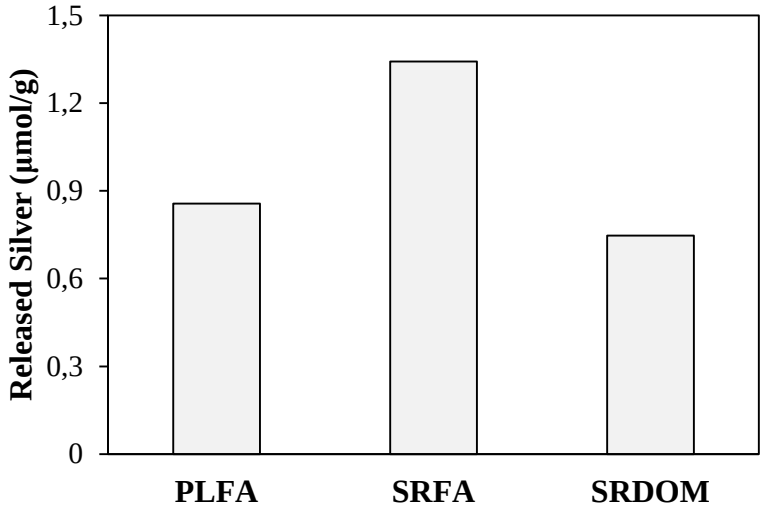
(1) Chemisorption

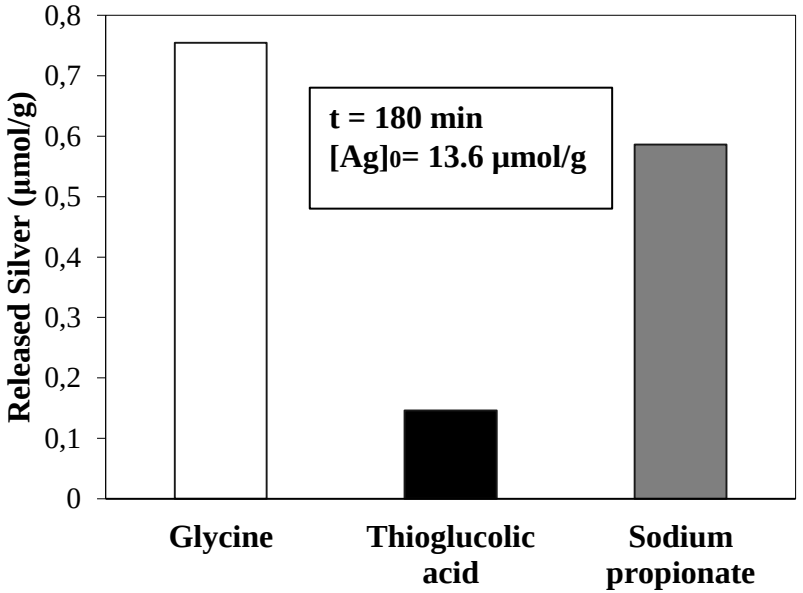
☑ $Ag^+(surf) + X^-(aq) \rightleftarrows AgX(S)$

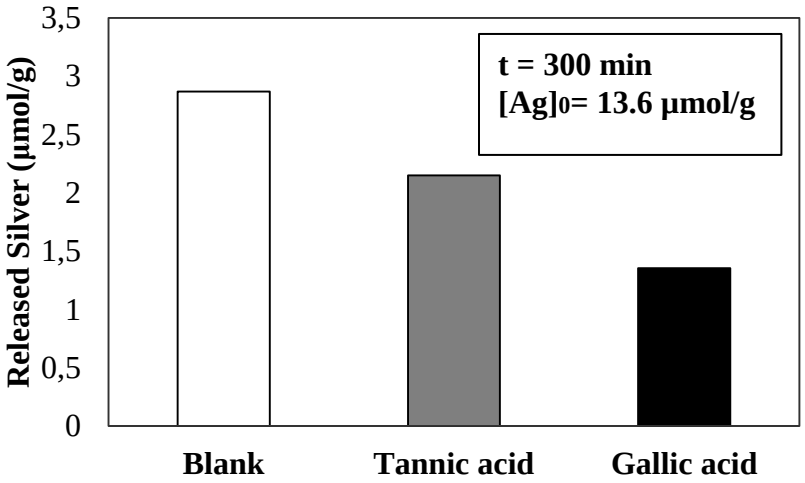
(2) Aqueous phase reaction

☒ $Ag^+(aq) + X^-(aq) \rightleftarrows AgX(aq)$

Silver Leaching + NOM







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