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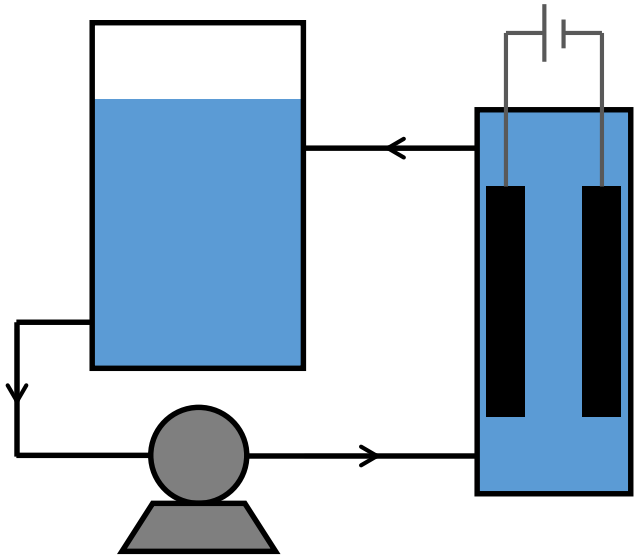
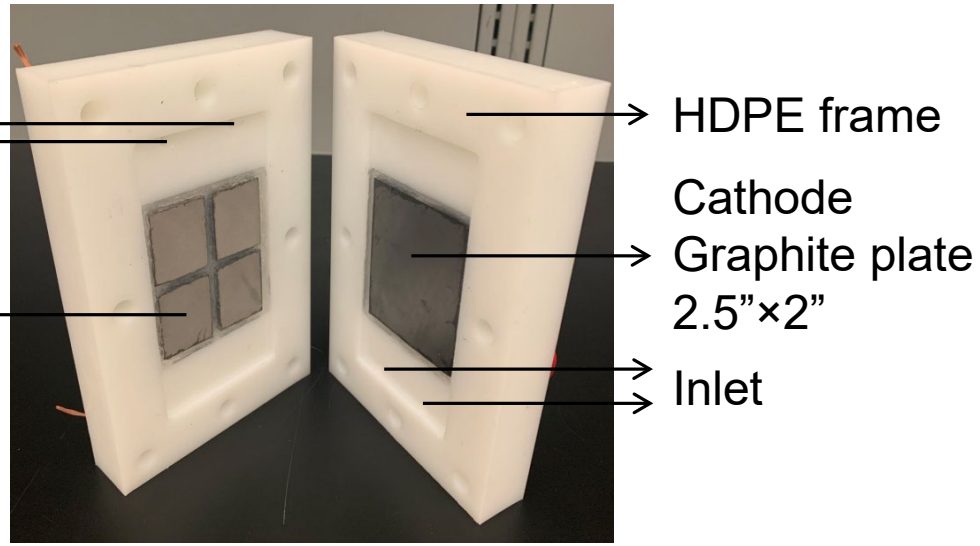
1. Ammonia Removal from Aquaculture Wastewater in Flow Cell

(experimental device)





Mechanism for ammonia removal

Anode

Cathode

$6H^+ + 6e^- \rightarrow 3H_2$

*If NH_4^+ is present (produce **eight** protons)*

$6Cl^- \rightarrow 3Cl_2 + 6e^-$

$3Cl_2 + 3H_2O \rightarrow 3HOCl + 3H^+ + 3Cl^-$

$2NH_4^+ + 3HOCl \rightarrow N_2 + 5H^+ + 3Cl^- + 3H_2O$

*If NH_4^+ is absent (produce **three** protons)*

$6Cl^- \rightarrow 3Cl_2 + 6e^-$

$3Cl_2 + 3H_2O \rightarrow 3HOCl + 3H^+ + 3Cl^-$

Reactions:

$NH_4^+ + HOCl \rightarrow NH_2Cl + H^+ + H_2O$

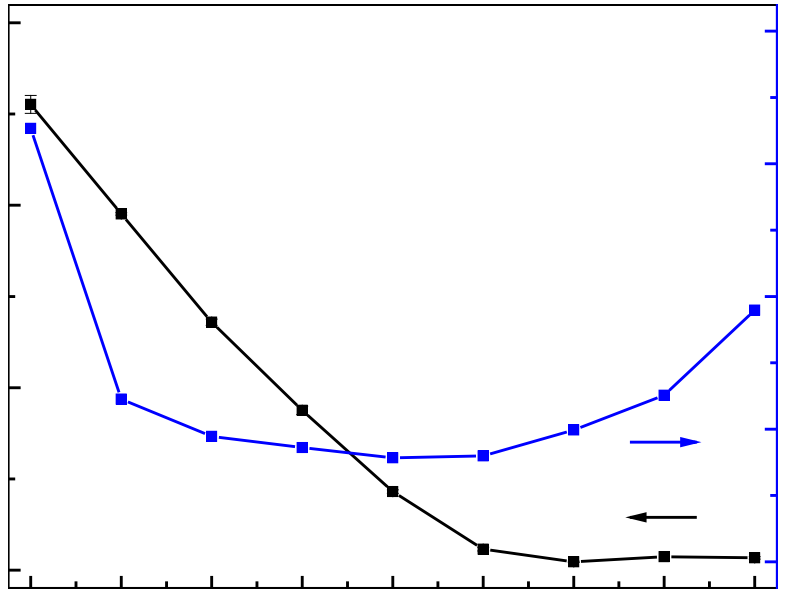
$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O$

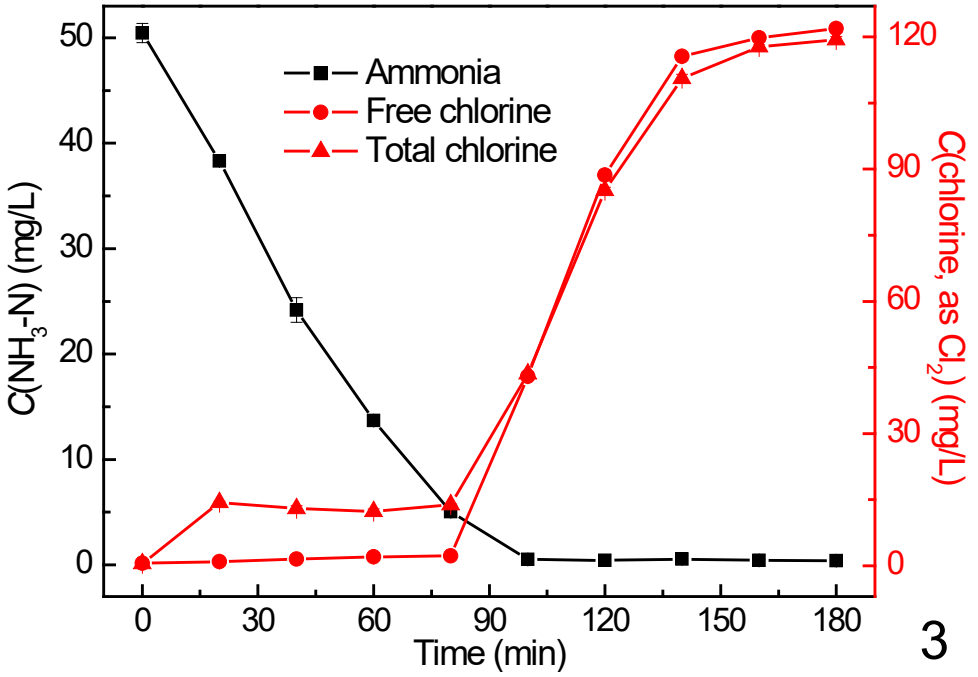
$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O$

Free chlorine: $HOCl$, OCl^-

Combined chlorine: NH_2Cl, $NHCl_2$, NCl_3

Total chlorine = free chlorine + combined chlorine

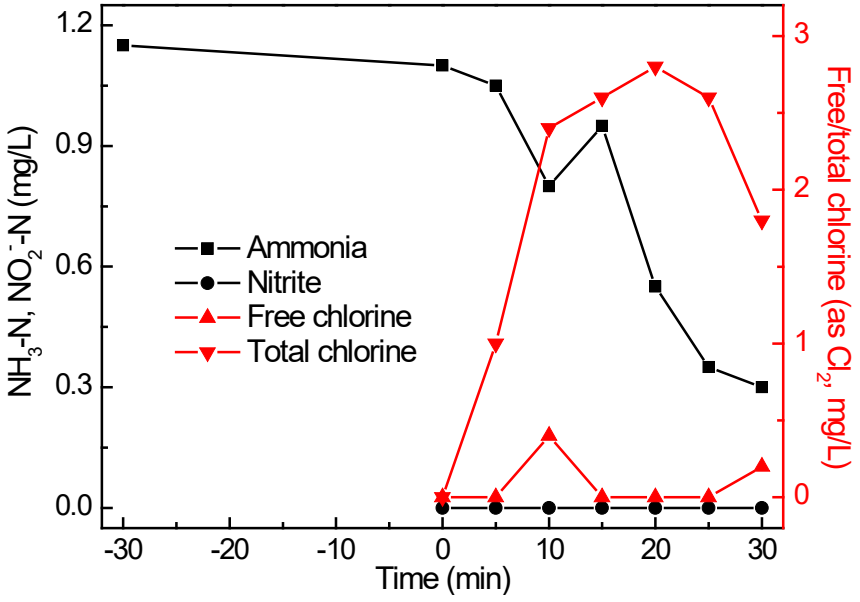


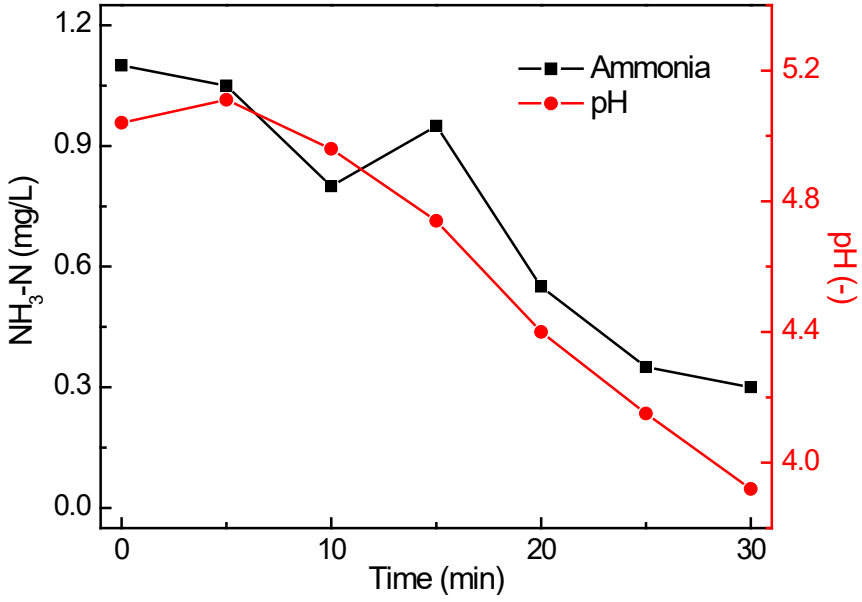


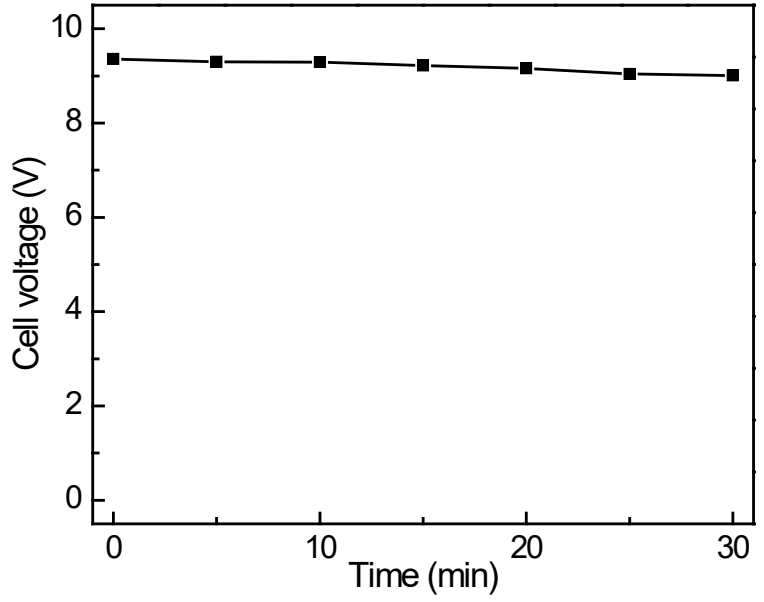
1. Ammonia Removal from Aquaculture Wastewater in Flow Cell
(list of experiments)

No.	Water volume (ml)	NaCl concentration (mM)	Current density (mA/cm^2)	Flow rate (ml/min)
1	400	2	15	200
2	400	5	15	200
3	400	5	25	200
4	400	5	15	400
5	400	2	15	200
6	400	5	20	200
7	400	5	15	800

No.	Water volume (ml)	NaCl concentration (mM)	Current density (mA/cm^2)	Flow rate (ml/min)
1	400	2	15	200
2	400	5	15	200
3	400	5	25	200
4	400	5	15	400
5	400	2	15	200
6	400	5	20	200
7	400	5	15	800







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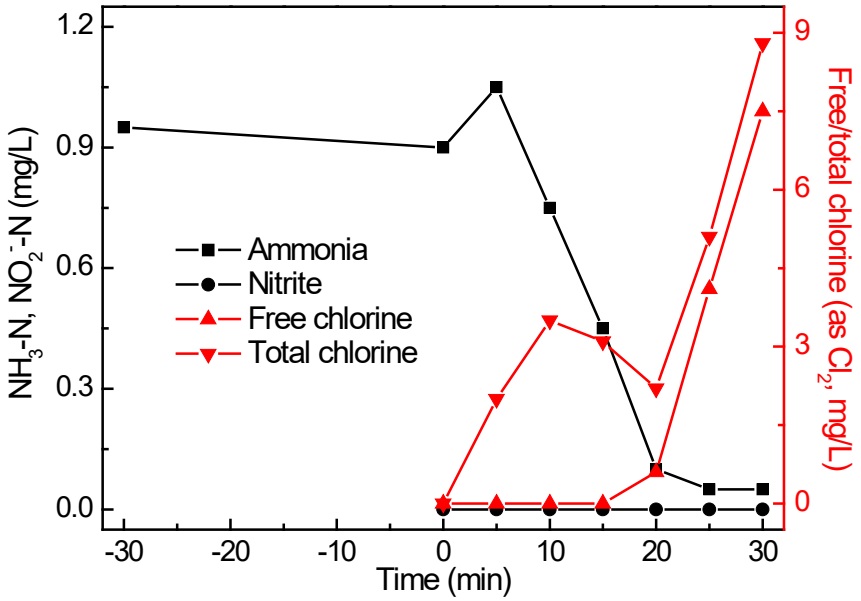

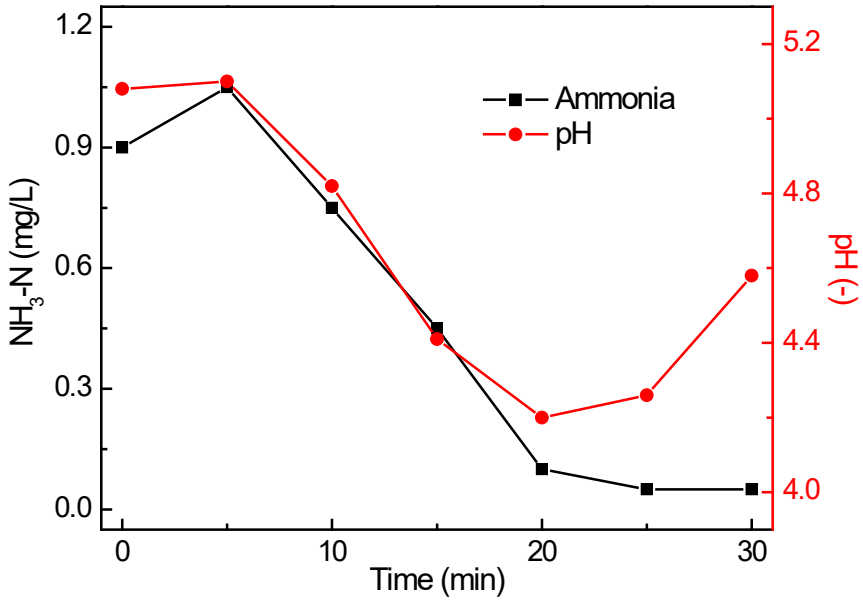

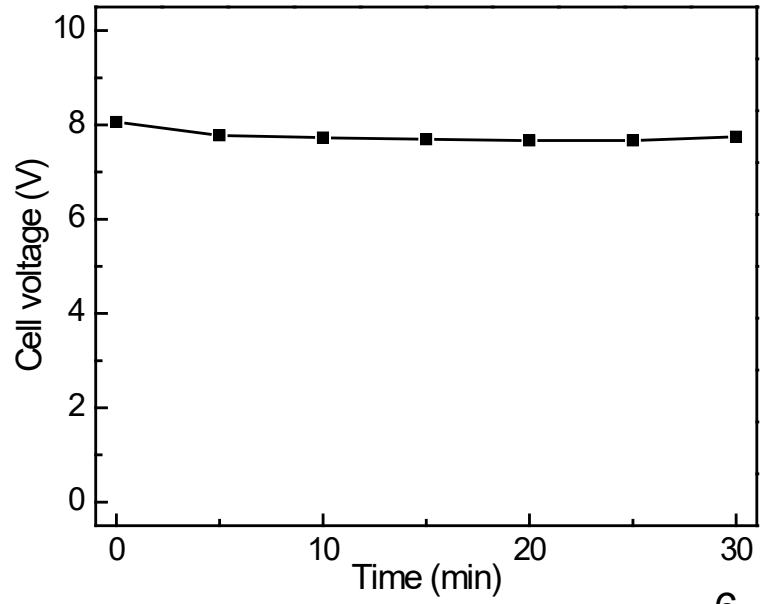

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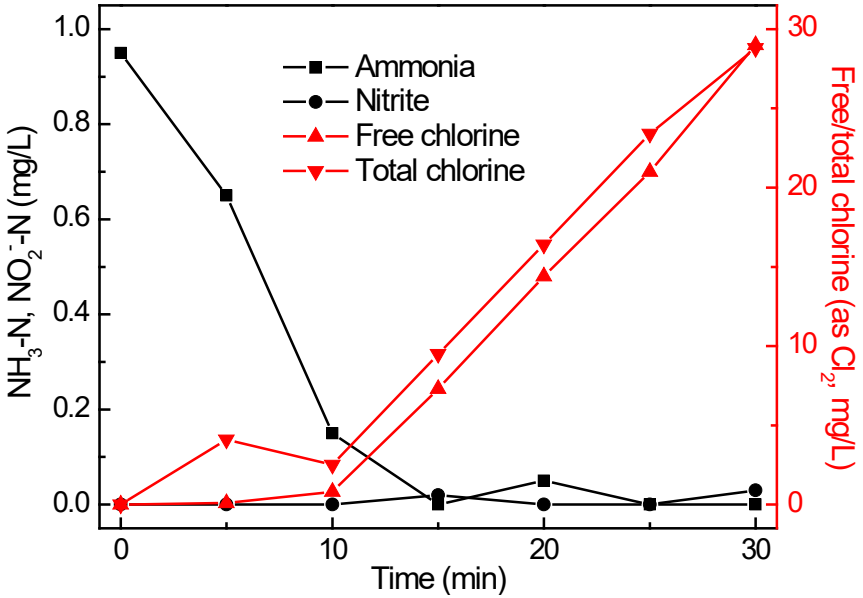

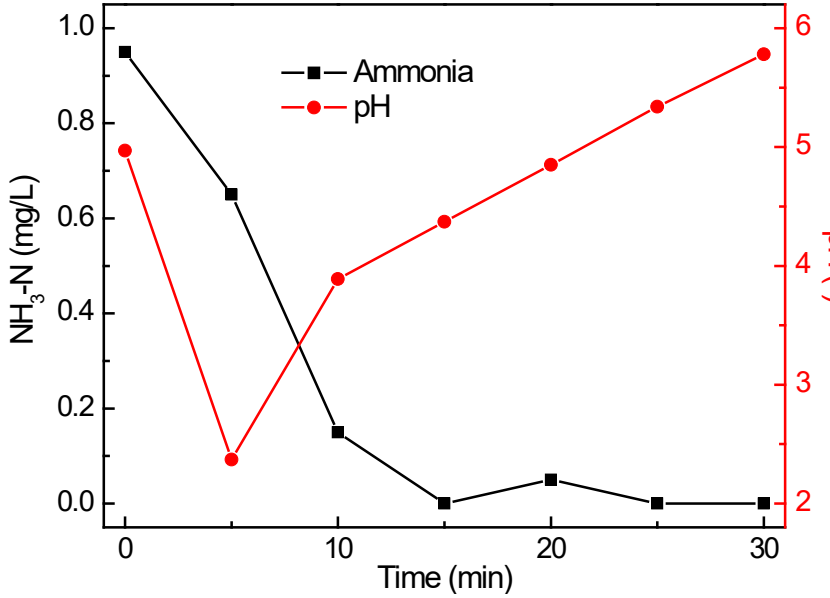

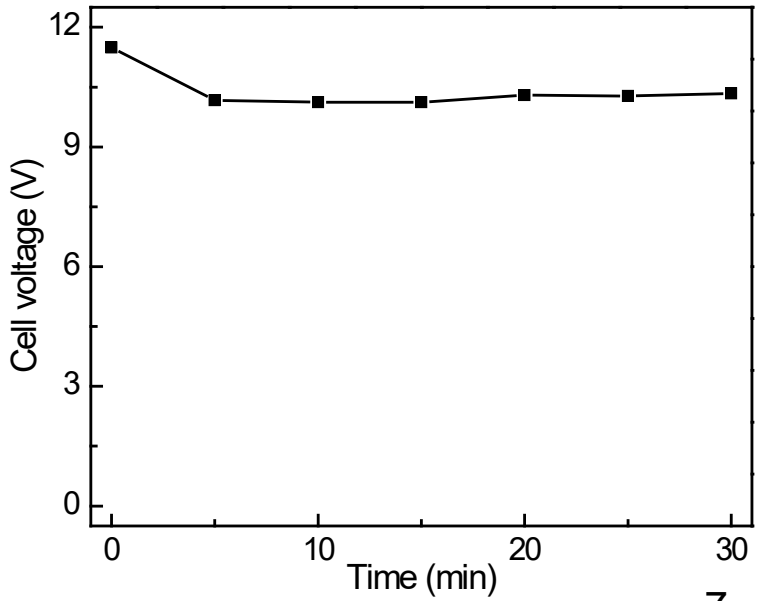

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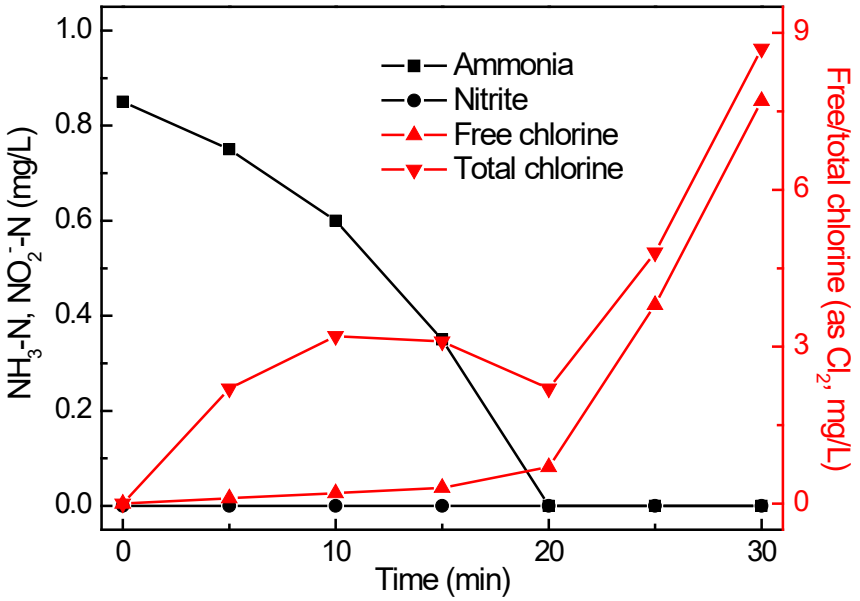

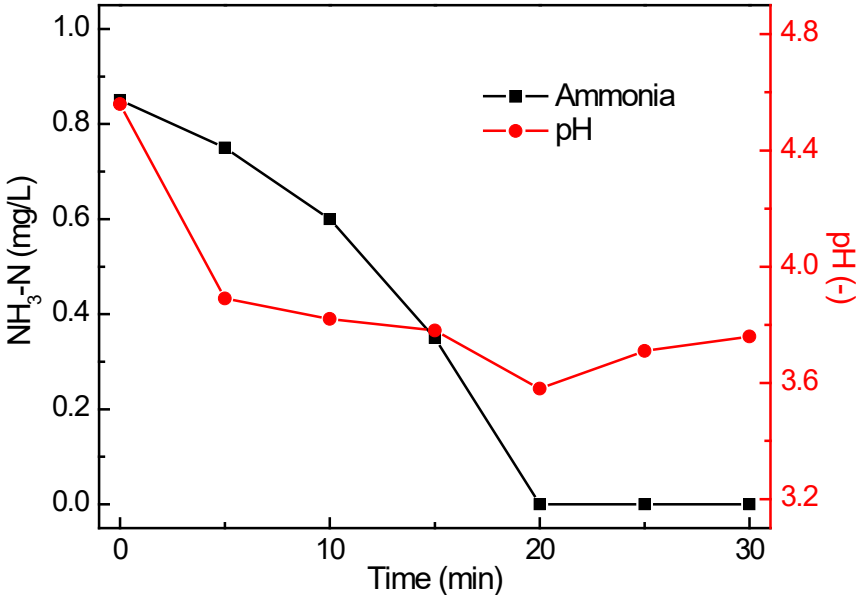

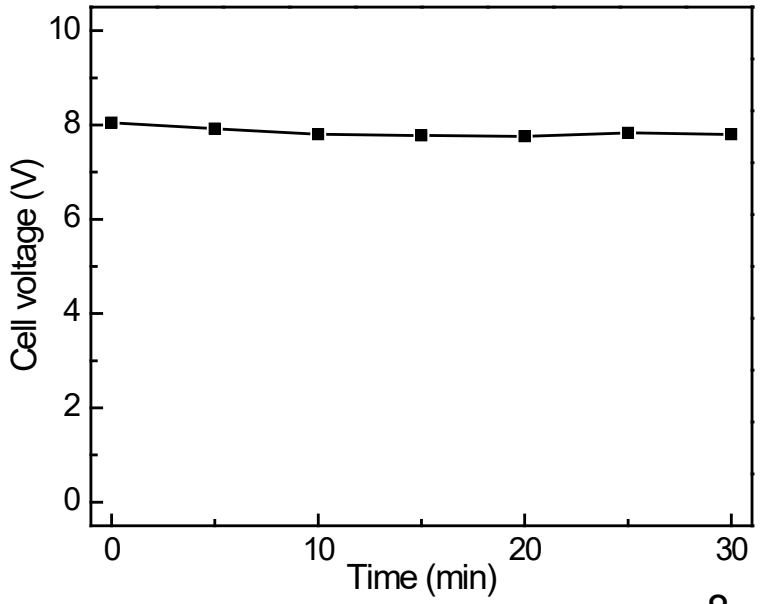

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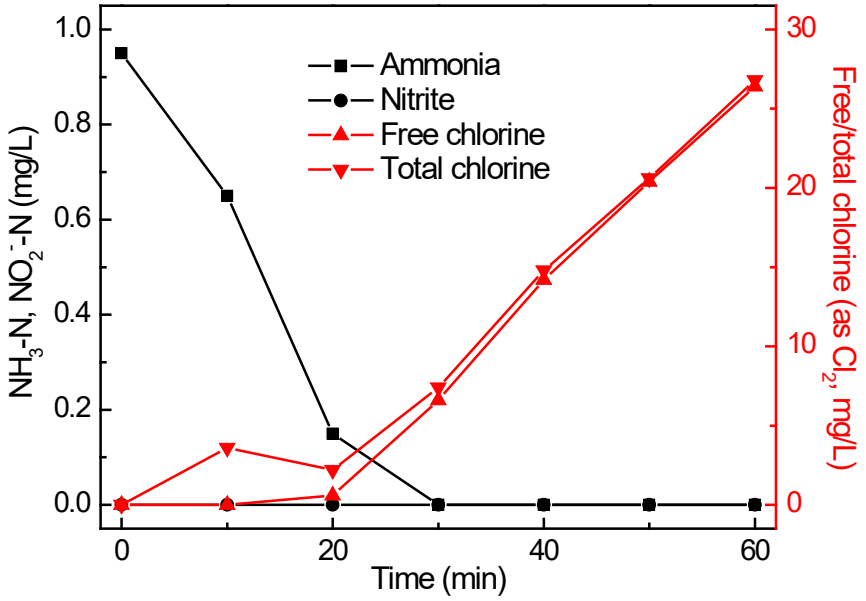

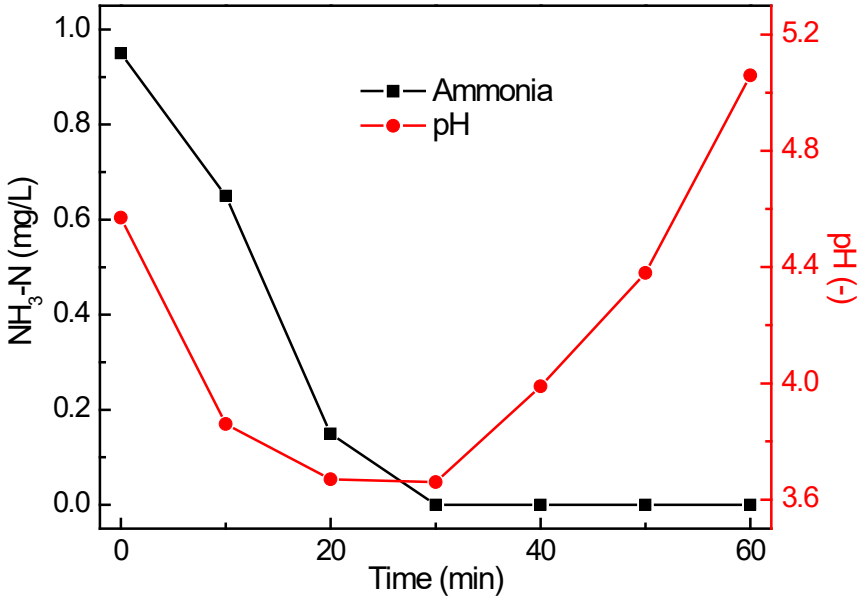

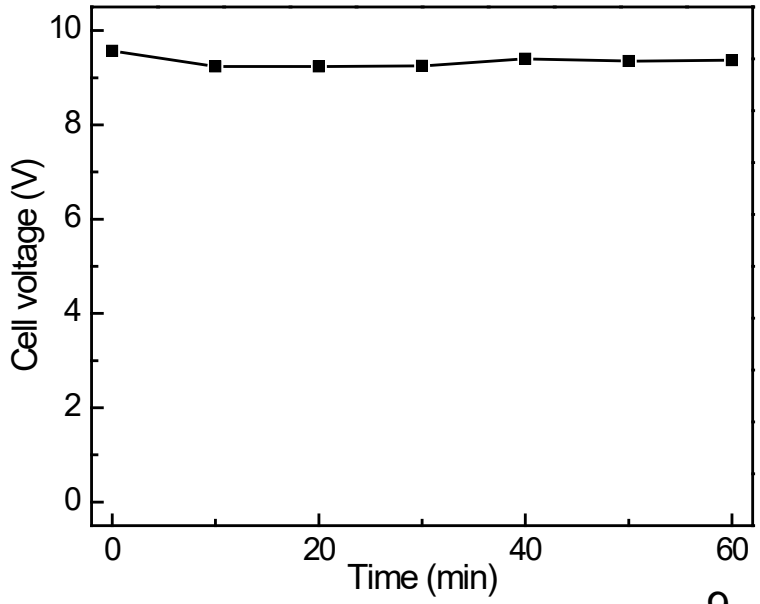

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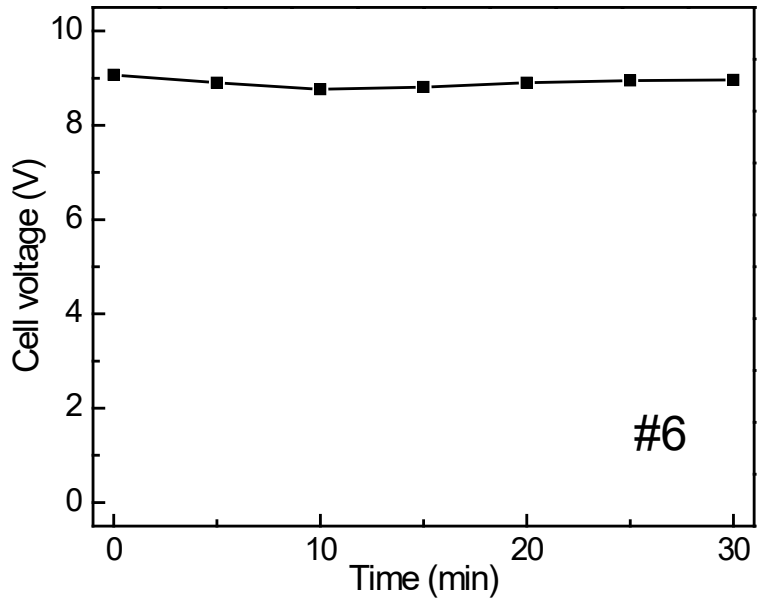

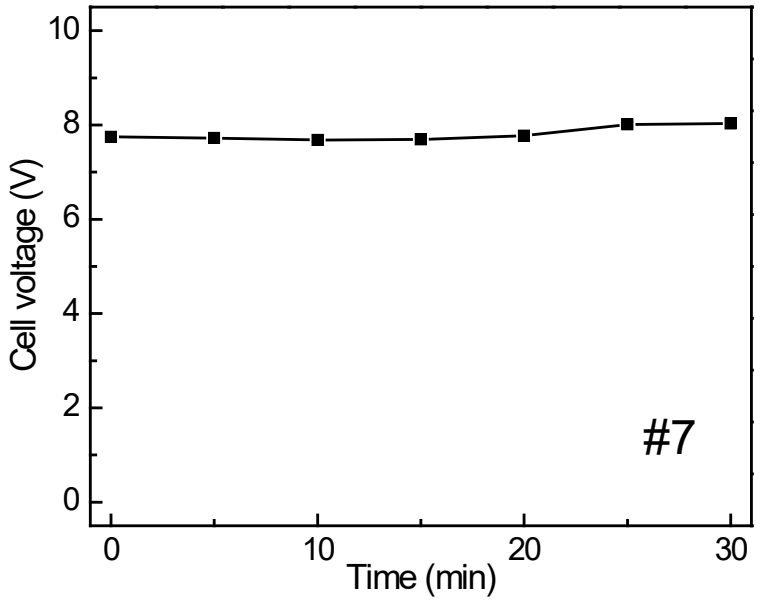

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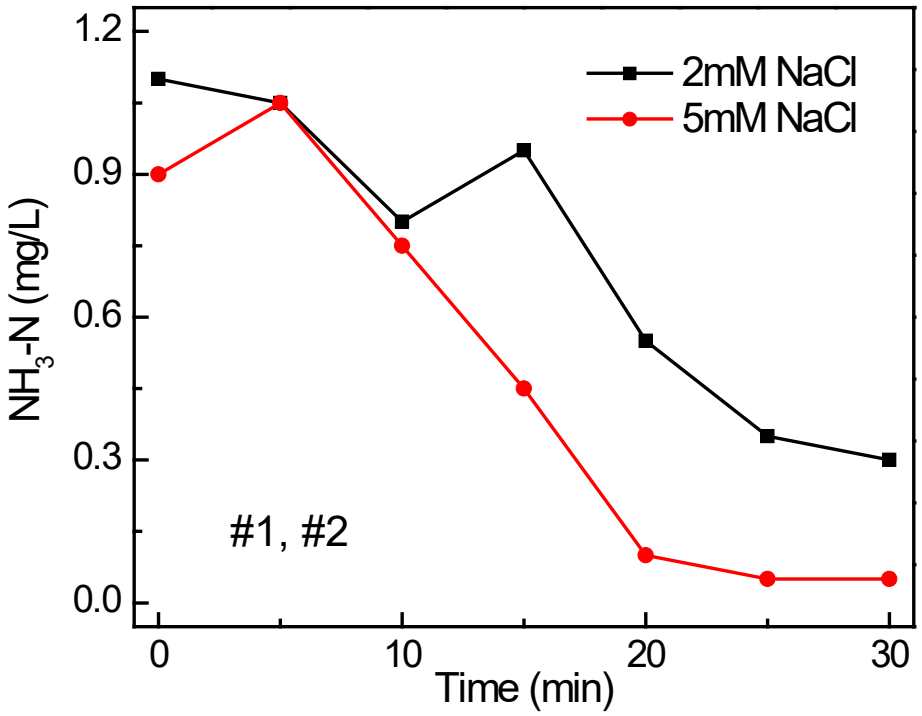

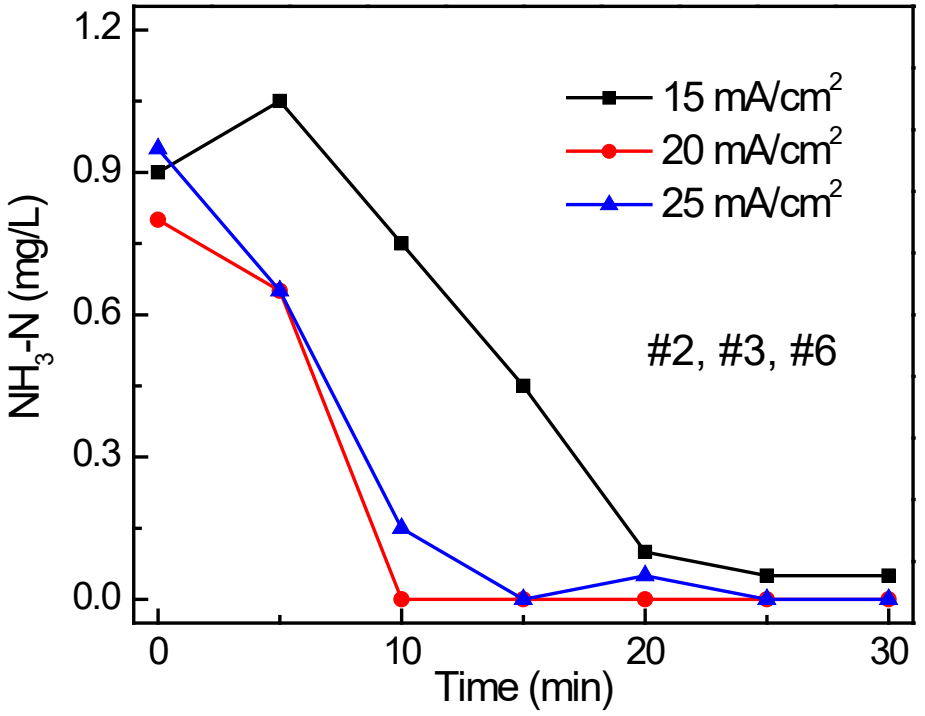

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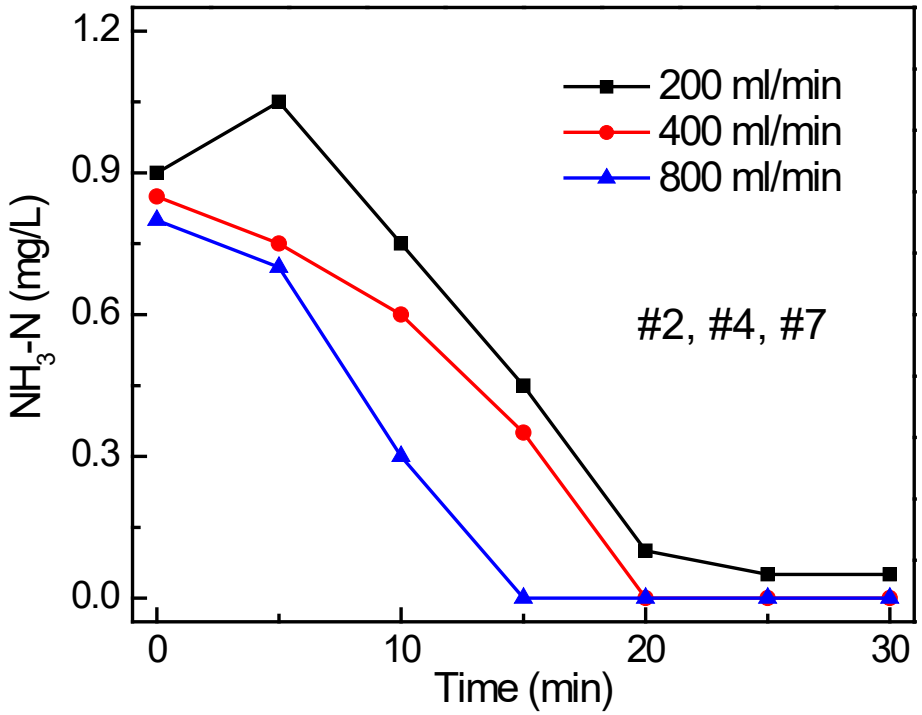
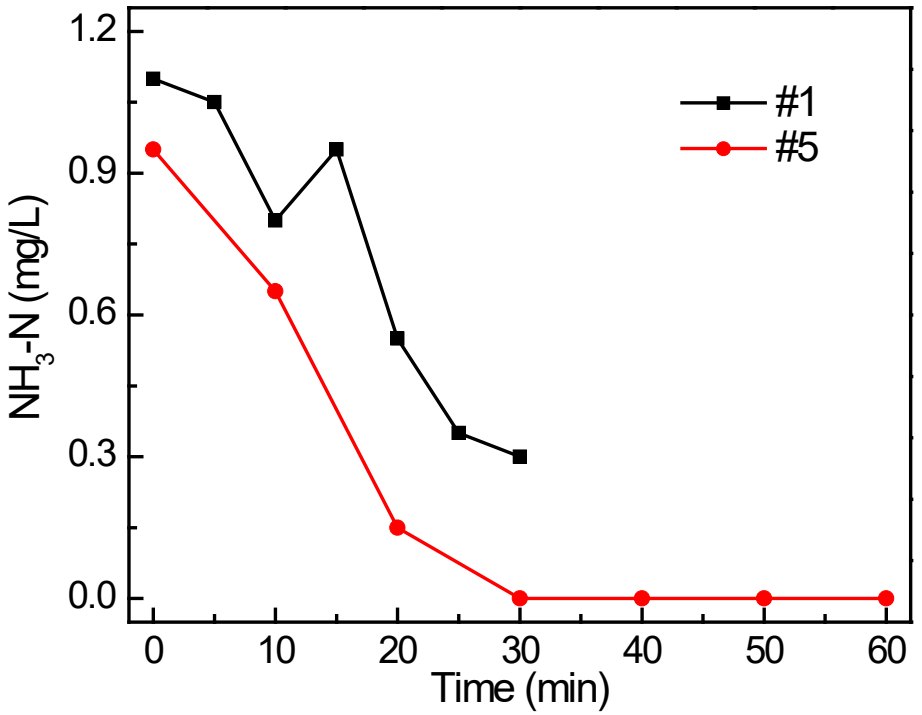
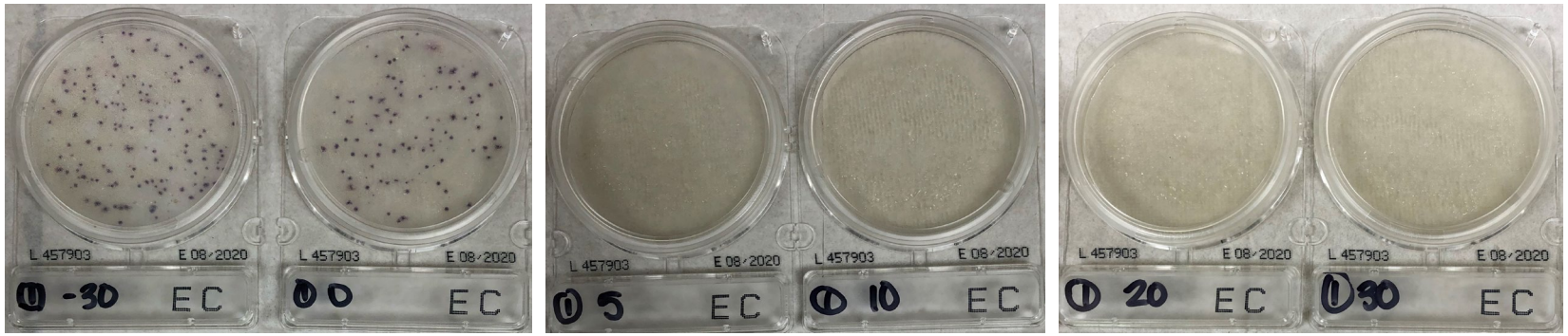
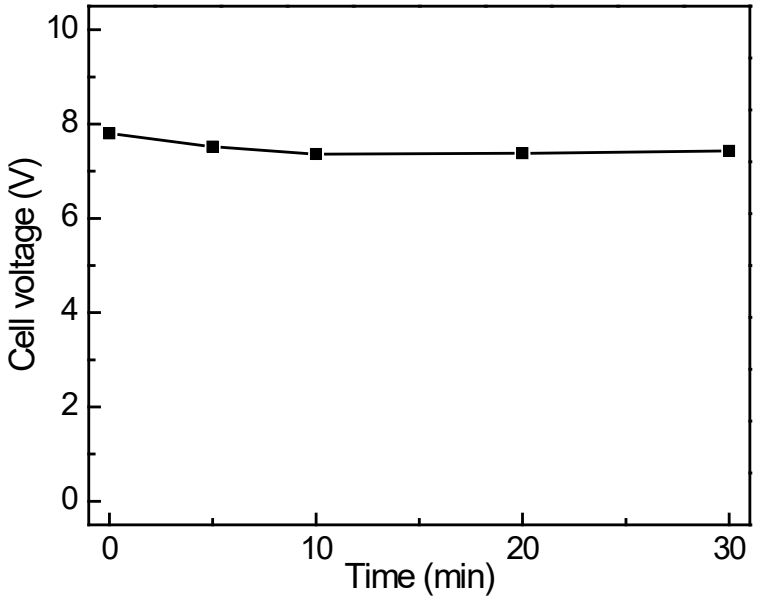




2. Ammonia removal and disinfection of aquaculture wastewater in flow cell

No.	Water volume (ml)	NaCl concentration (mM)	Current density (mA/cm^2)	Flow rate (ml/min)	E. coli
1	400	5	15	200	No
2	400	5	15	200	Yes





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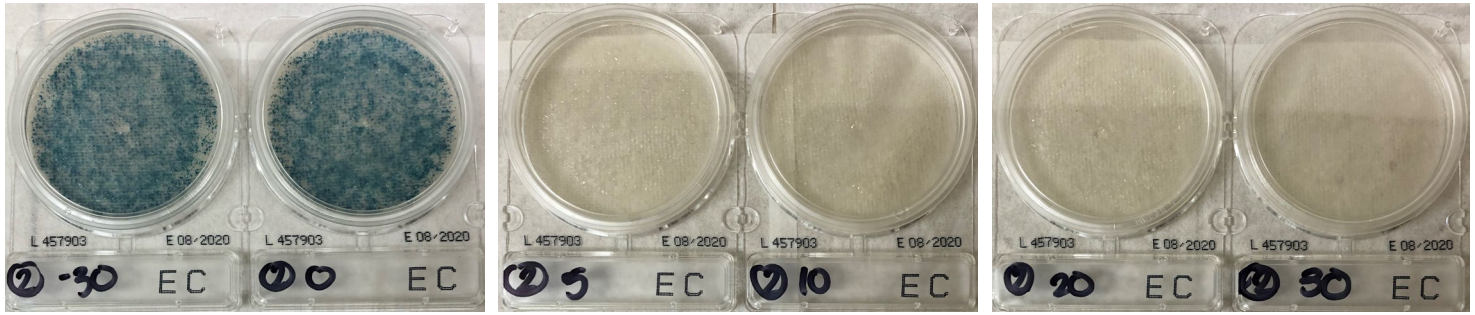
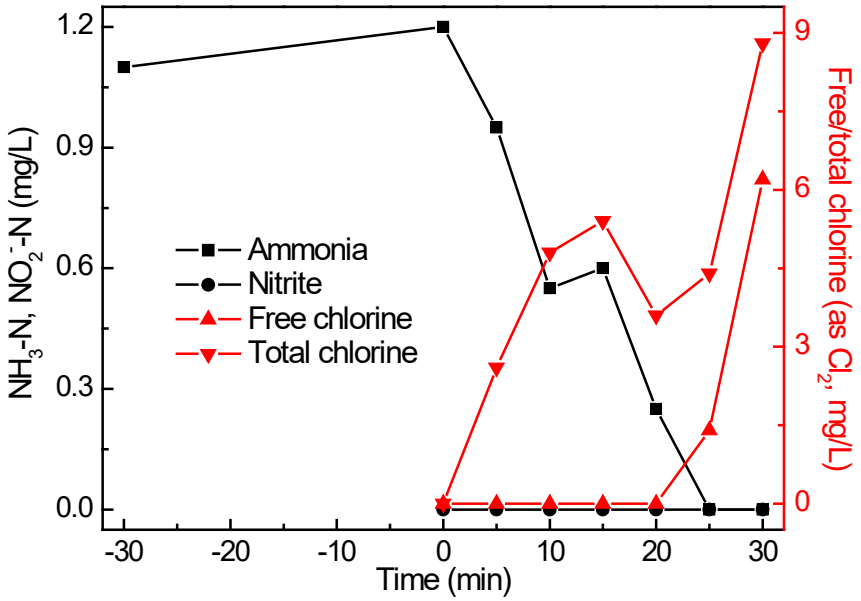
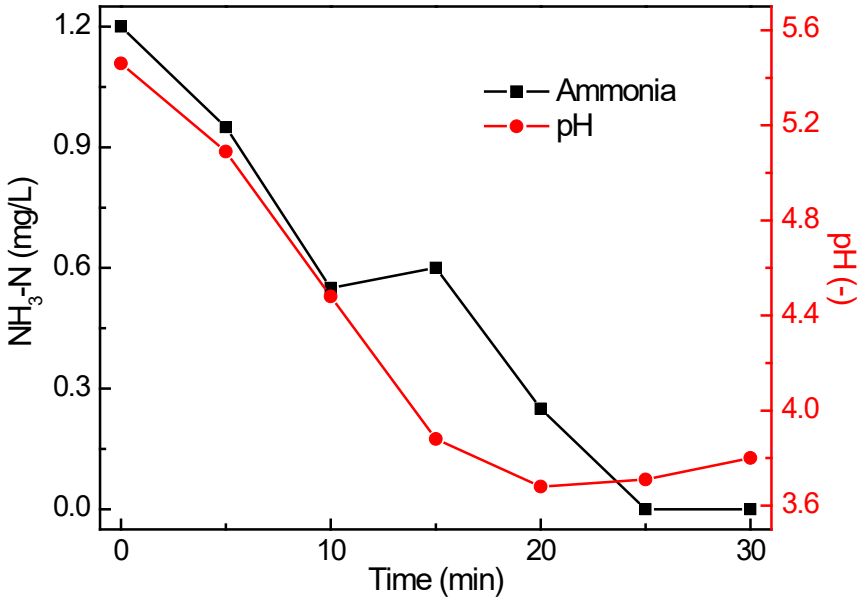
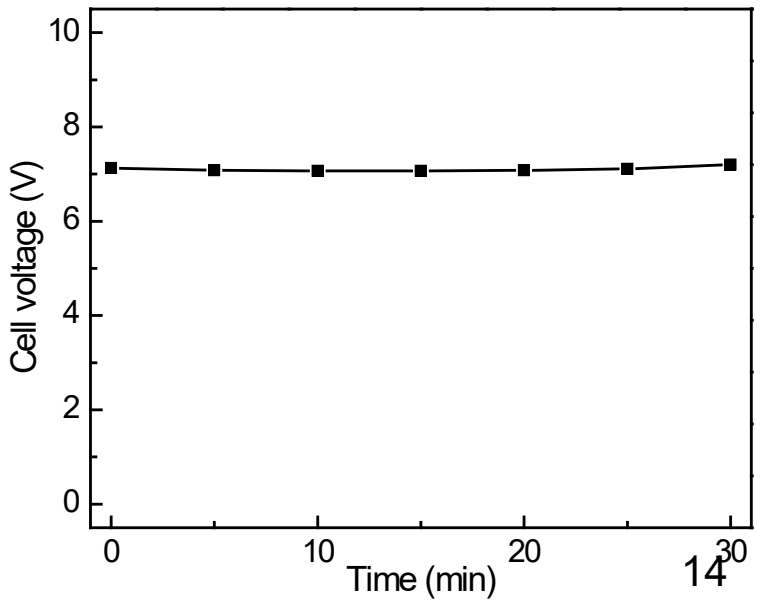
No.	Water volume (ml)	NaCl concentration (mM)	Current density (mA/cm^2)	Flow rate (ml/min)	E. coli
1	400	5	15	200	No
2	400	5	15	200	Yes









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8. Disinfection of irrigation water (Open ditch) by purging chlorine gas

A comparison of Bott Well pond and open ditch

Calcium

200078-01	Bottem Well- Pond	EPA 200.7	5.414	mg/L
200078-02	Reservoir 225	EPA 200.7	2.878	mg/L
200078-03	Open Ditch	EPA 200.7	1.689	mg/L
200078-04	Before Sand Filter	EPA 200.7	2.717	mg/L
200078-05	After Sand Filter	EPA 200.7	2.399	mg/L

Potassium

200078-01	Bottem Well- Pond	EPA 200.7	0.736	mg/L
200078-02	Reservoir 225	EPA 200.7	E 0.180	mg/L
200078-03	Open Ditch	EPA 200.7	E 0.181	mg/L
200078-04	Before Sand Filter	EPA 200.7	0.417	mg/L
200078-05	After Sand Filter	EPA 200.7	0.409	mg/L

Magnesium

200078-01	Bottem Well- Pond	EPA 200.7	3.488	mg/L
200078-02	Reservoir 225	EPA 200.7	1.138	mg/L
200078-03	Open Ditch	EPA 200.7	0.911	mg/L
200078-04	Before Sand Filter	EPA 200.7	1.804	mg/L
200078-05	After Sand Filter	EPA 200.7	1.689	mg/L

Sodium

200078-01	Bottem Well- Pond	EPA 200.7	8.543	mg/L
200078-02	Reservoir 225	EPA 200.7	1.231	mg/L
200078-03	Open Ditch	EPA 200.7	1.541	mg/L
200078-04	Before Sand Filter	EPA 200.7	4.035	mg/L
200078-05	After Sand Filter	EPA 200.7	4.060	mg/L

pH

200078-01	Bottem Well- Pond	EPA 150.1	8.5
200078-02	Reservoir 225	EPA 150.1	6.2
200078-03	Open Ditch	EPA 150.1	6.2
200078-04	Before Sand Filter	EPA 150.1	6.5
200078-05	After Sand Filter	EPA 150.1	6.6

Conductivity

200078-01	Bottem Well- Pond	EPA 120.1	93.4	uS/cm
200078-02	Reservoir 225	EPA 120.1	29.1	uS/cm
200078-03	Open Ditch	EPA 120.1	23.9	uS/cm
200078-04	Before Sand Filter	EPA 120.1	47.1	uS/cm
200078-05	After Sand Filter	EPA 120.1	44.5	uS/cm

A comparison of Bott Well pond and open ditch

Chloride

200078-01	Bottem Well- Pond	EPA 300.0	6.906	mg/l
200078-02	Reservoir 225	EPA 300.0	1.277	mg/l
200078-03	Open Ditch	EPA 300.0	1.844	mg/l
200078-04	Before Sand Filter	EPA 300.0	4.596	mg/l
200078-05	After Sand Filter	EPA 300.0	4.729	mg/l

Sulfate

200078-01	Bottem Well- Pond	EPA 300.0	4.078	mg/l
200078-02	Reservoir 225	EPA 300.0	E 0.383	mg/l
200078-03	Open Ditch	EPA 300.0	E 0.479	mg/l
200078-04	Before Sand Filter	EPA 300.0	0.967	mg/l
200078-05	After Sand Filter	EPA 300.0	1.037	mg/l

Total Suspended Solids

200078-01	Bottem Well- Pond	APHA 2540D	79.7	mg/l
200078-02	Reservoir 225	APHA 2540D	10.1	mg/l
200078-03	Open Ditch	APHA 2540D	38.6	mg/l
200078-04	Before Sand Filter	APHA 2540D	23.8	mg/l
200078-05	After Sand Filter	APHA 2540D	4.1	mg/l

Total Nitrogen

200078-01	Bottem Well- Pond	APHA 4500-P	1.37	mg/l as N
200078-02	Reservoir 225	APHA 4500-P	0.43	mg/l as N
200078-03	Open Ditch	APHA 4500-P	0.17	mg/l as N
200078-04	Before Sand Filter	APHA 4500-P	0.24	mg/l as N
200078-05	After Sand Filter	APHA 4500-P	0.07	mg/l as N

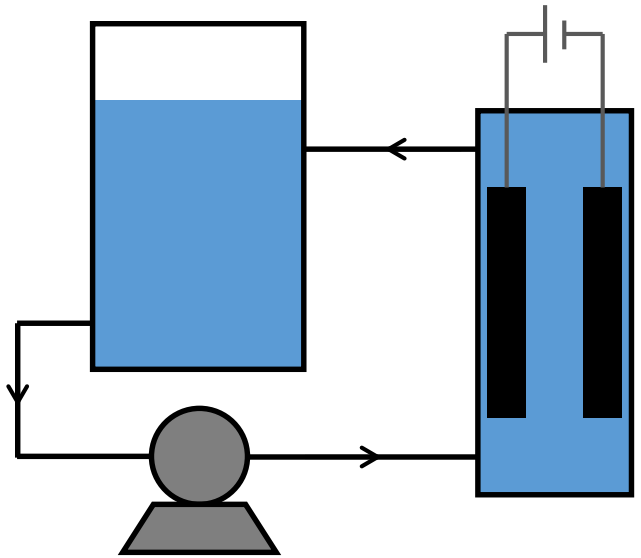
Total Phosphorus

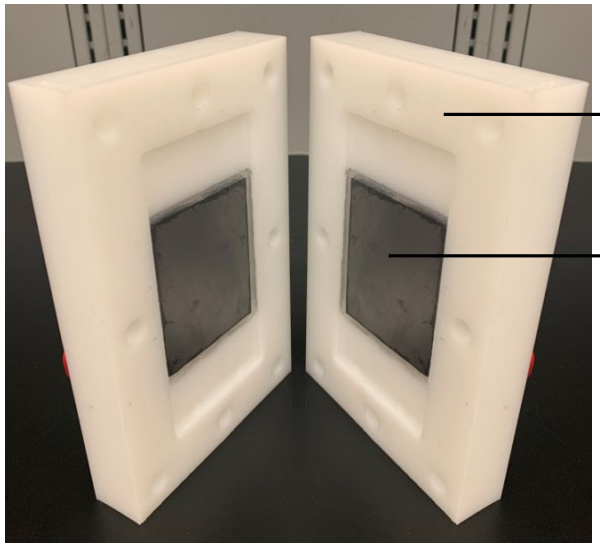
200078-01	Bottem Well- Pond	APHA 4500-P	0.298	mg/l as P
200078-02	Reservoir 225	APHA 4500-P	0.043	mg/l as P
200078-03	Open Ditch	APHA 4500-P	0.025	mg/l as P
200078-04	Before Sand Filter	APHA 4500-P	0.044	mg/l as P
200078-05	After Sand Filter	APHA 4500-P	E 0.010	mg/l as P

Total Organic Carbon

200078-01	Bottem Well- Pond	EPA 415.1	6.08	mg/l
200078-02	Reservoir 225	EPA 415.1	1.86	mg/l
200078-03	Open Ditch	EPA 415.1	0.71	mg/l
200078-04	Before Sand Filter	EPA 415.1	1.02	mg/l
200078-05	After Sand Filter	EPA 415.1	0.64	mg/l

Disinfection of irrigation water in flow cell
(experimental device and list of experiments)

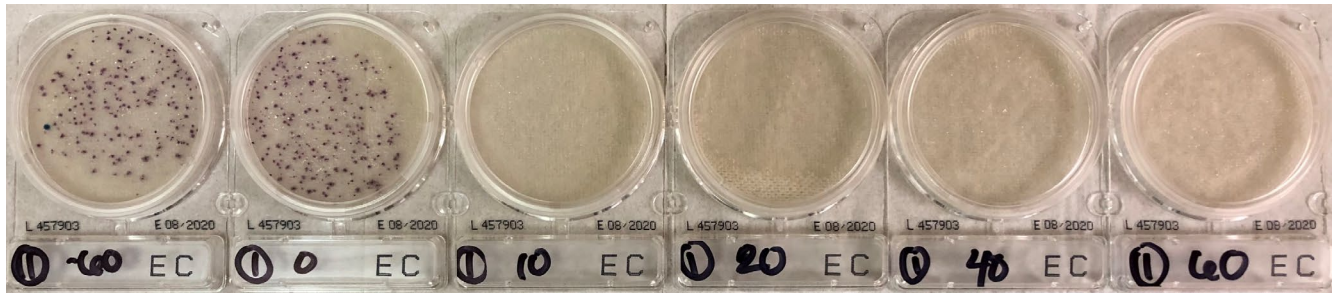




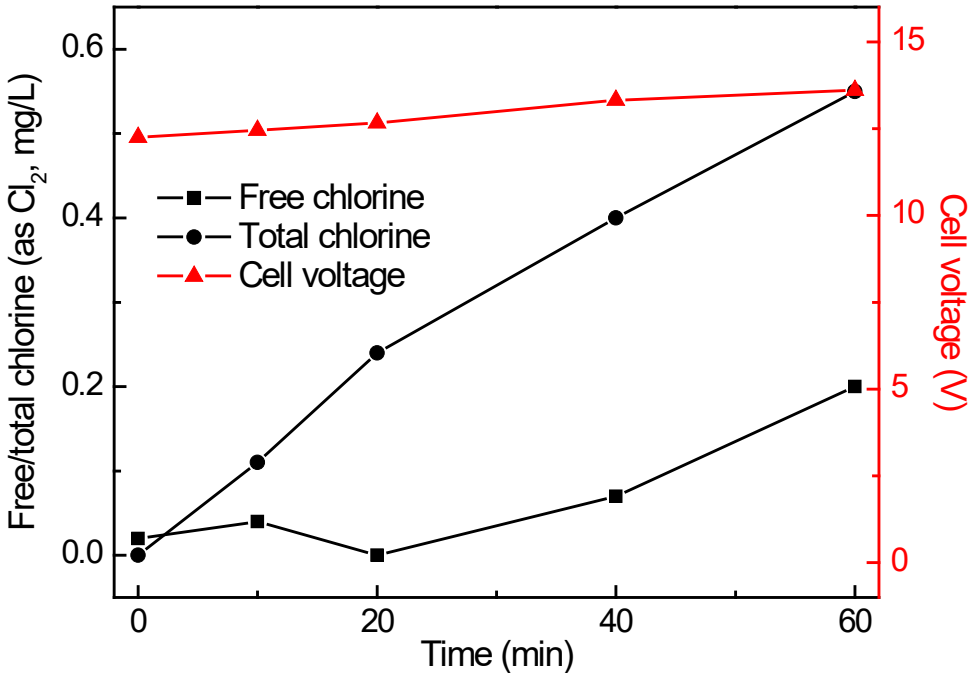
No.	Water volume (ml)	Current density (mA/cm^2)	Flow rate (ml/min)	E. coli
1	400	4	200	No
2	400	2	200	Yes
3	400	4	200	Yes
4	400	6	200	Yes
5	400	4	400	Yes

3. Disinfection of irrigation water (Bott Well pond) in flow cell

No.	Water volume (ml)	Current density (mA/cm^2)	Flow rate (ml/min)	E. coli
1	400	4	200	No
2	400	2	200	Yes
3	400	4	200	Yes
4	400	6	200	Yes
5	400	4	400	Yes

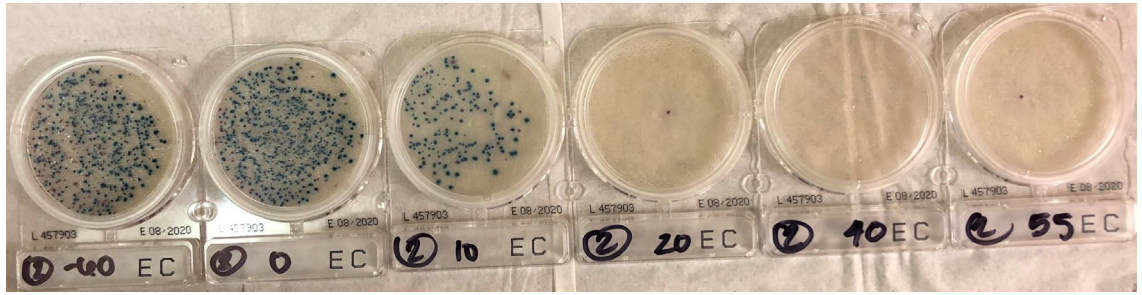


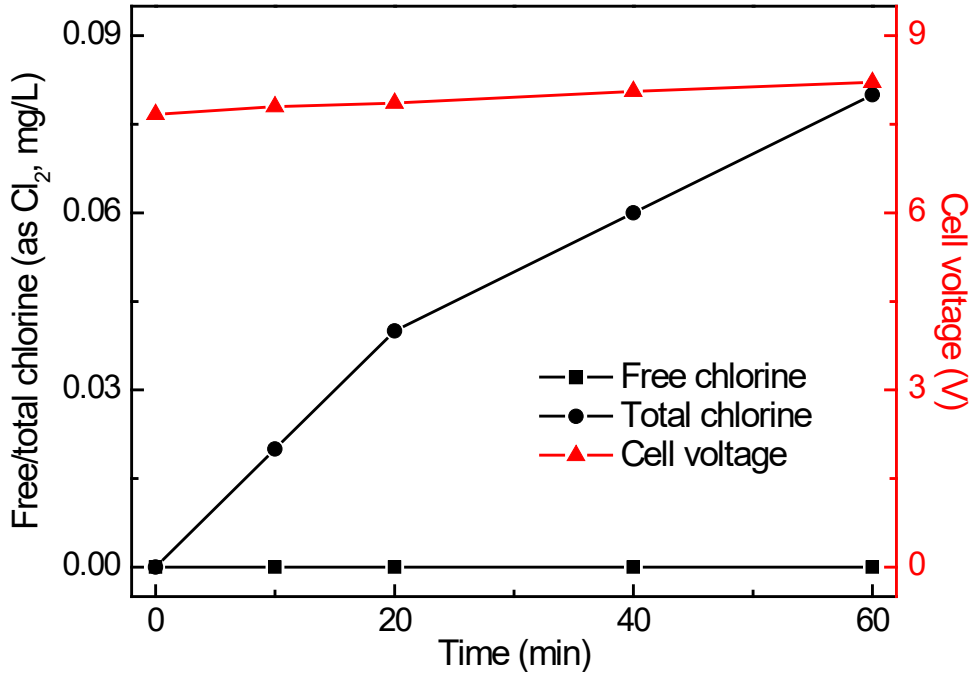
Note: peroxide tests were carried out in all disinfection experiments, but was not found



3. Disinfection of irrigation water (Bott Well pond) in flow cell

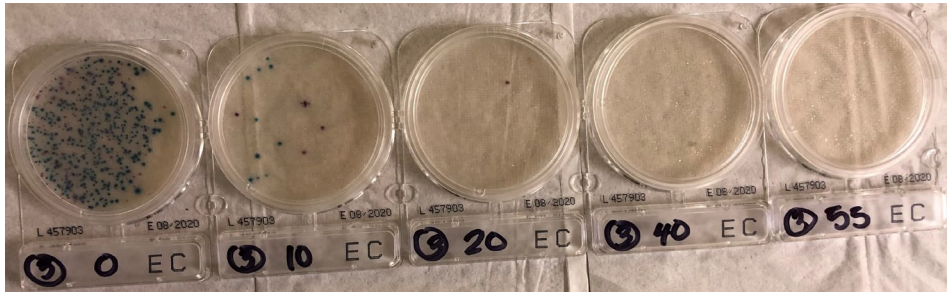
No.	Water volume (ml)	Current density (mA/cm^2)	Flow rate (ml/min)	E. coli
1	400	4	200	No
2	400	2	200	Yes
3	400	4	200	Yes
4	400	6	200	Yes
5	400	4	400	Yes

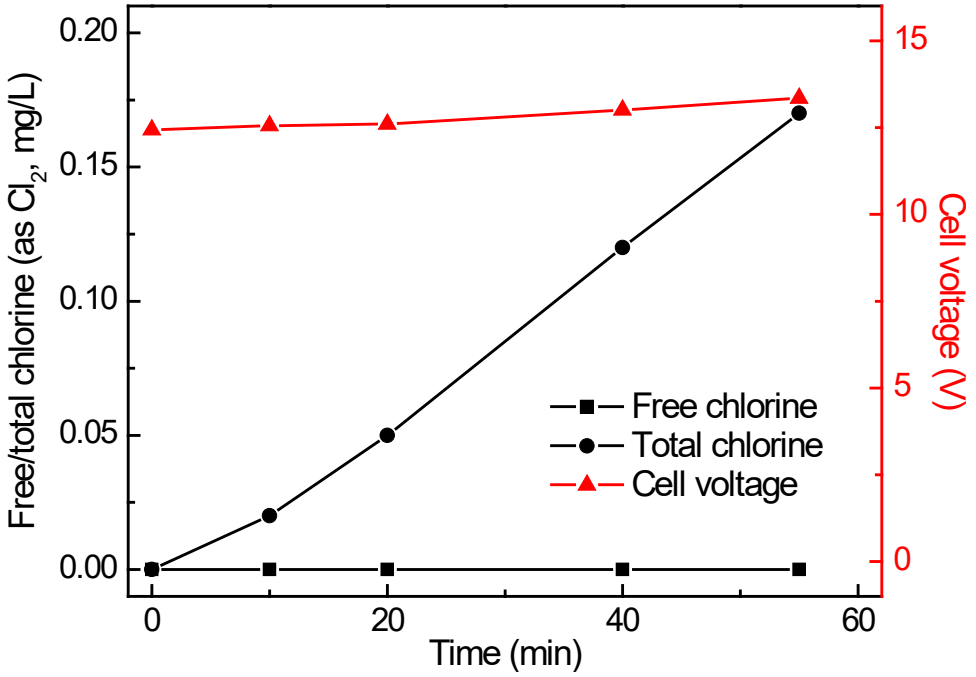




3. Disinfection of irrigation water (Bott Well pond) in flow cell

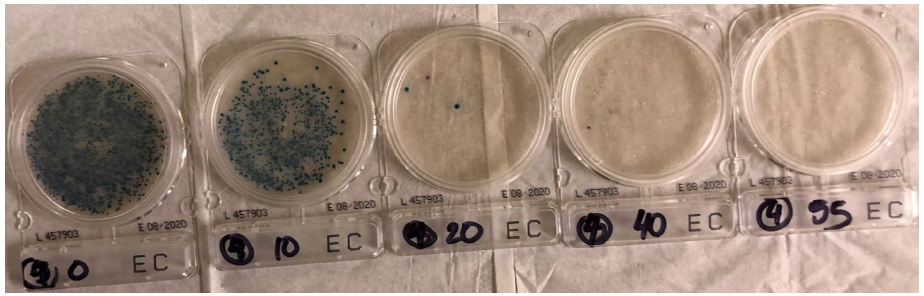
No.	Water volume (ml)	Current density (mA/cm^2)	Flow rate (ml/min)	E. coli
1	400	4	200	No
2	400	2	200	Yes
3	400	4	200	Yes
4	400	6	200	Yes
5	400	4	400	Yes

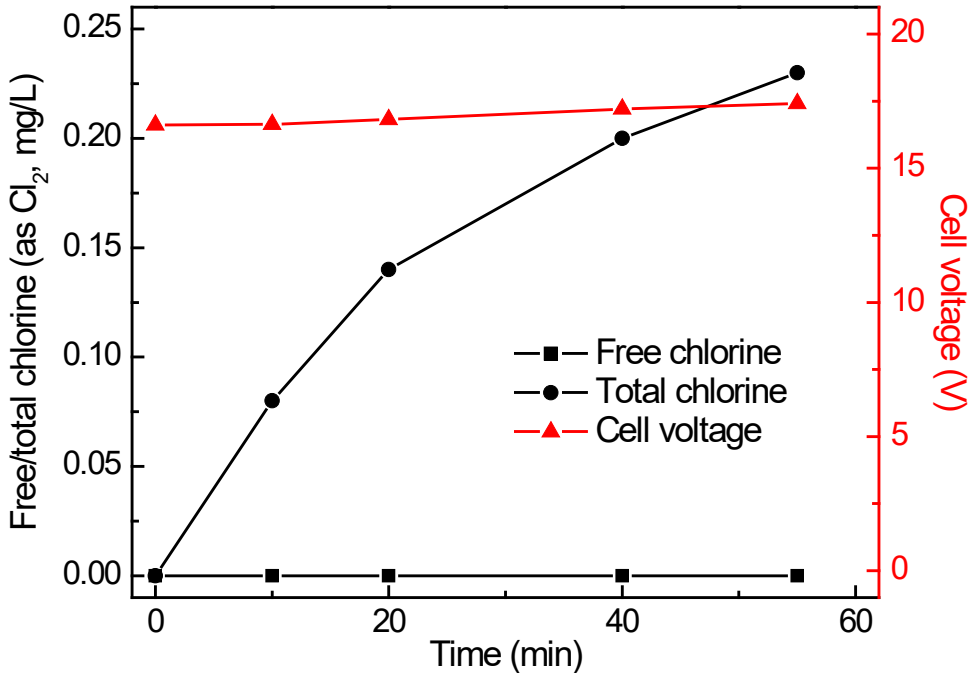




3. Disinfection of irrigation water (Bott Well pond) in flow cell

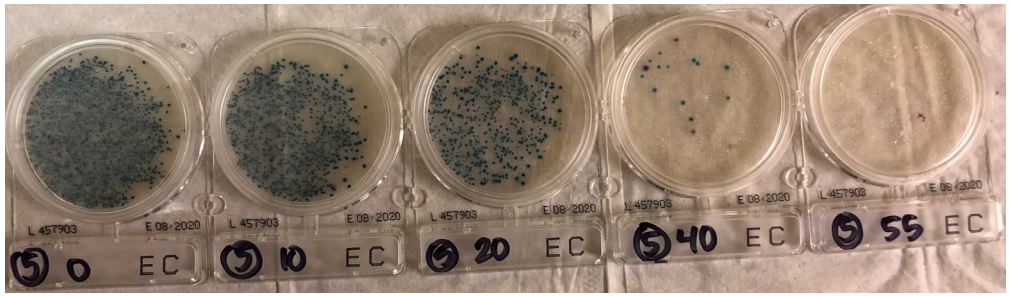
No.	Water volume (ml)	Current density (mA/cm^2)	Flow rate (ml/min)	E. coli
1	400	4	200	No
2	400	2	200	Yes
3	400	4	200	Yes
4	400	6	200	Yes
5	400	4	400	Yes

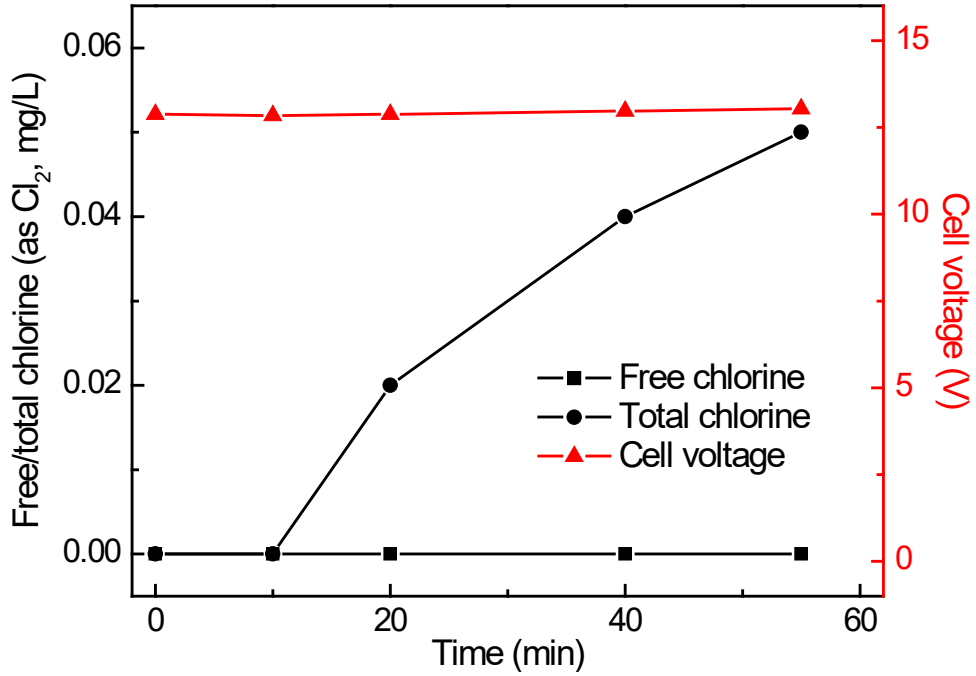




3. Disinfection of irrigation water (Bott Well pond) in flow cell

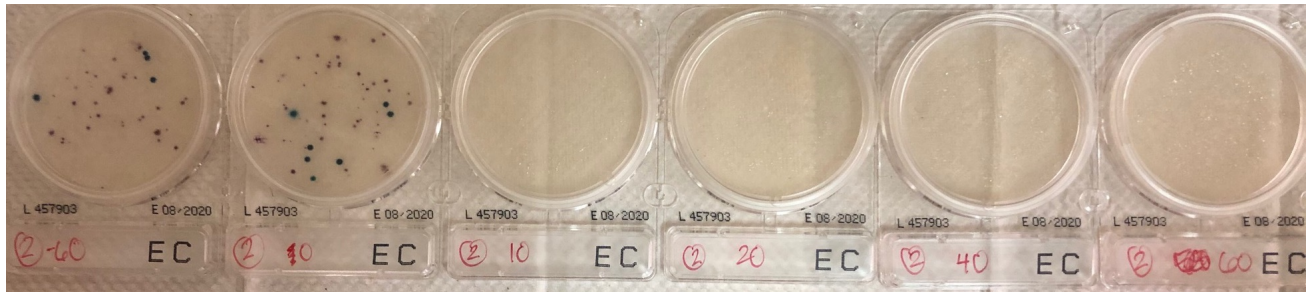
No.	Water volume (ml)	Current density (mA/cm^2)	Flow rate (ml/min)	E. coli
1	400	4	200	No
2	400	2	200	Yes
3	400	4	200	Yes
4	400	6	200	Yes
5	400	4	400	Yes

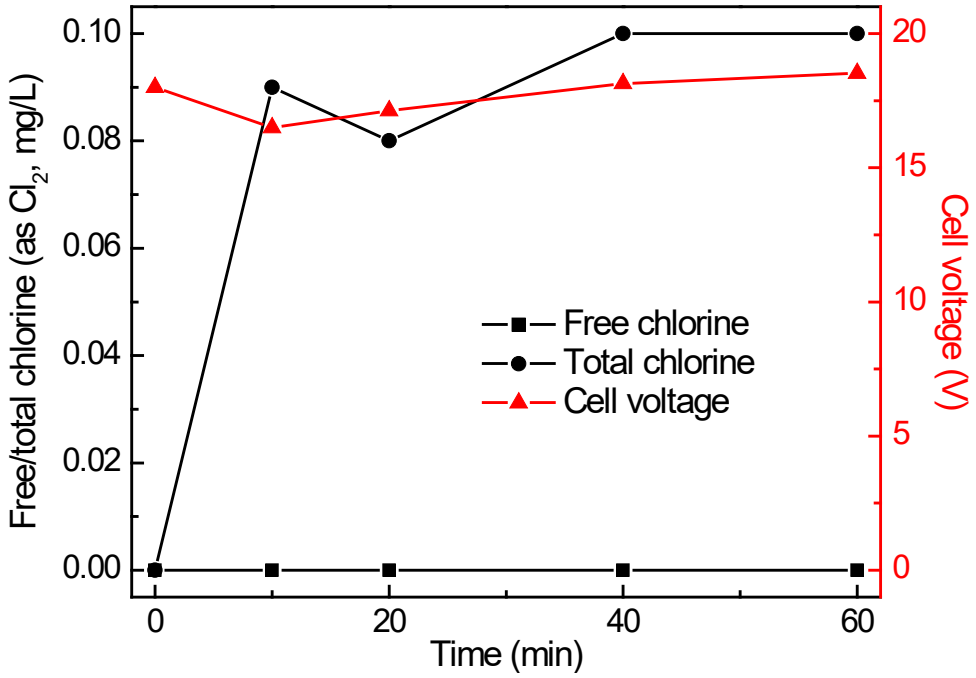




4. Disinfection of irrigation water (open ditch) in flow cell

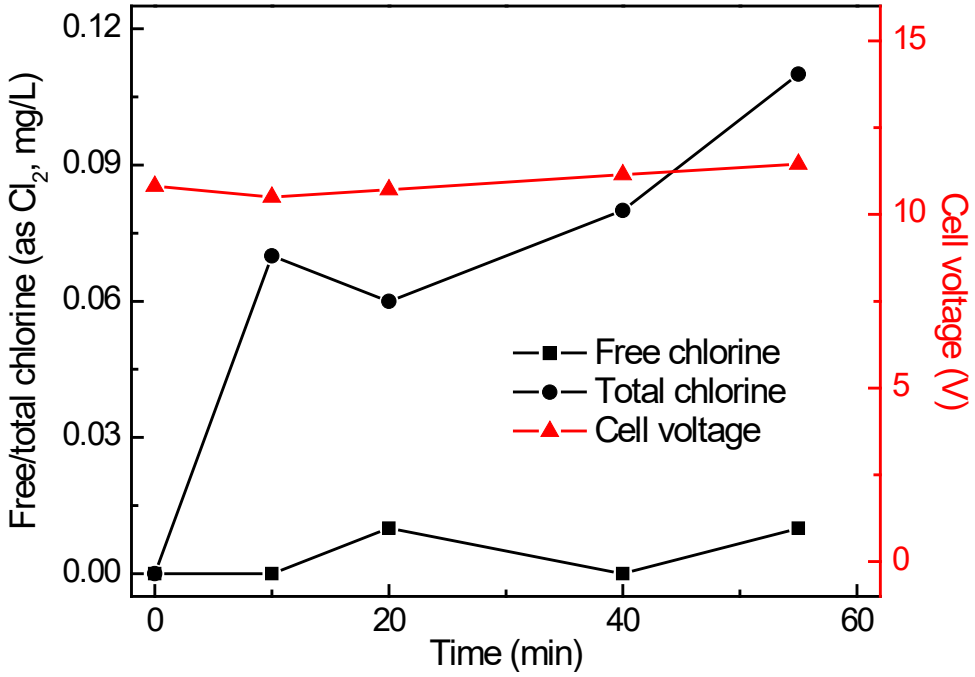
No.	Water volume (ml)	Current density (mA/cm^2)	Flow rate (ml/min)	E. coli
1	400	4	200	No
2	400	2	200	Yes
3	400	4	200	Yes
4	400	6	200	Yes
5	400	4	400	Yes





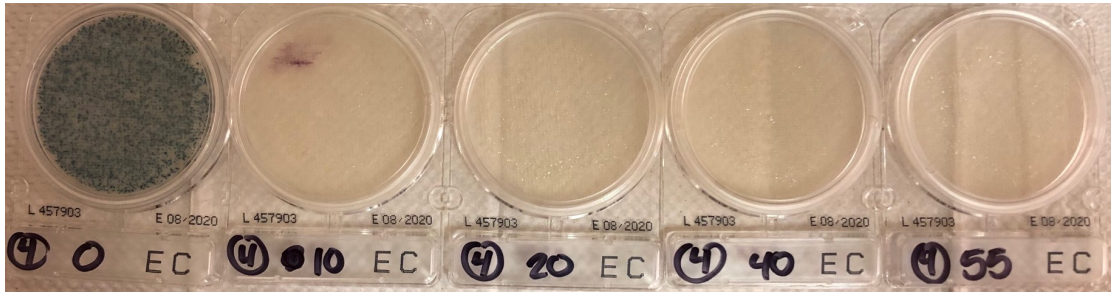
4. Disinfection of irrigation water (open ditch) in flow cell

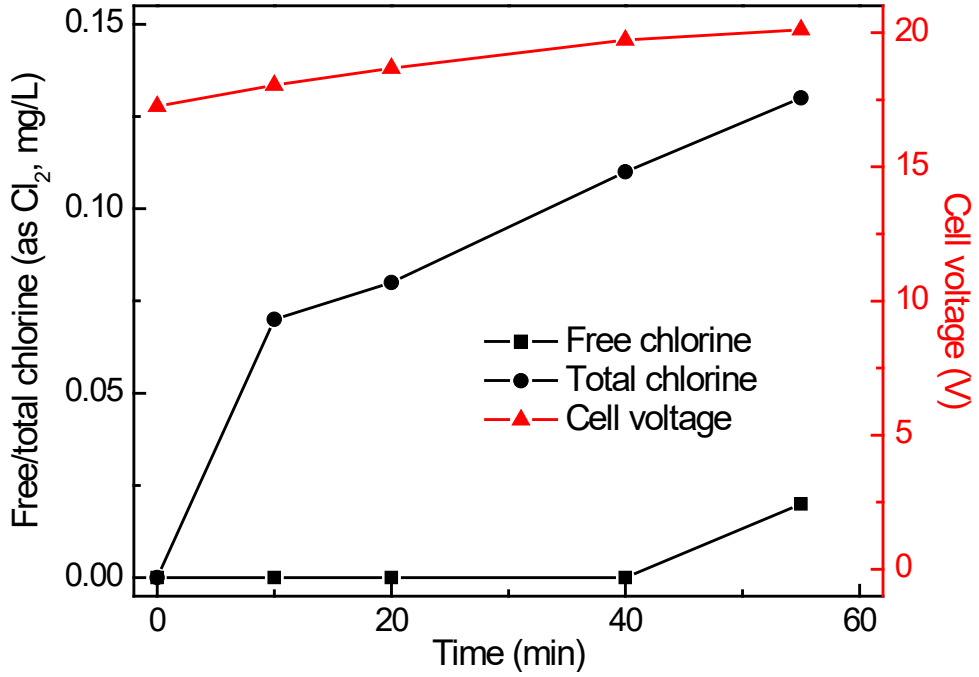
No.	Water volume (ml)	Current density (mA/cm^2)	Flow rate (ml/min)	E. coli
1	400	4	200	No
2	400	2	200	Yes
3	400	4	200	Yes
4	400	6	200	Yes
5	400	4	400	Yes



4. Disinfection of irrigation water (open ditch) in flow cell

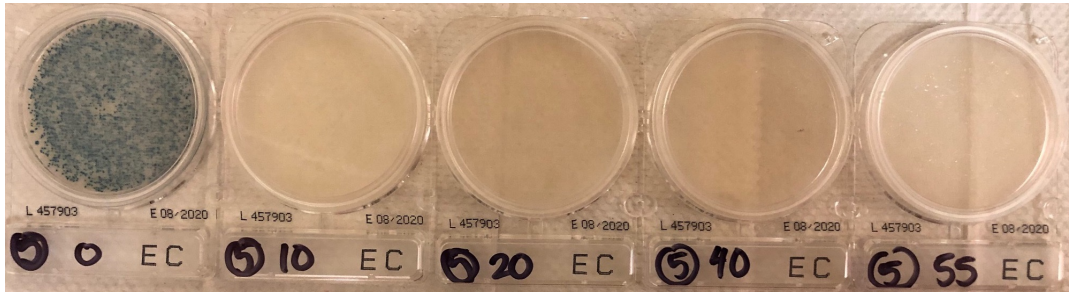
No.	Water volume (ml)	Current density (mA/cm^2)	Flow rate (ml/min)	E. coli
1	400	4	200	No
2	400	2	200	Yes
3	400	4	200	Yes
4	400	6	200	Yes
5	400	4	400	Yes

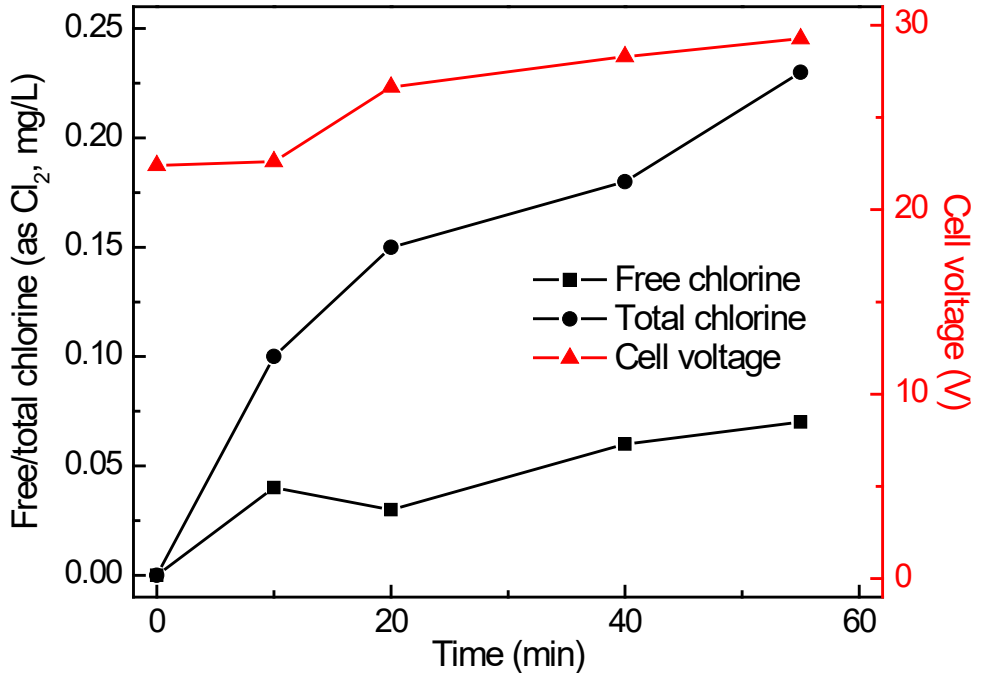




4. Disinfection of irrigation water (open ditch) in flow cell

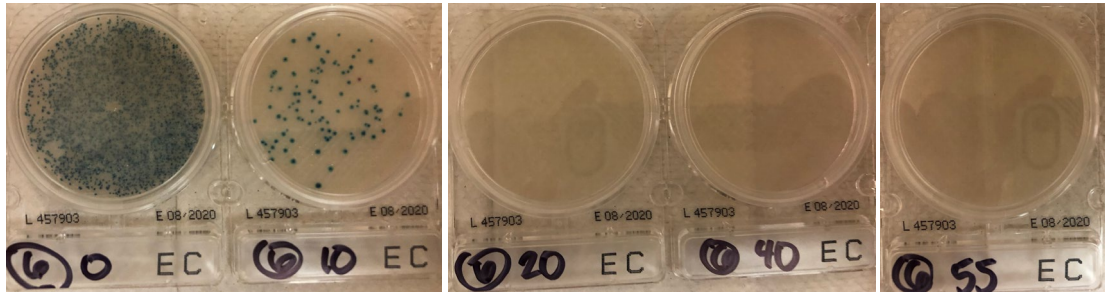
No.	Water volume (ml)	Current density (mA/cm^2)	Flow rate (ml/min)	E. coli
1	400	4	200	No
2	400	2	200	Yes
3	400	4	200	Yes
4	400	6	200	Yes
5	400	4	400	Yes

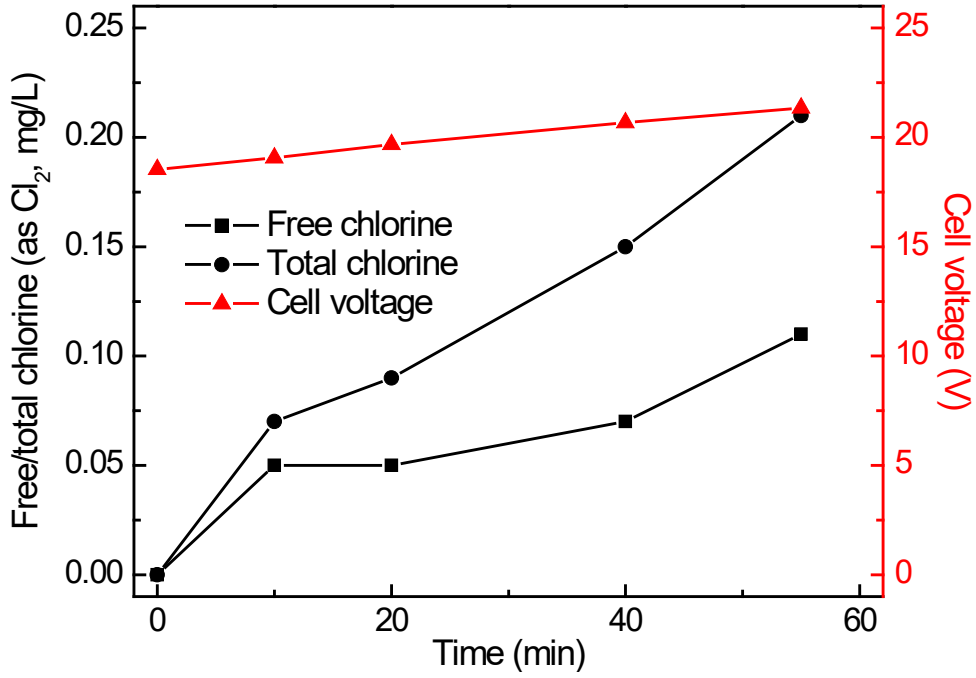




4. Disinfection of irrigation water (open ditch) in flow cell

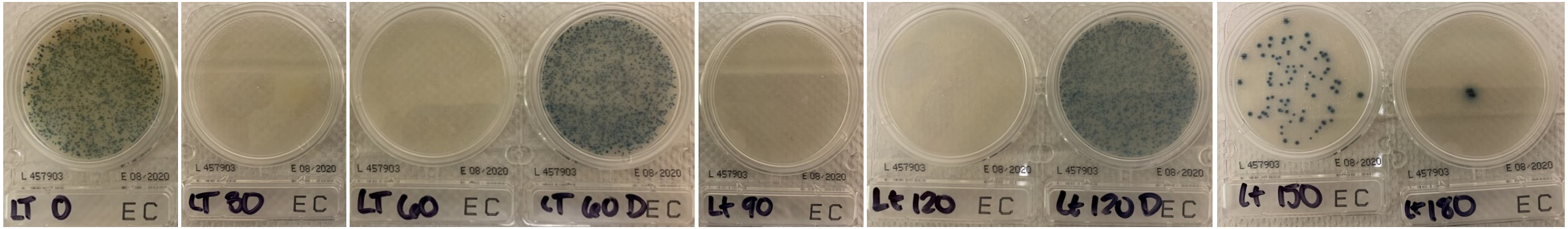
No.	Water volume (ml)	Current density (mA/cm^2)	Flow rate (ml/min)	E. coli
1	400	4	200	No
2	400	2	200	Yes
3	400	4	200	Yes
4	400	6	200	Yes
5	400	4	400	Yes

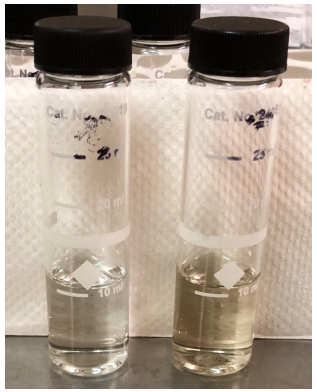




Three-hour stability test of disinfection of irrigation water (open ditch) in flow cell

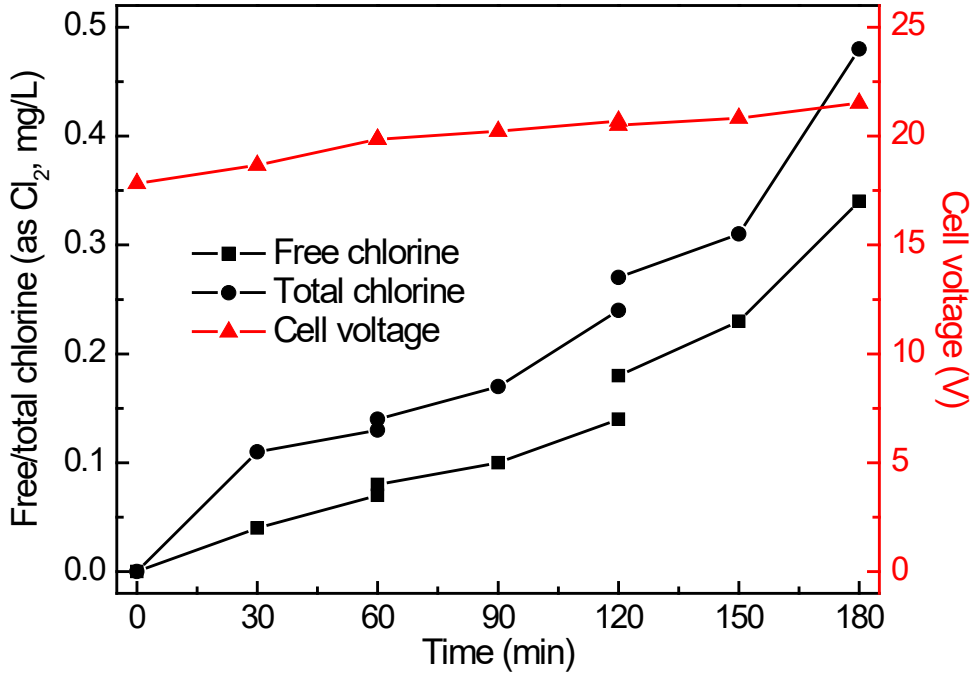
Water volume: 400 ml, current density: 4 mA/cm^2, flow rate: 200 ml/min
E. coli was added at 0min, 60min, and 120min
60 and 120 are before the addition of E. coli, 60D and 120D are after the addition of E. coli





Solution color (left) 0min (right) 180min

Black particles after 180min



Solution color change may partially contribute to light absorption

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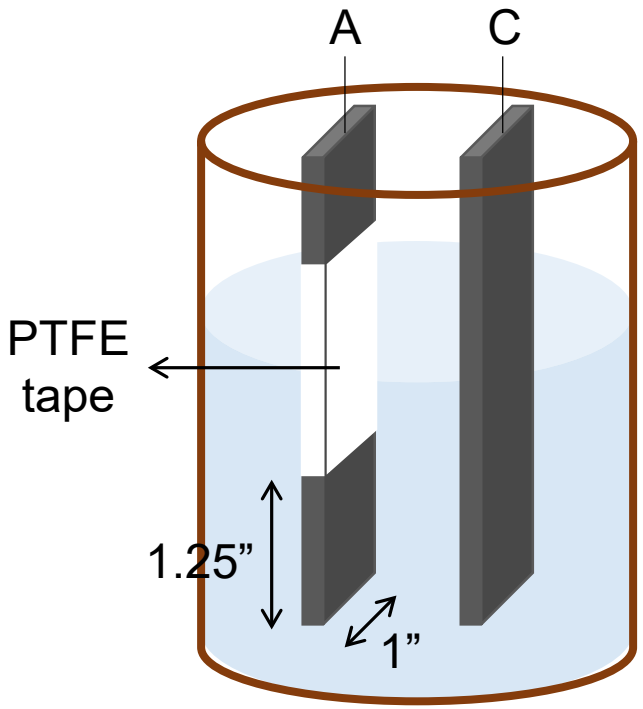
5. Disinfection of irrigation water (Bott Well pond) in side flow mode
6. Disinfection of irrigation water (Open ditch) in side flow mode

7. Disinfection of irrigation water (Bott Well pond) by purging chlorine gas
8. Disinfection of irrigation water (Open ditch) by purging chlorine gas

Side flow mode

Anode: PtRu/graphite, cathode: graphite
Solution: 50ml 0.1M NaCl
Electrolysis: 160mA (20mA/cm^2) for 30min

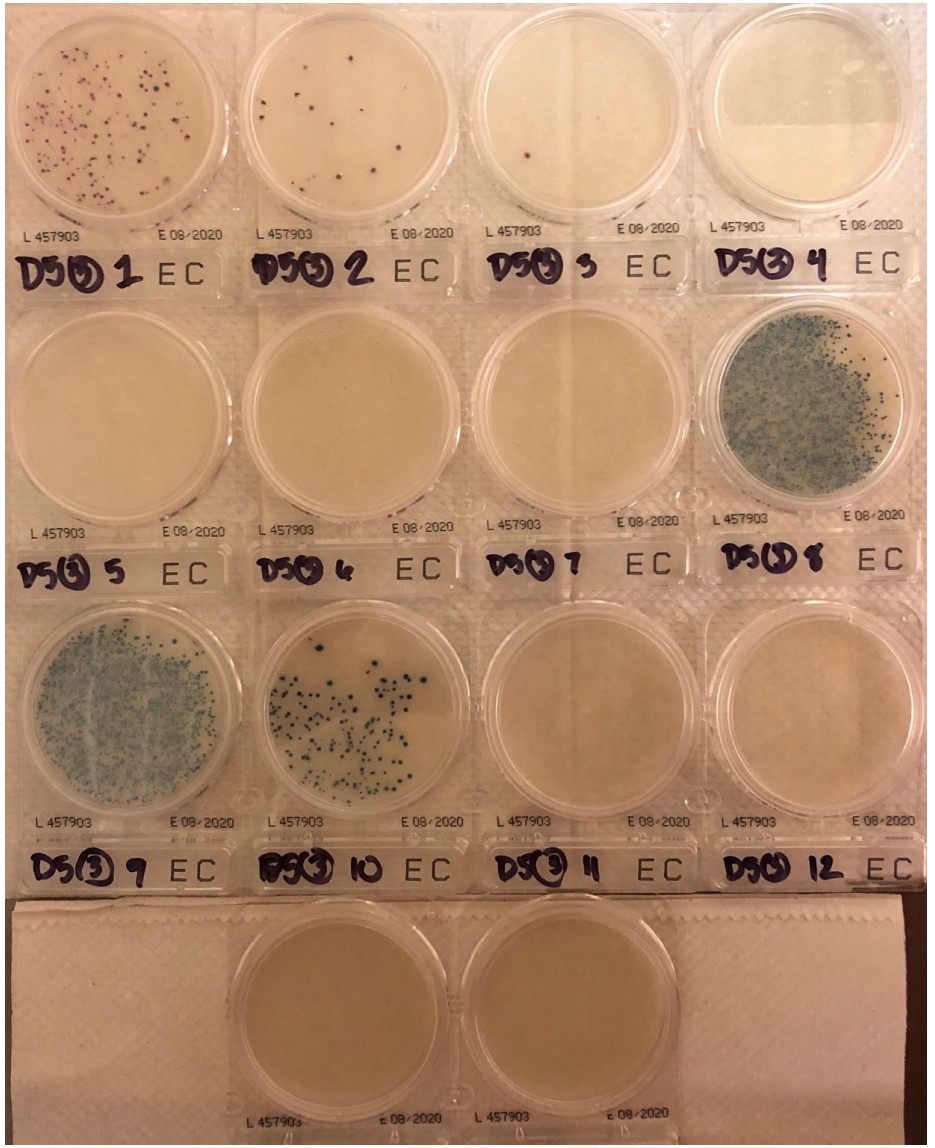


No.	Free chlorine in 500ml water (mg/L)	Added chlorine solution (ml)
1	0	0
2	0.1	0.045
3	0.2	0.090
4	0.5	0.225
5	1	0.450
6	2	0.901
7	5	2.252

5. Disinfection of irrigation water (Bott Well pond) in side flow mode

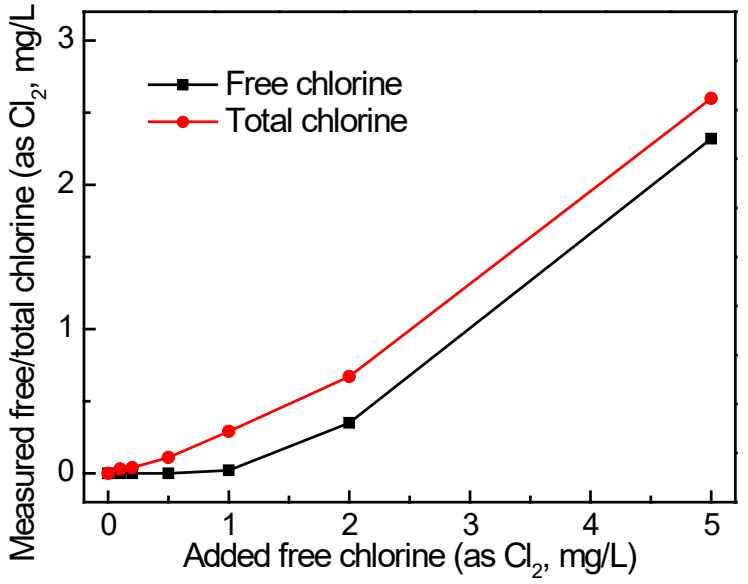
(effect of added free chlorine concentration)

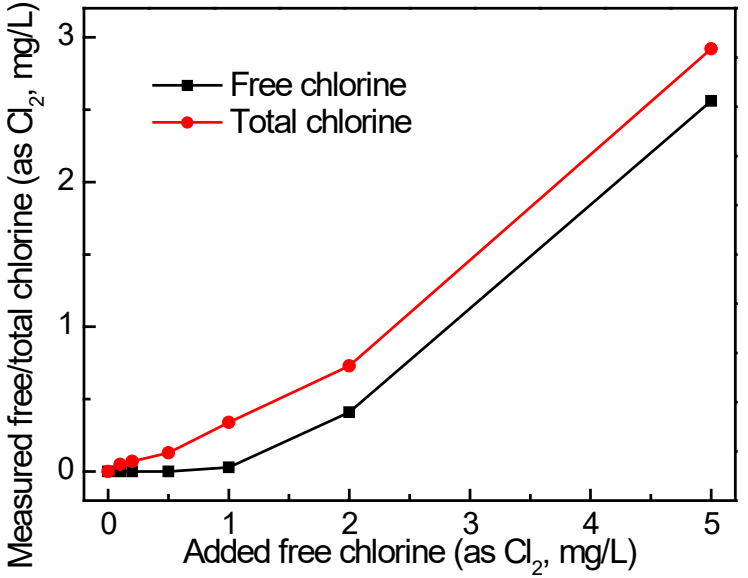
No.	E. coli	Added free chlorine (mg/L)
1	No	0
2	No	0.1
3	No	0.2
4	No	0.5
5	No	1
6	No	2
7	No	5
8	Added	0
9	Added	0.1
10	Added	0.2
11	Added	0.5
12	Added	1
13	Added	2
14	Added	5



5. Disinfection of irrigation water (Bott Well pond) in side flow mode (monitoring free/total chlorine)

No.	E. coli	Added free chlorine (mg/L)
1	No	0
2	No	0.1
3	No	0.2
4	No	0.5
5	No	1
6	No	2
7	No	5
8	Added	0
9	Added	0.1
10	Added	0.2
11	Added	0.5
12	Added	1
13	Added	2
14	Added	5

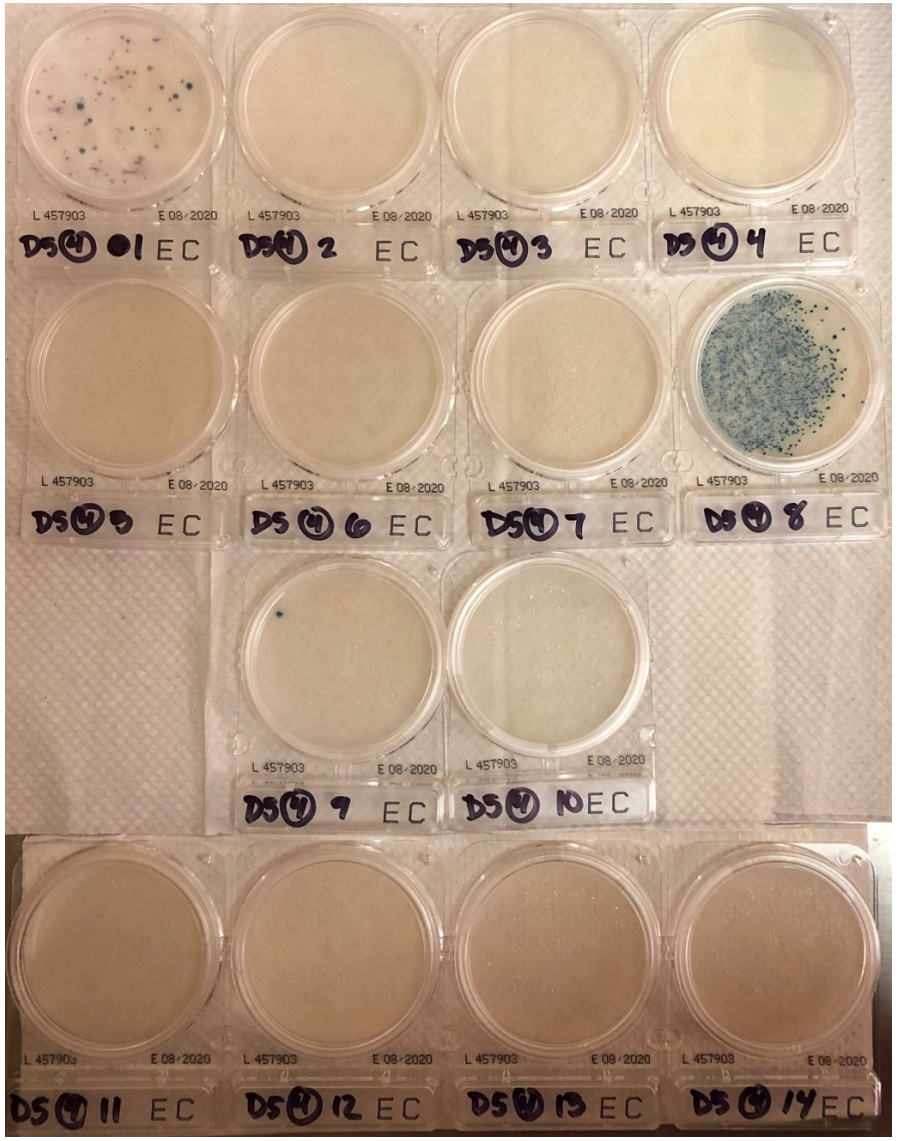




6. Disinfection of irrigation water (Open ditch) in side flow mode

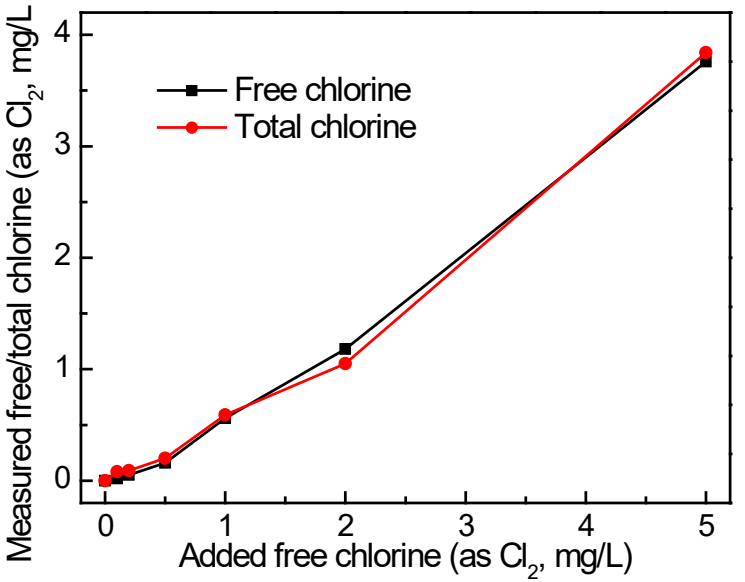
(effect of added free chlorine concentration)

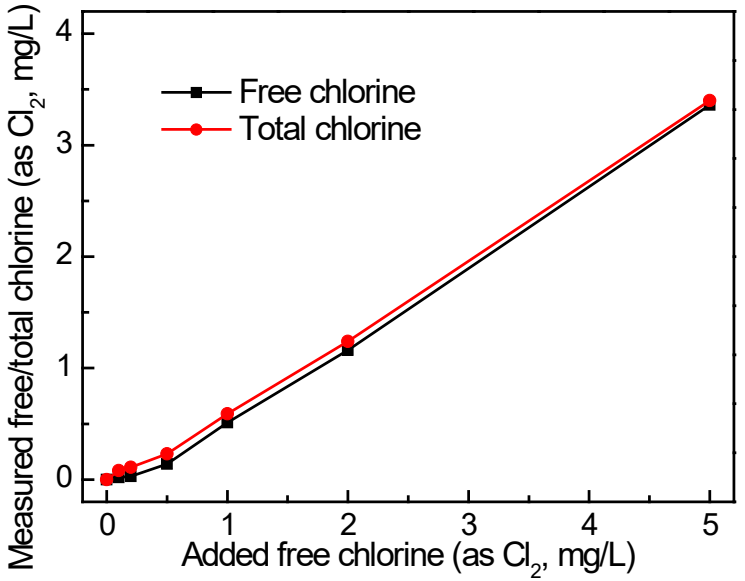
No.	E. coli	Added free chlorine (mg/L)
1	No	0
2	No	0.1
3	No	0.2
4	No	0.5
5	No	1
6	No	2
7	No	5
8	Added	0
9	Added	0.1
10	Added	0.2
11	Added	0.5
12	Added	1
13	Added	2
14	Added	5



6. Disinfection of irrigation water (Open ditch) in side flow mode
(monitoring free/total chlorine)

No.	E. coli	Added free chlorine (mg/L)
1	No	0
2	No	0.1
3	No	0.2
4	No	0.5
5	No	1
6	No	2
7	No	5
8	Added	0
9	Added	0.1
10	Added	0.2
11	Added	0.5
12	Added	1
13	Added	2
14	Added	5





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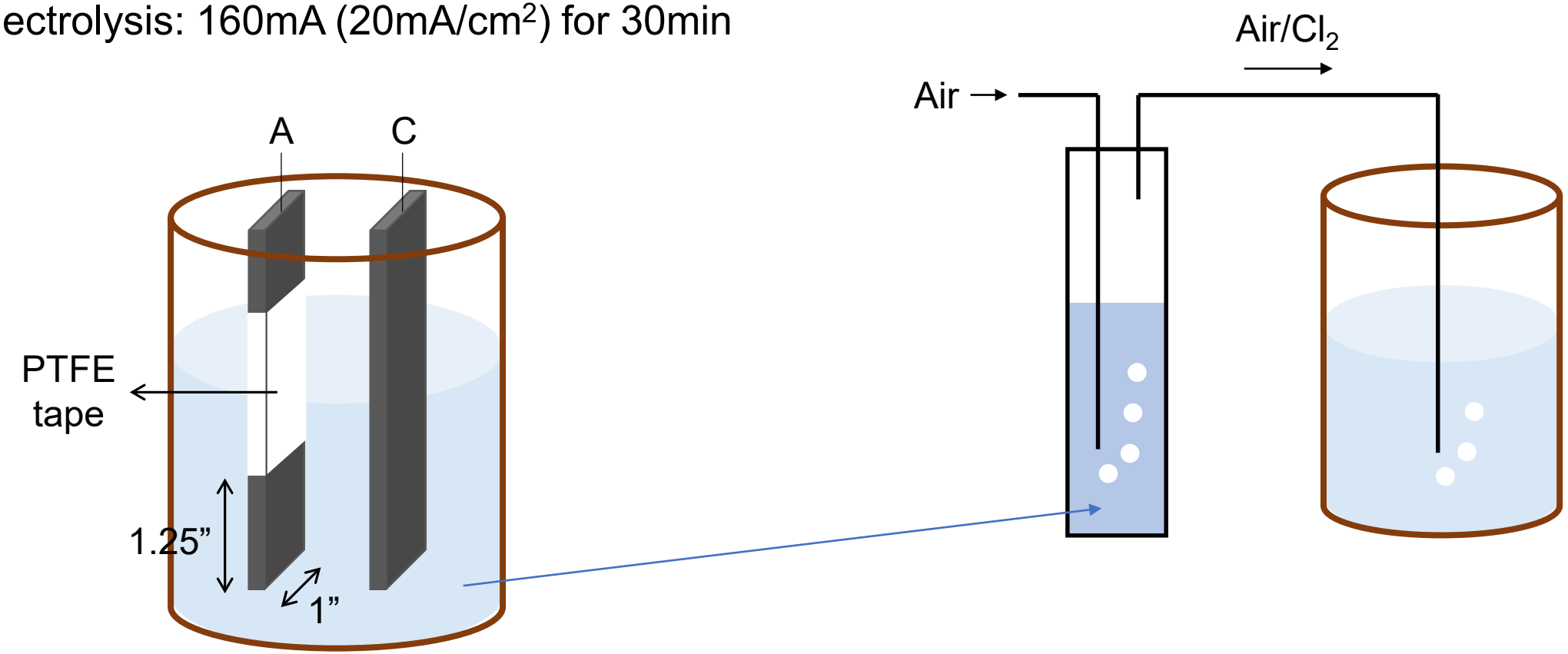
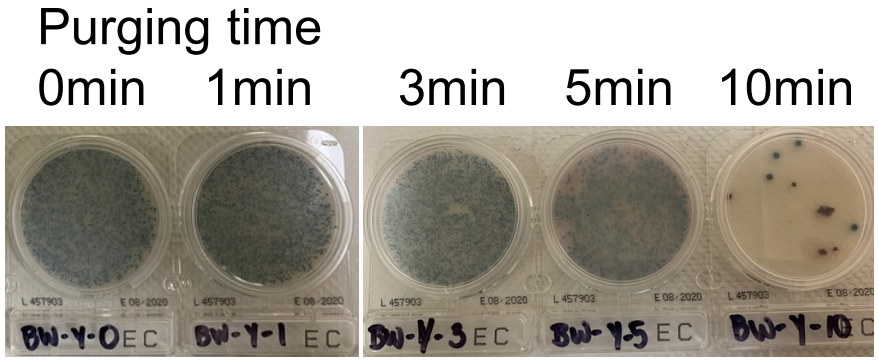
Purging mode

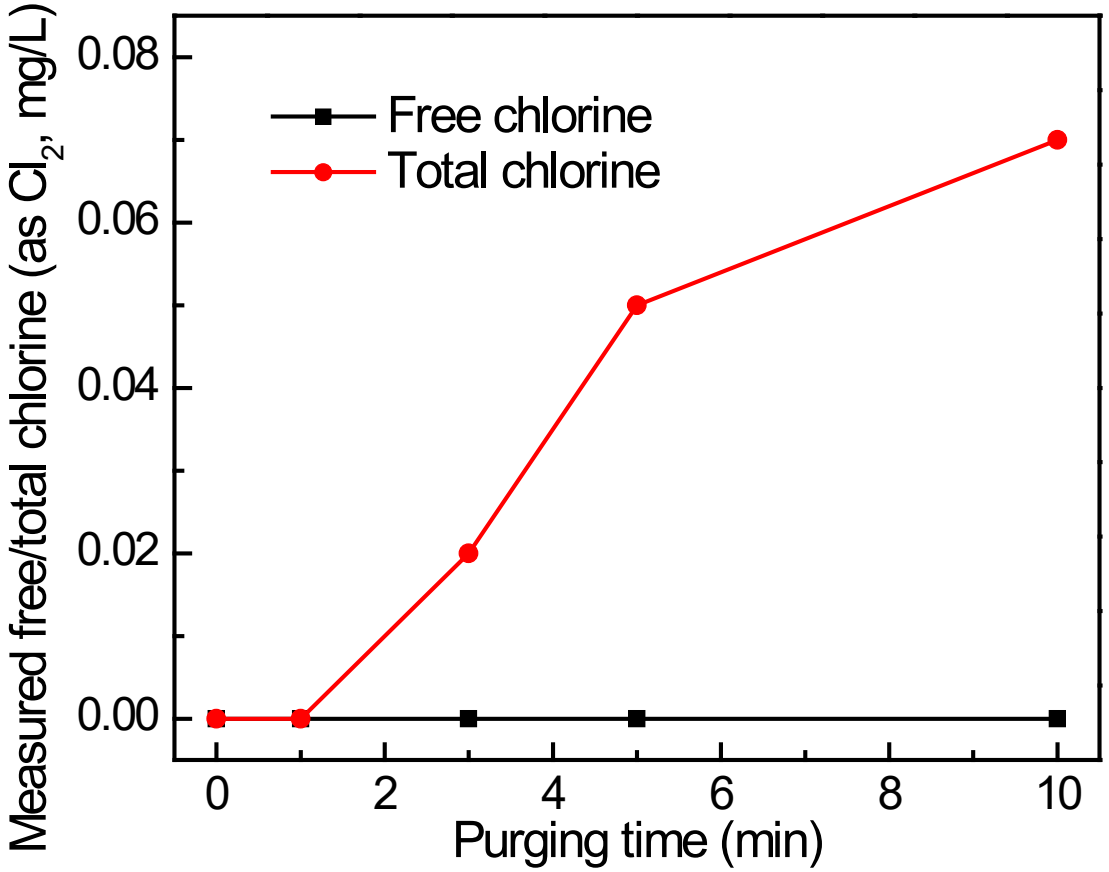
Anode: PtRu/graphite, cathode: graphite
Solution: 50ml 0.1M NaCl
Electrolysis: 160mA (20mA/cm^2) for 30min



7. Disinfection of irrigation water (Bott Well pond) by purging chlorine gas

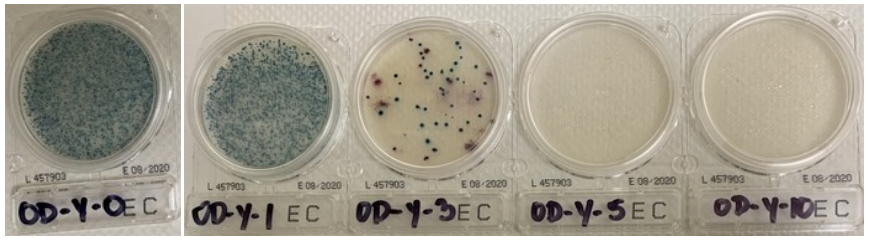
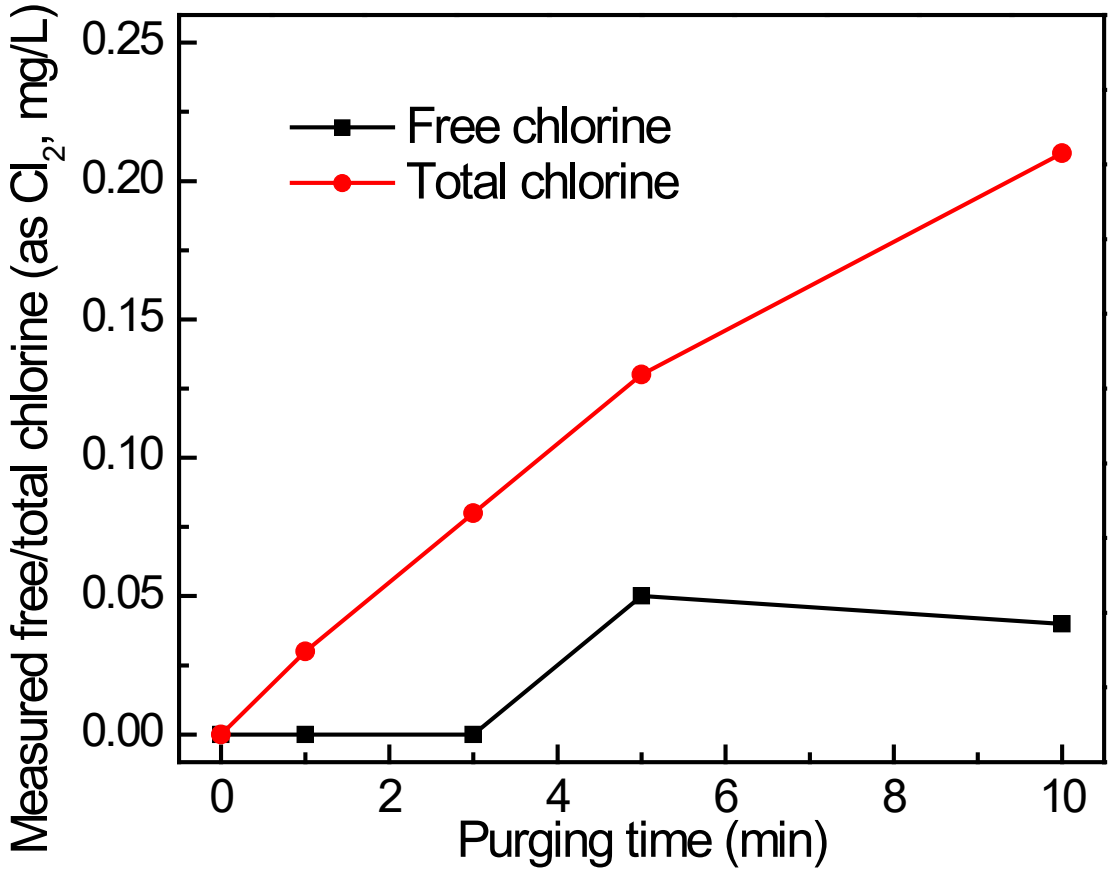
(effect of purging time, monitoring free/total chlorine)





8. Disinfection of irrigation water (Open ditch) by purging chlorine gas

(effect of purging time, monitoring free/total chlorine)

Purging time

0min 1min 3min 5min 10min