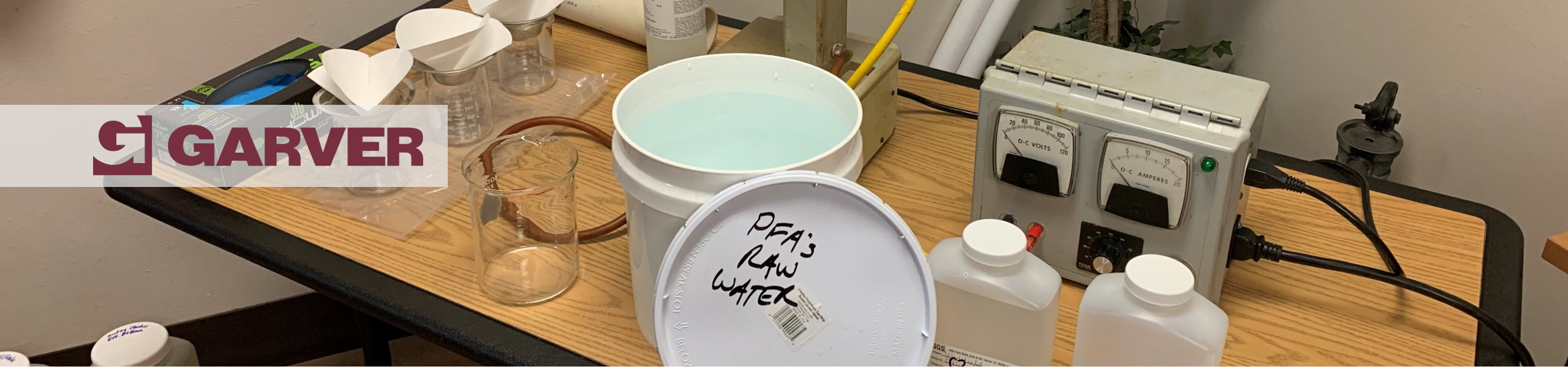



GARVER

# Electro-coagulation Bench and Pilot Testing Results for PFAS-Contaminated Well Water, Surface Water and Landfill Leachate

**ERIC DOLE, PE, PSAP**

*WATER & ENERGY PRACTICE LEAD*

**Multi State Salinity Coalition Conference**
February 24, 2022

# What is electro-coagulation?

An alternative to traditional chemical coagulation

Uses electricity + sacrificial metal blades to drive efficient chemical coagulation reactions w/out adding metal salts

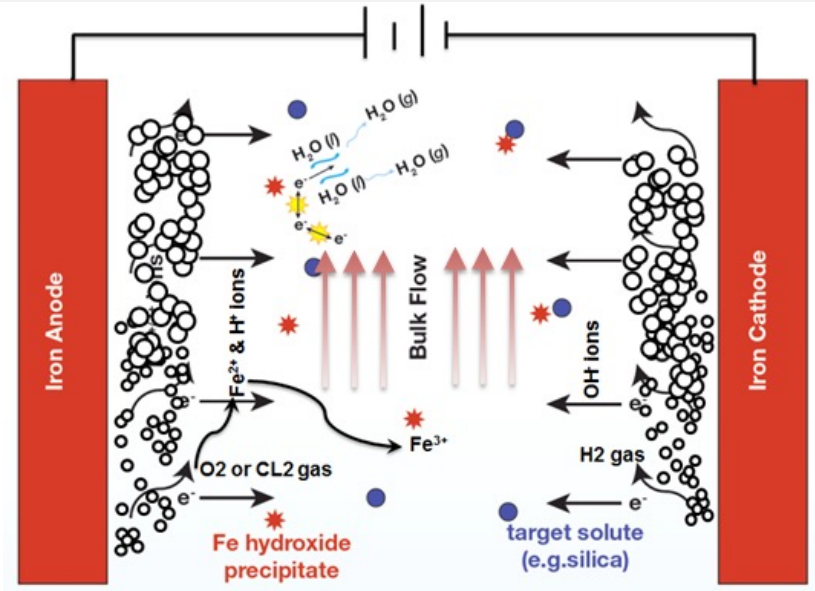
(-) charged contaminates magnetically attracted to anode

(+) charged contaminates magnetically attracted to cathode

Polarity reversal every minute prevents plating

# EC Removal Mechanisms

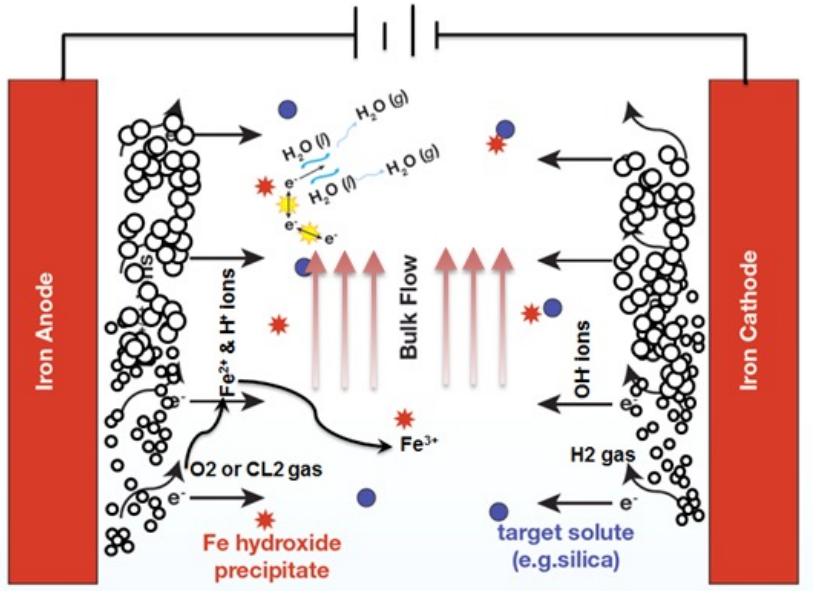
## EC Only (Fe Blades)




| | |
|---|---|
| $Al\,(s) \rightarrow Al^{3+} + 3e^-$<br>$Fe\,(s) \rightarrow Fe^{2+} + 2e^-$<br>$2H_2O \rightarrow O_2(g) + 4H^+ + 4e^-$ | Anodic reactions (Oxidation) |
| $2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-$ | Cathodic reactions (Reduction) |

AOP with hydroxyl radical from Fenton using Fe from blades vs Ferrous sulfate

## *AOP*
## EC (Fe Blades) + Fenton (H2O2) = OH`




| | |
|---|---|
| $Al\,(s) \rightarrow Al^{3+} + 3e^-$<br>$Fe\,(s) \rightarrow Fe^{2+} + 2e^-$<br>$2H_2O \rightarrow O_2(g) + 4H^+ + 4e^-$ | Anodic reactions (Oxidation) |
| $2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-$ + | Cathodic reactions (Reduction) |

$$Fe^{2+} + H_2O_2 \longrightarrow Fe^{3+} + HO^{\cdot} + OH^{\ominus}$$

$$Fe^{3+} + H_2O_2 \longrightarrow Fe^{2+} + HO_2^{\cdot} + H^{\oplus}$$

# EC Removal Mechanisms

**Oxidation/reduction reactions**

- Reduction @ cathode = OH generated; oxidation @ anode metal passivation
- Fe dose rate, bubble rate and mixing is function of amps

**Emulsion breaking**

- Oxygen and hydrogen ions bond into the water receptor sites of oil molecules
- Creates a water insoluble complex that separates water from oil

**Halogen complexing**

- Metal ions bind to chlorines in a chlorinated hydrocarbon molecule
- Results in a large insoluble complex

**Bleaching by oxygen ions**

- Oxidizes dyes, cyanides, bacteria, viruses, endocrine disruptors, biohazards at anode

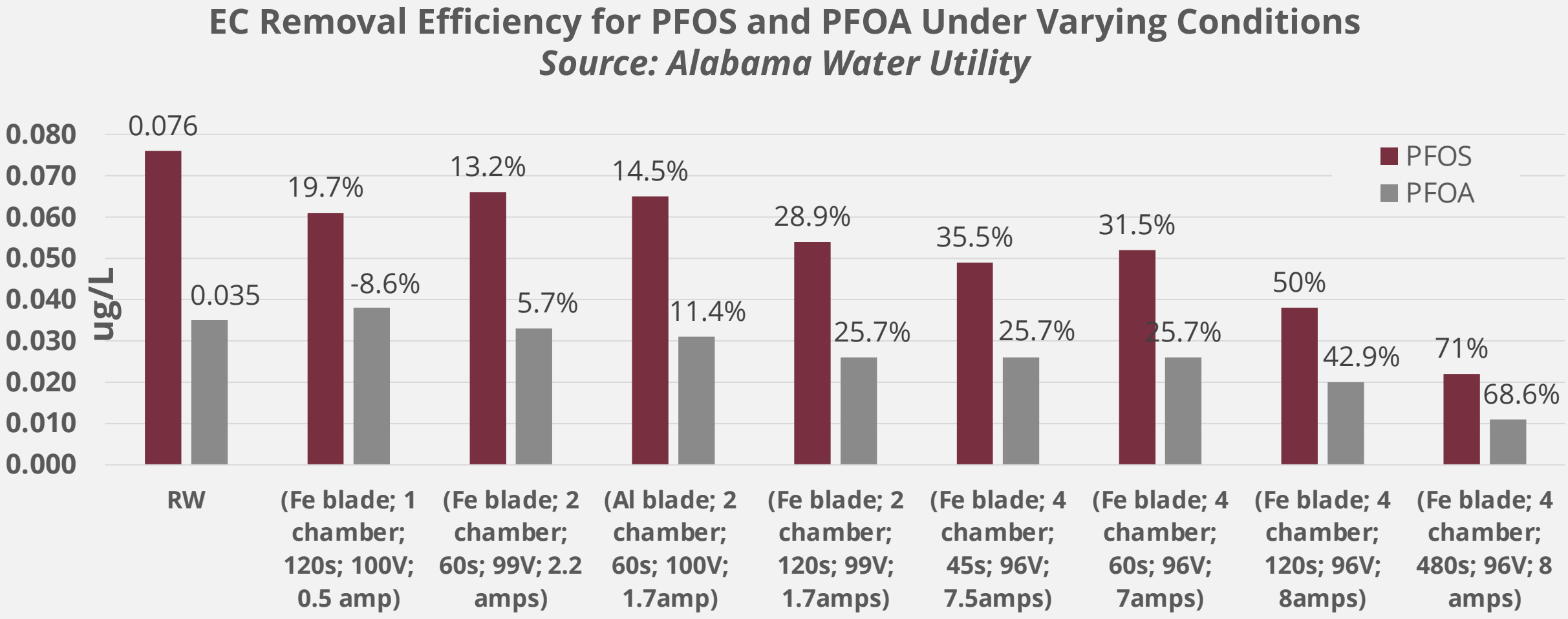
**Electron flooding**

- Decreases zeta potential to near 0 allowing agglomeration
- The increase of electrons creates an osmotic pressure that ruptures algae, bacteria, cysts, and viruses

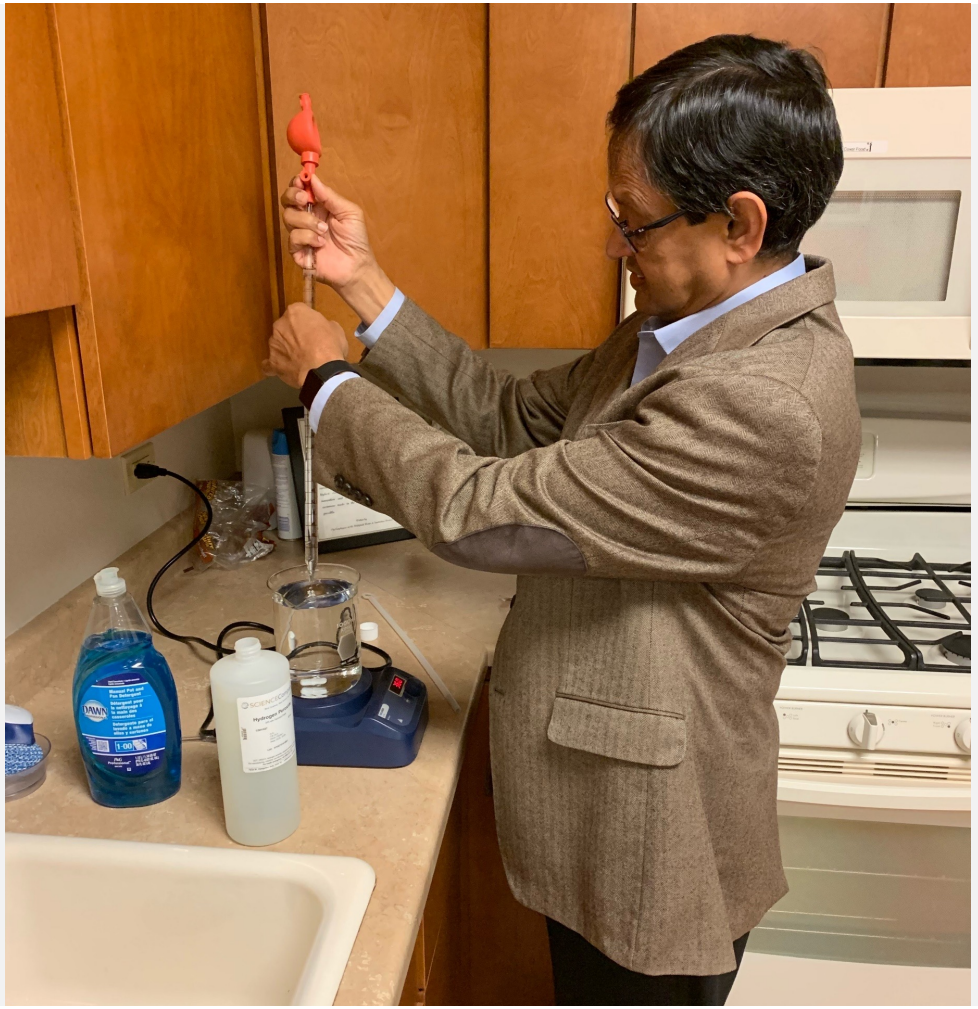
**Seeding**

- Seeding results from the anode oxidation of metal ions and cathode reduction forming OH ions
- Forms insoluble sweep floc that precipitate as complex metal oxides

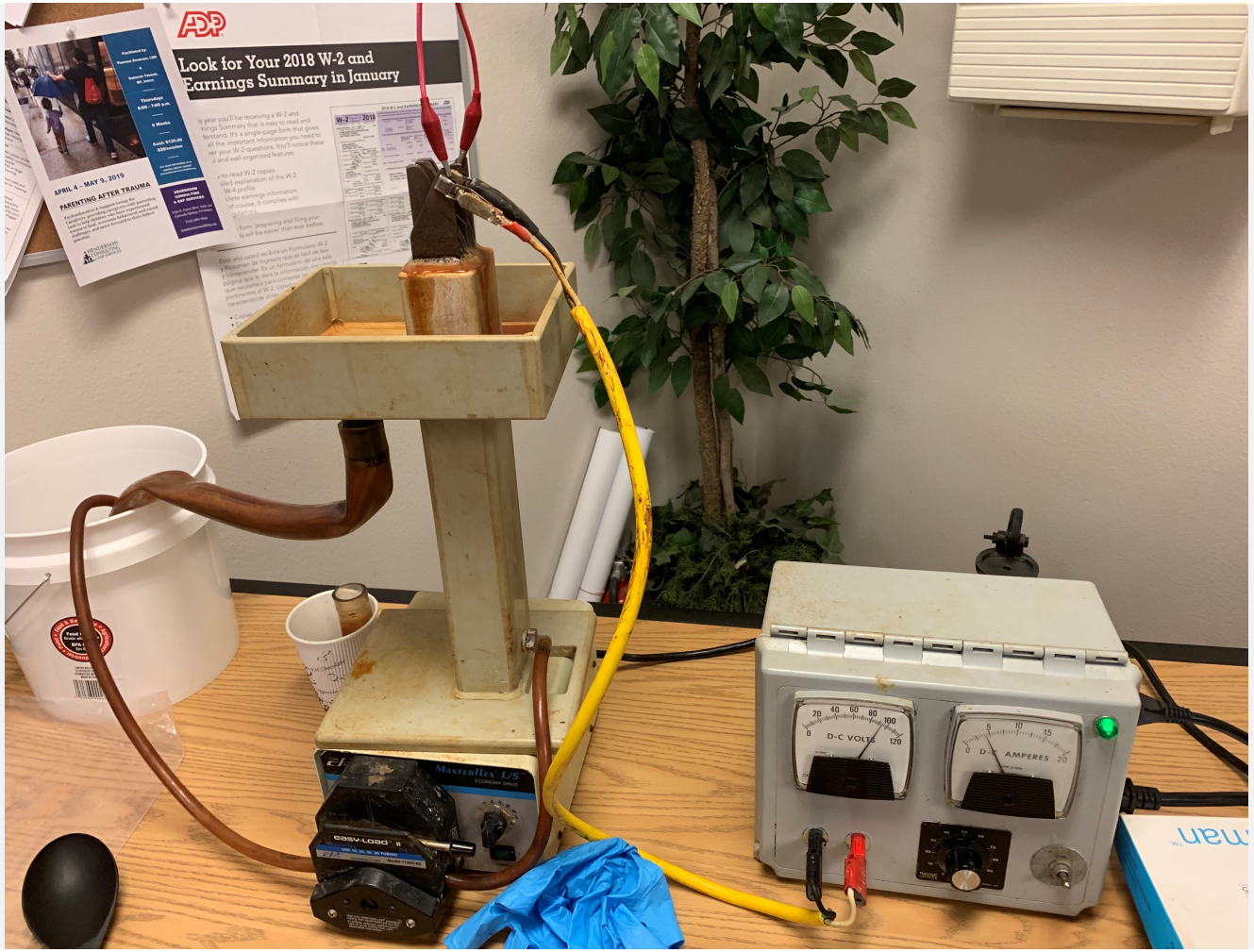
# EC Case Study #1 Source Water in AL w/ PFC's

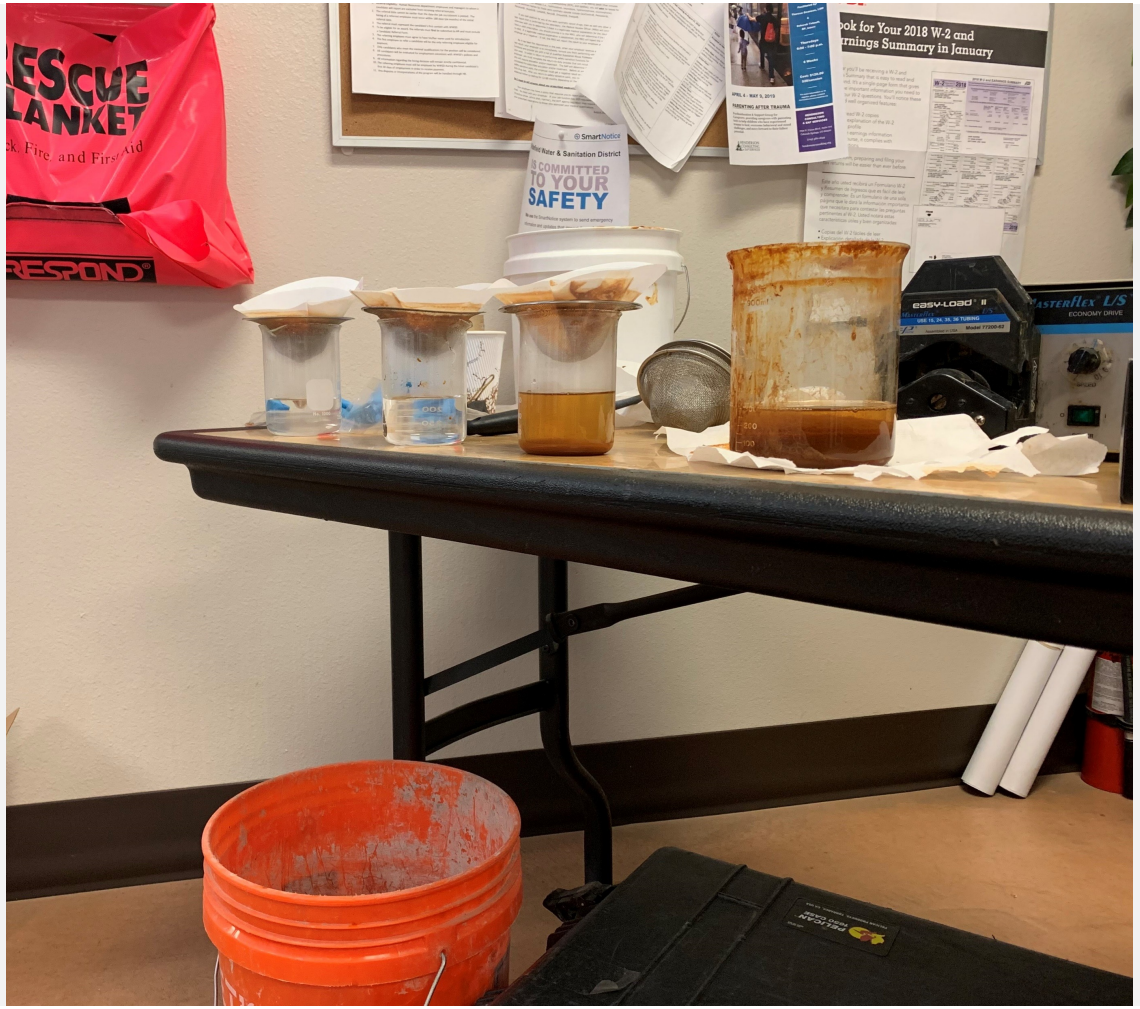


# EC Case Study #2 Widefield Water & Sanitation District

# EC Case Study #2 Widefield Water & Sanitation District



# EC Case Study #2 Widefield Water & Sanitation District

2 min HRT | Fe Blades only | ambient pH

Client Name: Widefield

eport #: 442299

Sampling Point: Influent

PWS ID: CO0121900

**EEA Methods**

| Analyte ID # | Analyte | Method | Reg Limit | MRL† | Result | Units | Preparation Date | Analyzed Date | EEA ID # |
|---|---|---|---|---|---|---|---|---|---|
| 120226-60-0 | 10:2 Fluorotelomer sulfonic acid (10:2 FTS) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 757124-22-4 | 4:2 Fluorotelomer sulfonic acid (4:2 FTS) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 27619-97-2 | 6:2 Fluorotelomer sulfonic acid (6:2 FTS) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 39108-34-4 | 8:2 Fluorotelomer sulfonic acid (8:2 FTS) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 958445-44-8 | ADONA | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 73606-19-6 | F-53B Major | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 83329-89-9 | F-53B Minor | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 13252-13-6 | GenX | L402 | --- | 5.0 | < 5.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 29311-67-9 | Nafion Byproduct 1 | L402 | --- | 5.0 | < 5.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 749836-20-2 | Nafion Byproduct 2 | L402 | --- | 5.0 | < 5.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 4151-50-2 | N-ethylperfluorooctane sulfonamide (NEtFOSA) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 1691-99-2 | N-ethylperfluorooctane sulfonamidoethanol | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 31506-32-8 | N-methylperfluorooctane sulfonamide (NMeFOSA) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 24448-09-7 | N-methylperfluorooctane sulfonamidoethanol | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 375-73-5 | Perfluorobutanesulfonic acid (PFBS) | L402 | --- | 2.0 | **44** | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 375-22-4 | Perfluorobutanoic acid (PFBA) | L402 | --- | 5.0 | **26** | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 335-76-2 | Perfluorodecanoic acid (PFDA) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 375-85-9 | Perfluoroheptanoic acid (PFHpA) | L402 | --- | 2.0 | **21** | ng/L | 02/15/19 0 | | |
| 355-46-4 | Perfluorohexanesulfonic acid (PFHxS) | L402 | --- | 2.0 | **170** | ng/L | 02/15/19 0 | | |
| 307-24-4 | Perfluorohexanoic acid (PFHxA) | L402 | --- | 2.0 | **72** | ng/L | 02/15/19 0 | | |
| 307-55-1 | Perfluorododecanoic acid (PFDoA) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 0 | | |
| 375-95-1 | Perfluorononanoic acid (PFNA) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 1763-23-1 | Perfluorooctanesulfonic acid (PFOS) | L402 | --- | 2.0 | **140** | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 2991-50-6 | N-ethyl Perfluorooctanesulfonamidoacetic acid | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 2355-31-9 | N-methyl Perfluorooctanesulfonamidoacetic acid | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 335-67-1 | Perfluorooctanoic acid (PFOA) | L402 | --- | 2.0 | **44** | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 72629-94-8 | Perfluorotridecanoic acid (PFTrDA) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 2058-94-8 | Perfluoroundecanoic acid (PFUnA) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| NA | Perfluorododecanesulfonic acid (PFDoS) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 0 | | |
| 335-77-3 | Perfluorodecanesulfonic acid (PFDS) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 0 | | |
| 375-92-8 | Perfluoroheptanesulfonic acid (PFHpS) | L402 | --- | 2.0 | **3.6** | ng/L | 02/15/19 0 | | |
| 67905-19-5 | Perfluorohexadecanoic acid (PFHxDA) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 0 | | |
| 151772-58-6 | Perfluoro-2-methoxyethoxyacetic acid | L402 | --- | 5.0 | < 5.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 801212-59-9 | Perfluoro-4-isopropoxybutanoic acid | L402 | --- | 5.0 | < 5.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 674-13-5 | Perfluoro-2-methoxyacetic acid | L402 | --- | 5.0 | < 5.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 863090-89-5 | Perfluoro-4-methoxybutanoic acid (PFMOBA) | L402 | --- | 5.0 | < 5.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 377-73-1 | Perfluoro-3-methoxypropanoic acid (PFMOPrA) | L402 | --- | 5.0 | < 5.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 68259-12-1 | Perfluorononanesulfonic acid (PFNS) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 39492-88-1 | Perfluoro(3,5-dioxahexanoic) acid | L402 | --- | 5.0 | < 5.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 39492-89-2 | Perfluoro(3,5,7-trioxaoctanoic) acid | L402 | --- | 5.0 | < 5.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 39492-90-5 | Perfluoro(3,5,7,9-tetraoxadecanoic) acid | L402 | --- | 5.0 | < 5.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 754-91-6 | Perfluorooctane sulfonamide (PFOSA) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 2706-90-3 | Perfluoropentanoic acid (PFPeA) | L402 | --- | 2.0 | **57** | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 2706-91-4 | Perfluoropentanesulfonic acid (PFPeS) | L402 | --- | 2.0 | **29** | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |
| 376-06-7 | Perfluorotetradecanoic acid (PFTeDA) | L402 | --- | 2.0 | < 2.0 | ng/L | 02/15/19 08:38 | 02/16/19 02:07 | 4187907 |

$PFOS_{RAW}$ = 140 ng/L → $PFOS_{TREATED}$ = 3.1 ng/L

**98% Removal Efficiency**

$PFOA_{RAW}$ = 44 ng/L → $PFOA_{TREATED}$ = 5.0 ng/L

**89% Removal Efficiency**

Client Name: Widefield Water & Sanitation District

Report #: 453104

Sampling Point: Electro Coagulation Effluent

PWS ID: CO0121900

**EEA Methods**

| Analyte ID # | Analyte | Method | Reg Limit | MRL† | Result | Units | Preparation Date | Analyzed Date | EEA ID # |
|---|---|---|---|---|---|---|---|---|---|
| 120226-60-0 | 10:2 Fluorotelomer sulfonic acid (10:2 FTS) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 757124-22-4 | 4:2 Fluorotelomer sulfonic acid (4:2 FTS) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 27619-97-2 | 6:2 Fluorotelomer sulfonic acid (6:2 FTS) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 39108-34-4 | 8:2 Fluorotelomer sulfonic acid (8:2 FTS) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 958445-44-8 | ADONA | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 73606-19-6 | 9Cl-PF3ONS/F-53B Major | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 83329-89-9 | 11Cl-PF3OUdS/F-53B Minor | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 13252-13-6 | HFPO-DA/GenX | L402 | --- | 5.0 | < 5.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 29311-67-9 | Nafion Byproduct 1 | L402 | --- | 5.0 | < 5.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 749836-20-2 | Nafion Byproduct 2 | L402 | --- | 5.0 | < 5.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 4151-50-2 | N-ethylperfluorooctane sulfonamide (NEtFOSA) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 1691-99-2 | N-ethylperfluorooctane sulfonamidoethanol | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 31506-32-8 | N-methylperfluorooctane sulfonamide (NMeFOSA) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 24448-09-7 | N-methylperfluorooctane sulfonamidoethanol | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 375-73-5 | Perfluorobutanesulfonic acid (PFBS) | L402 | --- | 2.0 | **43** | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 375-22-4 | Perfluorobutanoic acid (PFBA) | L402 | --- | 5.0 | **53** | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 335-76-2 | Perfluorodecanoic acid (PFDA) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| | d (PFHpA) | L402 | --- | 2.0 | **14** | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| | ic acid (PFHxS) | L402 | --- | 2.0 | **53** | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| | d (PFHxA) | L402 | --- | 2.0 | **71** | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| | cid (PFDoA) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 375-95-1 | Perfluorononanoic acid (PFNA) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 1763-23-1 | Perfluorooctanesulfonic acid (PFOS) | L402 | --- | 2.0 | **3.1** | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 2991-50-6 | N-ethyl Perfluorooctanesulfonamidoacetic acid | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 2355-31-9 | N-methyl Perfluorooctanesulfonamidoacetic acid | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 335-67-1 | Perfluorooctanoic acid (PFOA) | L402 | --- | 2.0 | **5.0** | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 72629-94-8 | Perfluorotridecanoic acid (PFTrDA) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 2058-94-8 | Perfluoroundecanoic acid (PFUnA) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| | fonic acid (PFDoS) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| | ic acid (PFDS) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| | nic acid (PFHpS) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| | c acid (PFHxDA) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 151772-58-6 | Perfluoro-2-methoxyethoxyacetic acid | L402 | --- | 5.0 | < 5.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 801212-59-9 | Perfluoro-4-isopropoxybutanoic acid | L402 | --- | 5.0 | < 5.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 674-13-5 | Perfluoro-2-methoxyacetic acid | L402 | --- | 5.0 | < 5.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 863090-89-5 | Perfluoro-4-methoxybutanoic acid (PFMOBA) | L402 | --- | 5.0 | < 5.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 68259-12-1 | Perfluorononanesulfonic acid (PFNS) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 39492-88-1 | Perfluoro(3,5-dioxahexanoic) acid | L402 | --- | 5.0 | < 5.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 39492-89-2 | Perfluoro(3,5,7-trioxaoctanoic) acid | L402 | --- | 5.0 | < 5.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 39492-90-5 | Perfluoro(3,5,7,9-tetraoxadecanoic) acid | L402 | --- | 5.0 | < 5.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 754-91-6 | Perfluorooctane sulfonamide (PFOSA) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 2706-90-3 | Perfluoropentanoic acid (PFPeA) | L402 | --- | 2.0 | **52** | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 2706-91-4 | Perfluoropentanesulfonic acid (PFPeS) | L402 | --- | 2.0 | **24** | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |
| 376-06-7 | Perfluorotetradecanoic acid (PFTeDA) | L402 | --- | 2.0 | < 2.0 | ng/L | 05/30/19 08:30 | 05/31/19 04:50 | 4303157 |

# EC Case Study #3 Landfill Leachate Treatment



**Electro-coagulated Landfill Leachate flowing into DAF**

# EC Case Study #3 Landfill Leachate Treatment

**2nd Round Treatment/Tests - PFCs - Cresol - TSS - TDS - BOD - blended leachate water**

Enthalpy Analytical Job No. 1220-751-1

| Discharge Limits | 2,300 ng/l | | | 60 ng/l | | | Origins Lab O 1.92; P 0.698 daily max O 0.561; P 0.205 month aver | | Origins Lab 6.65 daily max 4.45 monthly avera | | 7,500 | | | | 7,500 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *PFOA-ng/L | % Removal | *PFOA Solids ng/l | *PFOS-ng/L | % Removal | *PFOS Solids ng/l | *M & P Cresol mg/l | % Removal | Zn mg/l | % Removal | **TSS mg/l | % Removal | ***TDS mg/l | % Removal | **BOD mg/l | % Removal |
| #1 | 1,540 | | | 421 | | | 1.82 | | 0.063 | | 49 | | 20,000 | | 2,900 | |
| #2 | 661 | 57.08 | 27,500 | 53.9 | 87.20 | 10,600 | 0.199 | 89.07 | 0.099 | -57.14 | 150 | -206.1 | 19,000 | 5.0 | 2,700 | 6.9 |
| #3 | 193 | 70.80 | 31,900 | 11.1 | 97.36 | 8,230 | 0.226 | 87.58 | 0.036 | 42.86 | 12 | 75.5 | 19,000 | 5.0 | 2,700 | 6.9 |
| #4 | 818 | 46.88 | 16,500 | 158 | 62.47 | 4,380 | 0.208 | 88.57 | 0.038 | 39.68 | 13 | 73.5 | 18,000 | 10.0 | 2,300 | 20.7 |
| #5 | 640 | 58.44 | 22,900 | 38.2 | 90.93 | 6,980 | 0.164 | 90.99 | ND | 100.00 | 11 | 77.6 | 19,000 | 5.0 | 2,500 | 13.8 |
| #6 | 284 | 81.56 | 12,600 | 11.6 | 97.24 | 3,390 | 0.542 | 70.22 | 0.033 | 47.62 | 6 | 87.8 | 19,000 | 5.0 | 2,500 | 13.8 |
| #7 | 47.2 | 96.94 | 11,900 | 2.36 | 99.44 | 2,210 | 2 | -9.89 | ND | 100.00 | 15 | 69.4 | 19,000 | 5.0 | 3,100 | -6.9 |
| #8 | 3.97 | 99.74 | 70 | 2.36 | 99.44 | 20 | ND | 100.00 | 0.111 | -76.19 | 4 | 91.8 | 17,000 | 15.0 | 2 | 99.9 |
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# EC Case Study #3 Landfill Leachate Treatment

**2nd Round Treatment/Tests - PFCs - Cresol - TSS - TDS - BOD - blended leachate water**

Enthalpy Analytical Job No. 1220-751-1

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Discharge Limits** | | | 2,300 ng/l | | | 60 ng/l | | | Origins Lab O 1.92; P 0.698 daily max O 0.561; P 0.205 month aver | | Origins Lab 6.65 daily max 4.45 monthly avera | | 7,500 | | 7,500 | |
| | *PFOA-ng/L | % Removal | *PFOA Solids ng/l | *PFOS-ng/L | % Removal | *PFOS Solids ng/l | *M & P Cresol mg/l | % Removal | Zn mg/l | % Removal | **TSS mg/l | % Removal | ***TDS mg/l | % Removal | **BOD mg/l | % Removal |
| **#1** | 1,540 | | | 421 | | | 1.82 | | 0.063 | | 49 | | 20,000 | | 2,900 | |
| **#2** | 661 | 57.08 | 27,500 | 53.9 | 87.20 | 10,600 | 0.199 | 89.07 | 0.099 | -57.14 | 150 | -206.1 | 19,000 | 5.0 | 2,700 | 6.9 |
| **#3** | 193 | 70.80 | 31,900 | 11.1 | 97.36 | 8,230 | 0.226 | 87.58 | 0.036 | 42.86 | 12 | 75.5 | 19,000 | 5.0 | 2,700 | 6.9 |
| **#4** | 818 | 46.88 | 16,500 | 158 | 62.47 | 4,380 | 0.208 | 88.57 | 0.038 | 39.68 | 13 | 73.5 | 18,000 | 10.0 | 2,300 | 20.7 |
| **#5** | 640 | 58.44 | 22,900 | 38.2 | 90.93 | 6,980 | 0.164 | 90.99 | ND | 100.00 | 11 | 77.6 | 19,000 | 5.0 | 2,500 | 13.8 |
| **#6** | 284 | 81.56 | 12,600 | 11.6 | 97.24 | 3,390 | 0.542 | 70.22 | 0.033 | 47.62 | 6 | 87.8 | 19,000 | 5.0 | 2,500 | 13.8 |
| **#7** | 47.2 | 96.94 | 11,900 | 2.36 | 99.44 | 2,210 | 2 | -9.89 | ND | 100.00 | 15 | 69.4 | 19,000 | 5.0 | 3,100 | -6.9 |
| **#8** | 3.97 | 99.74 | 70 | 2.36 | 99.44 | 20 | ND | 100.00 | 0.111 | -76.19 | 4 | 91.8 | 17,000 | 15.0 | 2 | 99.9 |
| | | | | | | | | | | | | | | | | |

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**2nd Round Treatment/Tests - PFCs - Cresol - TSS - TDS - BOD - blended leachate water**

Enthalpy Analytical Job No. 1220-751-1

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Discharge Limits** | 2,300 ng/l | | | 60 ng/l | | | Origins Lab<br>O 1.92; P 0.698 daily max<br>O 0.561; P 0.205 month aver | | Origins Lab<br>6.65 daily max<br>4.45 monthly avera | | 7,500 | | | | 7,500 | |
| | *PFOA-ng/L | % Removal | *PFOA Solids ng/l | *PFOS-ng/L | % Removal | *PFOS Solids ng/l | *M & P Cresol mg/l | % Removal | Zn mg/l | % Removal | **TSS mg/l | % Removal | ***TDS mg/l | % Removal | **BOD mg/l | % Removal |
| **#1** | 1,540 | | | 421 | | | 1.82 | | 0.063 | | 49 | | 20,000 | | 2,900 | |
| **#2** | 661 | 57.08 | 27,500 | 53.9 | 87.20 | 10,600 | 0.199 | 89.07 | 0.099 | -57.14 | 150 | -206.1 | 19,000 | 5.0 | 2,700 | 6.9 |
| **#3** | 193 | 70.80 | 31,900 | 11.1 | 97.36 | 8,230 | 0.226 | 87.58 | 0.036 | 42.86 | 12 | 75.5 | 19,000 | 5.0 | 2,700 | 6.9 |
| **#4** | 818 | 46.88 | 16,500 | 158 | 62.47 | 4,380 | 0.208 | 88.57 | 0.038 | 39.68 | 13 | 73.5 | 18,000 | 10.0 | 2,300 | 20.7 |
| **#5** | 640 | 58.44 | 22,900 | 38.2 | 90.93 | 6,980 | 0.164 | 90.99 | ND | 100.00 | 11 | 77.6 | 19,000 | 5.0 | 2,500 | 13.8 |
| **#6** | 284 | 81.56 | 12,600 | 11.6 | 97.24 | 3,390 | 0.542 | 70.22 | 0.033 | 47.62 | 6 | 87.8 | 19,000 | 5.0 | 2,500 | 13.8 |
| **#7** | 47.2 | 96.94 | 11,900 | 2.36 | 99.44 | 2,210 | 2 | -9.89 | ND | 100.00 | 15 | 69.4 | 19,000 | 5.0 | 3,100 | -6.9 |
| **#8** | 3.97 | 99.74 | 70 | 2.36 | 99.44 | 20 | ND | 100.00 | 0.111 | -76.19 | 4 | 91.8 | 17,000 | 15.0 | 2 | 99.9 |
| | | | | | | | | | | | | | | | | |

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# EC Case Study #3 Landfill Leachate Treatment

**2nd Round Treatment/Tests - PFCs - Cresol - TSS - TDS - BOD - blended leachate water**

Enthalpy Analytical Job No. 1220-751-1

Origins Lab O 1.92; P 0.698 daily max

Origins Lab 6.65 daily max

| Discharge Limits | 2,300 ng/l | | | 60 ng/l | | | O 0.561; P 0.205 month aver | | 4.45 monthly avera | | 7,500 | | | | 7,500 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *PFOA-ng/L | % Removal | *PFOA Solids ng/l | *PFOS-ng/L | % Removal | *PFOS Solids ng/l | *M & P Cresol mg/l | % Removal | **Zn mg/l** | **% Removal** | **TSS mg/l | % Removal | ***TDS mg/l | % Removal | **BOD mg/l | % Removal |
| **#1** | 1,540 | | | 421 | | | 1.82 | | 0.063 | | 49 | | 20,000 | | 2,900 | |
| **#2** | 661 | 57.08 | 27,500 | 53.9 | 87.20 | 10,600 | 0.199 | 89.07 | 0.099 | -57.14 | 150 | -206.1 | 19,000 | 5.0 | 2,700 | 6.9 |
| **#3** | 193 | 70.80 | 31,900 | 11.1 | 97.36 | 8,230 | 0.226 | 87.58 | 0.036 | 42.86 | 12 | 75.5 | 19,000 | 5.0 | 2,700 | 6.9 |
| **#4** | 818 | 46.88 | 16,500 | 158 | 62.47 | 4,380 | 0.208 | 88.57 | 0.038 | 39.68 | 13 | 73.5 | 18,000 | 10.0 | 2,300 | 20.7 |
| **#5** | 640 | 58.44 | 22,900 | 38.2 | 90.93 | 6,980 | 0.164 | 90.99 | ND | 100.00 | 11 | 77.6 | 19,000 | 5.0 | 2,500 | 13.8 |
| **#6** | 284 | 81.56 | 12,600 | 11.6 | 97.24 | 3,390 | 0.542 | 70.22 | 0.033 | 47.62 | 6 | 87.8 | 19,000 | 5.0 | 2,500 | 13.8 |
| **#7** | 47.2 | 96.94 | 11,900 | 2.36 | 99.44 | 2,210 | 2 | -9.89 | ND | 100.00 | 15 | 69.4 | 19,000 | 5.0 | 3,100 | -6.9 |
| **#8** | 3.97 | 99.74 | 70 | 2.36 | 99.44 | 20 | ND | 100.00 | 0.111 | -76.19 | 4 | 91.8 | 17,000 | 15.0 | 2 | 99.9 |
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**2nd Round Treatment/Tests - PFCs - Cresol - TSS - TDS - BOD - blended leachate water**

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Discharge Limits** | Enthalpy Analytical Job No. 1220-751-1 | | | | | | Origins Lab O 1.92; P 0.698 daily max O 0.561; P 0.205 month aver | | Origins Lab 6.65 daily max 4.45 monthly avera | | 7,500 | | | | 7,500 | |
| | 2,300 ng/l | | | 60 ng/l | | | | | | | | | | | | |
| | *PFOA-ng/L | % Removal | *PFOA Solids ng/l | *PFOS-ng/L | % Removal | *PFOS Solids ng/l | ***M & P Cresol mg/l** | **% Removal** | Zn mg/l | % Removal | **TSS mg/l | % Removal | ***TDS mg/l | % Removal | **BOD mg/l | % Removal |
| **#1** | 1,540 | | | 421 | | | 1.82 | | 0.063 | | 49 | | 20,000 | | 2,900 | |
| **#2** | 661 | 57.08 | 27,500 | 53.9 | 87.20 | 10,600 | 0.199 | 89.07 | 0.099 | -57.14 | 150 | -206.1 | 19,000 | 5.0 | 2,700 | 6.9 |
| **#3** | 193 | 70.80 | 31,900 | 11.1 | 97.36 | 8,230 | 0.226 | 87.58 | 0.036 | 42.86 | 12 | 75.5 | 19,000 | 5.0 | 2,700 | 6.9 |
| **#4** | 818 | 46.88 | 16,500 | 158 | 62.47 | 4,380 | 0.208 | 88.57 | 0.038 | 39.68 | 13 | 73.5 | 18,000 | 10.0 | 2,300 | 20.7 |
| **#5** | 640 | 58.44 | 22,900 | 38.2 | 90.93 | 6,980 | 0.164 | 90.99 | ND | 100.00 | 11 | 77.6 | 19,000 | 5.0 | 2,500 | 13.8 |
| **#6** | 284 | 81.56 | 12,600 | 11.6 | 97.24 | 3,390 | 0.542 | 70.22 | 0.033 | 47.62 | 6 | 87.8 | 19,000 | 5.0 | 2,500 | 13.8 |
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| **#8** | 3.97 | 99.74 | 70 | 2.36 | 99.44 | 20 | ND | 100.00 | 0.111 | -76.19 | 4 | 91.8 | 17,000 | 15.0 | 2 | 99.9 |
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GARVER

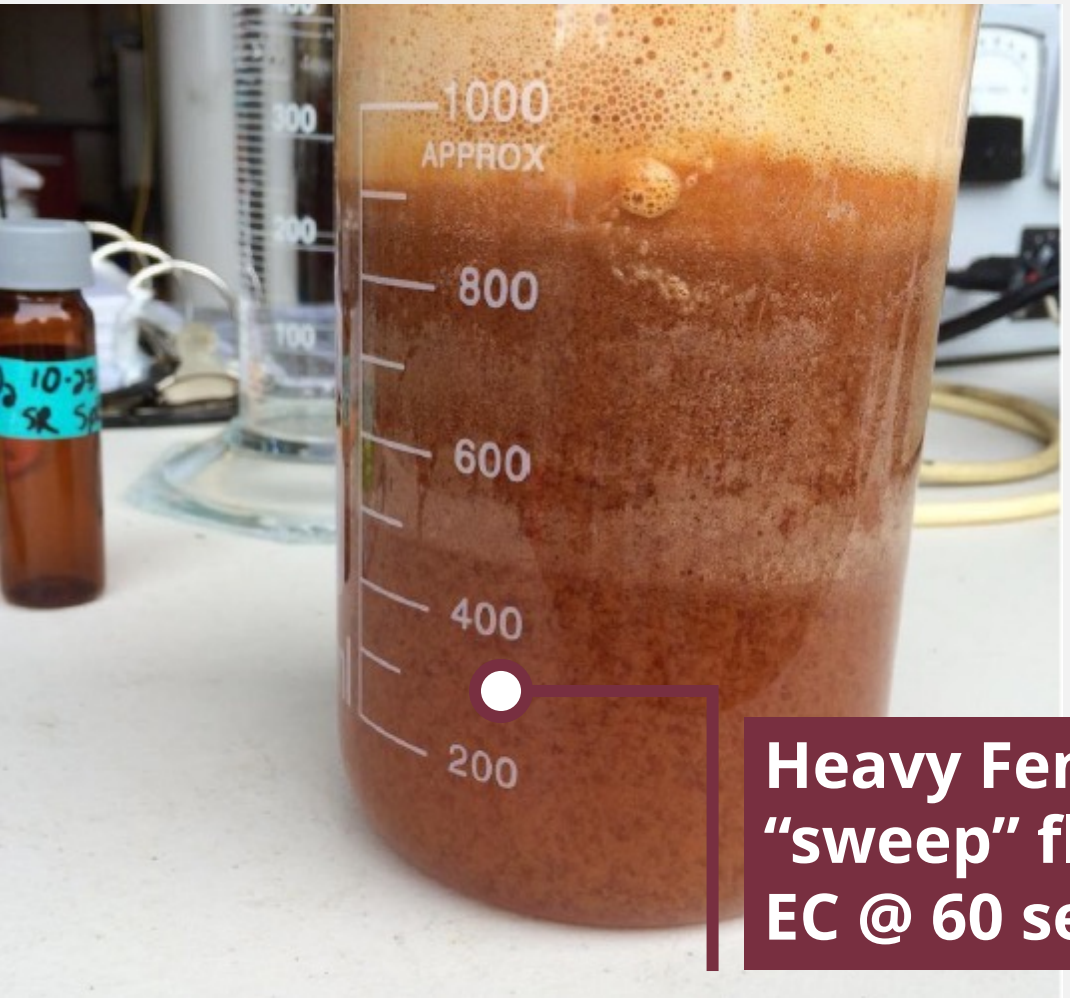
# Questions?

**ERIC DOLE, PE, PSAP**
EJDole@GarverUSA.com

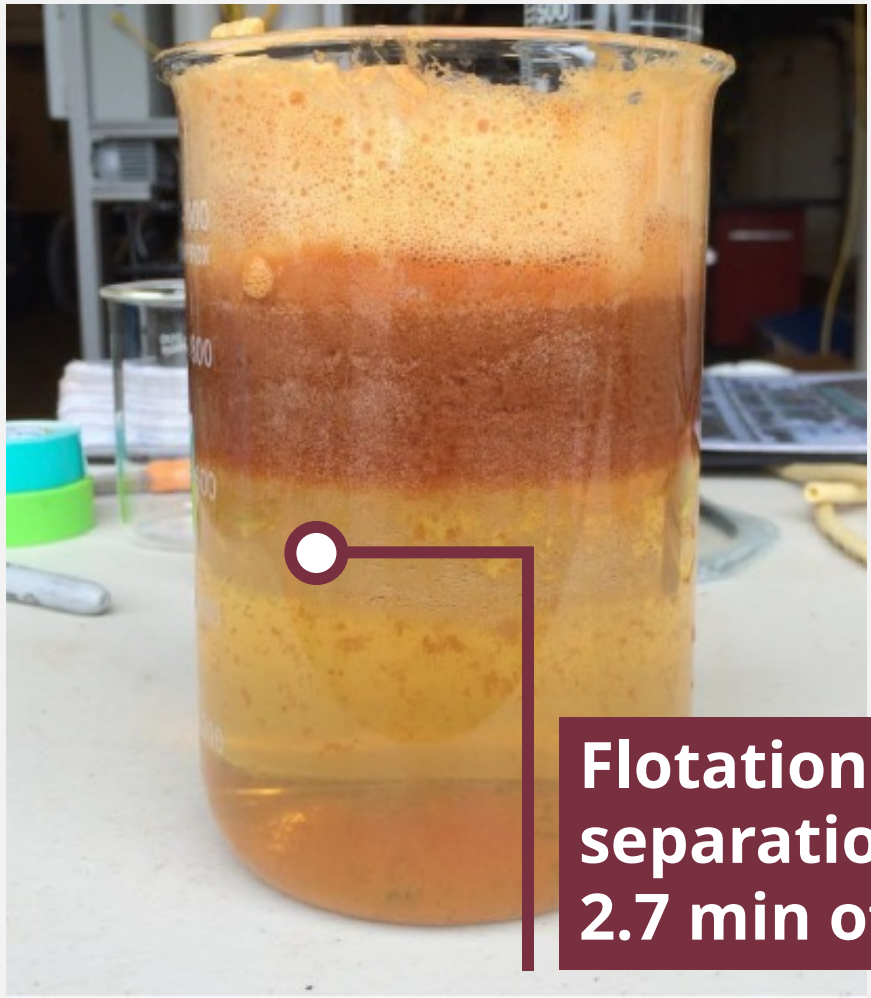
# EC Case Study #1 MBR Effluent Spiked w/ PFC + EDC

**EC + H2O2 + Fe3+ from anode drove Fenton Rxn as seen from foaming, heat and orange/red vs teal floc**

# EC Case Study #1 MBR Effluent Spiked w/ PFC + EDC




Heavy Fenton "sweep" floc w/ EC @ 60 sec HRT



Flotation separation after 2.7 min of settling

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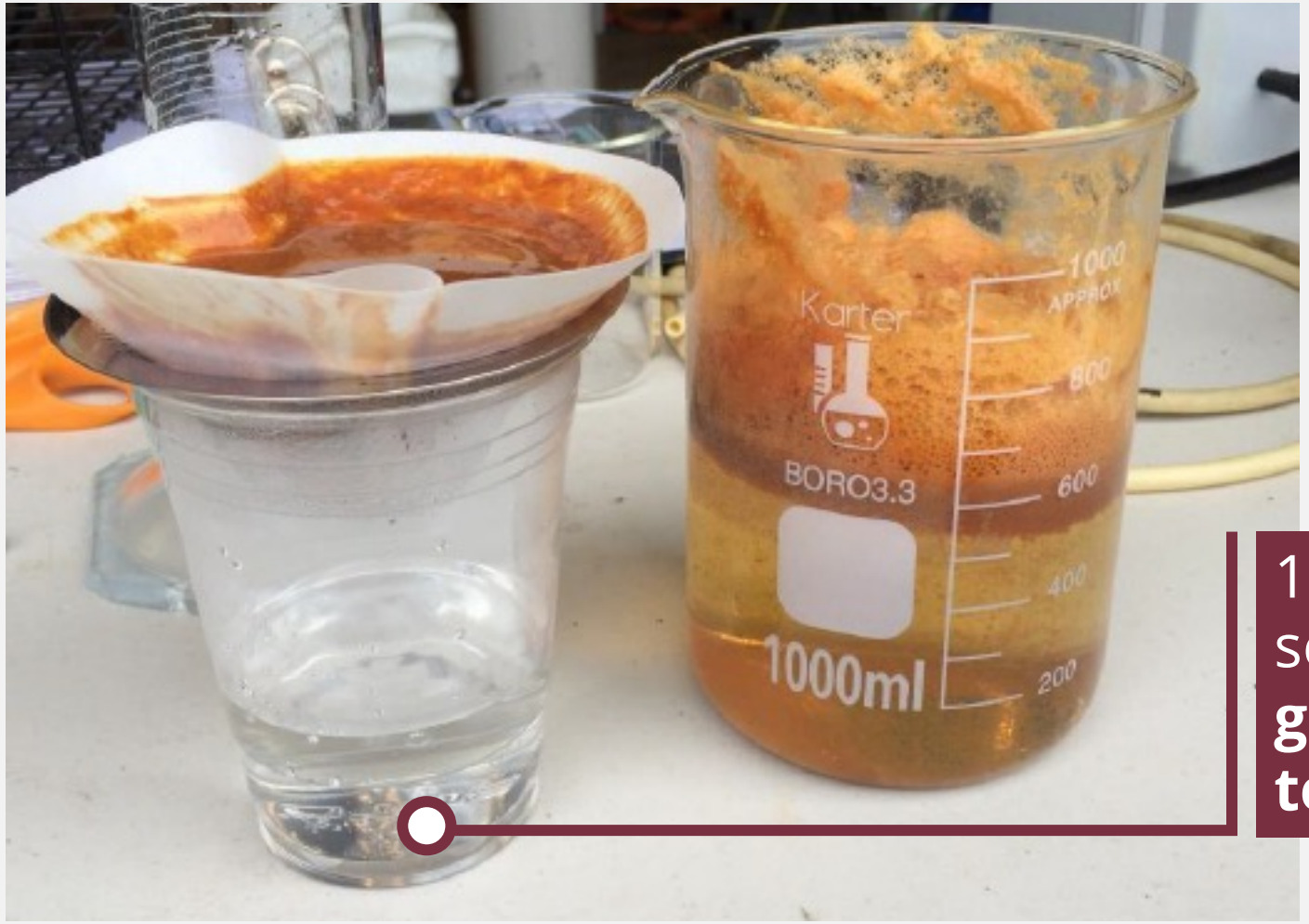


11 um filtrate after total of 5 min settle time. **CSM now has post grad course studying EC due to test results.**