



Helena Hinrichsen
Envytech Solutions AB
Chief Commercial Officer PFAS Europe

Envytech Solutions AB
Mölnadalsvägen 22 | 412 63 Göteborg | envytech.se

Talk Outline

- Short overview of the SAFF technology
- Presentation of treatment results using a Full scale SAFF40 treatment system for surface water runoff at a military airport
- Developments regarding the efficiency of Foam Fractionation and SAFF for short chain removal



*Active SAFF plant treating groundwater,
Korsør Brandskole, RESC, Denmark*



SAFF – Surface Active Foam Fractionation



Exclusive Distributor Scandinavia / Europe and UK



Exclusive Distributor North America



Exclusive Distributor Scandinavia



Also called "FlouroFloc" in Denmark

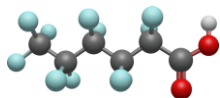


Exclusive Distributor Scandinavia, Distributor Europe

SAFF[®]

Surface Active Foam Fractionation

- A concentration treatment



Perfluorinated substances has
Hydrophilic head → Head loves water
Hydrophobic tail → Tail hates water

The bubble becomes the perfect tail sticks in/on the bubble easy to remove as a foam

Works very effective for longer chain PFAS and with varying effect on short chain PFAS

SAFF works in 3 steps:

First step – Treatment step: 10 x concentration

Second step – Waste minimization: 1500 x conc.

Third step – Waste concentration: up to 3.5 million x conc.



Patent Pending Solution

- Exclusive to SAFF[®]



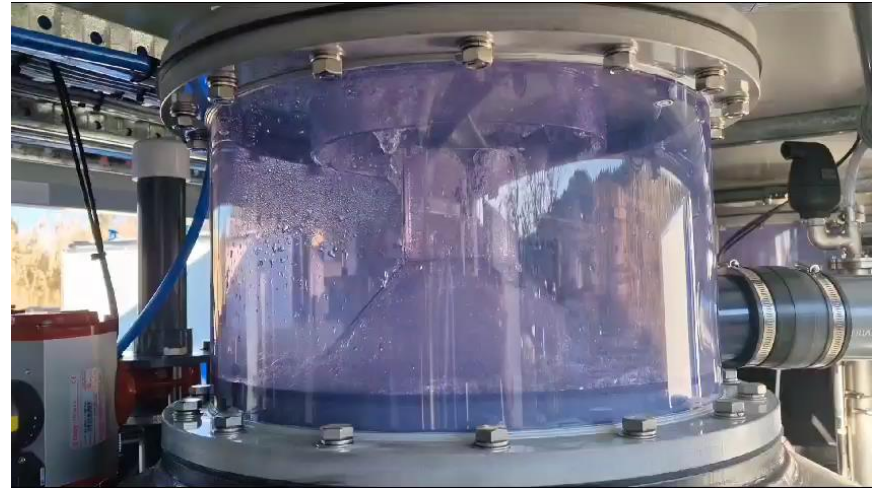
Concentration

SAFF – Surface Active Foam Fractionation – IRL

Primary Fractionation of raw leachate



Primary Fractionation of raw groundwater



Up to 10 x initial concentration

Concentration

SAFF – Surface Active Foam Fractionation – Lets check it out

Secondary Fractionation



Up to 1500 x initial concentration

Tertiary Fractionation



Up to 3,5 Million x initial concentration

When and Why SAFF

SAFF is a very robust treatment option. PFAS removal efficiency is:

- ✓ NOT sensitive to PFAS levels (High/Low)
- ✓ NOT sensitive to pH
- ✓ NOT sensitive to Suspended particles
DOM, DOC, Salinity
- ✓ Not sensitive to cross contaminants,
(organics, metals, salts)

Further more

SAFF needs no pre treatment steps
(bagfilter 200 um)

Capable of removing PFAS4 and PFAS6 up to 99,9%
using no consumables or additives

Produces minimal waste amounts

Uses only electricity, 0,7 kwh/m3 treated

Proven technology with over 500 000 m3 treated



Mobile treatment, winter isolated

“Plug and play” installation procedure

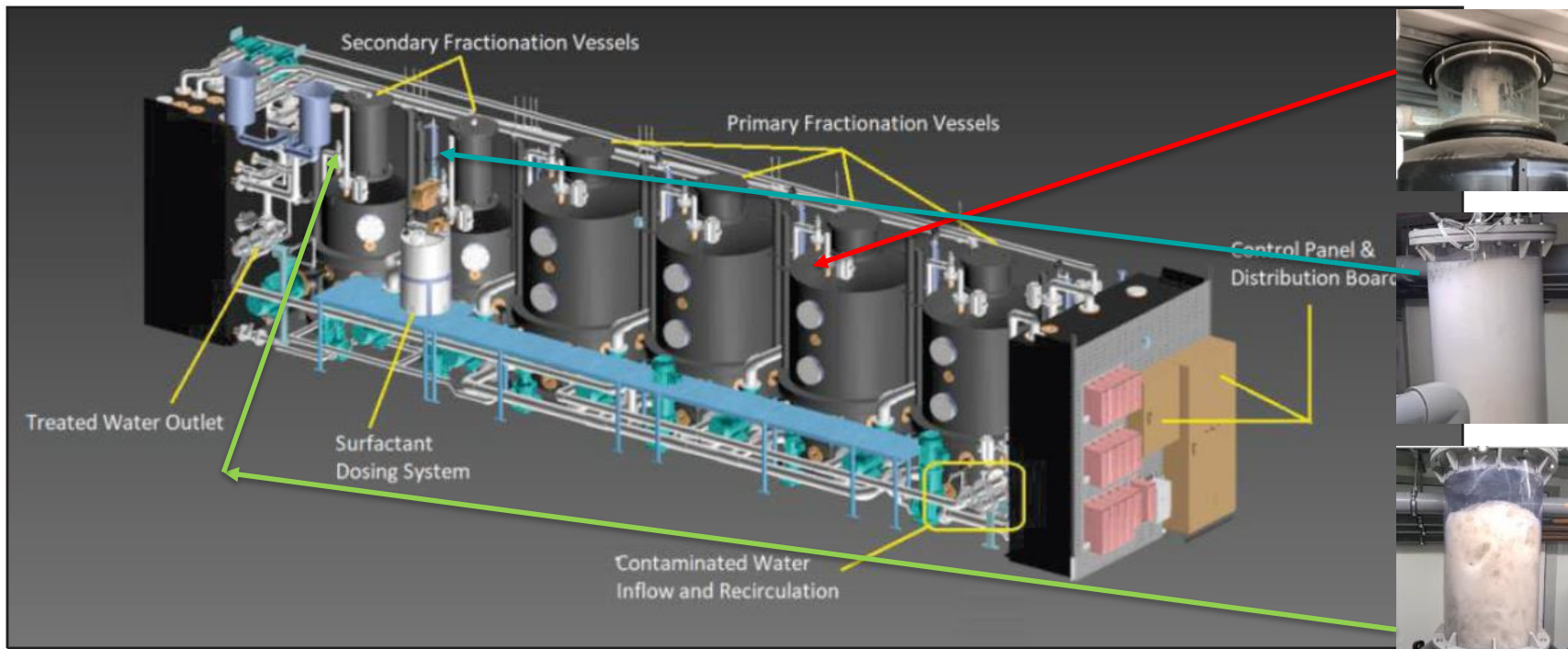
Tuning after start up – needed because all waters are different, approx. 2 days

Remote surveillance, fine tuning, 24h / 7 day controlled
You can follow flow, status, electricity used, total volume and more via the app!

Every pump, valve and sensor, reports data continuously. We can see exactly when, what and where a problem has occurred and can usually fix it remotely straight away



EPOC Envytech SAFF40 containerised System



Treatment control

SAFF is remotely surveilanced by producers EPOC Enviro 24/7

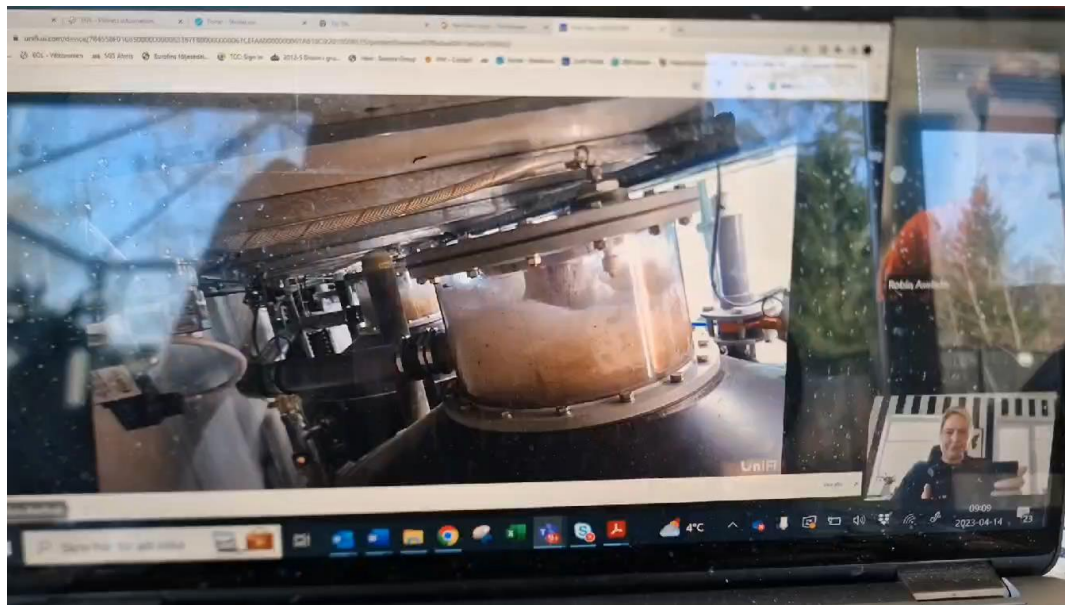
Envytech staff can watch process, change settings for fine tuning of foam control. Remotely

We train local staff at comissioning, so minimum cost will be spent on external service crew

Can "live" guide local staff for service, sampling or questions on the performance or all else.



Video from full scale soilwashing plant in Belgium, treating soil wash process water for >11 months



The system is completely automatic and have work health and safety measures for minimizing possible contact with PFAS aerosols

Expected Removal Rates

Comparison of results of PFAS removal rates for Groundwater/
Leachate / Fire Fighting water / Surface water runoff at airport

| Substance | OPEC GW Australia 150 000 m ³ | NSR Leachate 30 000 m ³ | Telge Leachate 250 000 m ³ | Löt Leachate 15 000 m ³ | Mjölbo Leachate 9000 m ³ | Swedish Airport 40 m ³ | Fire Fighting water Refinery 12 000 m ³ | EU LIFE SouRCe Groundwater | EU LIFE SouRCe Groundwater |
|------------------|---|---------------------------------------|--|---------------------------------------|--|--------------------------------------|--|-------------------------------|-------------------------------|
| PFDA | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 96% | Up to 99,9% |
| PFNA | 100% | 100% | 100% | 100% | 100% | 100% | 100% | Up to 99,9% | Up to 99,9% |
| 6:2 FTS | 100% | 100% | 100% | 100% | 100% | 100% | 99,5% | Up to 99,9% | Up to 99,9% |
| PFOA | 100% | 100% | 100% | 100% | 99% | 98% | 99% | ND | Up to 99,9% |
| PFOS | 100% | 99% | 98% | 100% | 100% | 100% | 100% | 84% | 98% |
| PFHXS | 97% | 100% | 100% | 99% | 99% | 79% | 99,5% | 51% | 99% |
| PFHPA | 67% | 99% | 98% | 90% | 92% | 99% | 95% | 93% | Up to 99,9% |
| PFHXA | 20% | 54% | 29% | 35% | 10% | 0% | 35% | 42% | 99% |
| PFPeA | 24% | 0% | 3% | 38% | 7% | 0% | 0% | 4% | 98% |
| PFBA | 21% | 8% | 1% | 0% | 0% | 0% | 0% | 76% | 99% |
| PFBS | 22% | 43% | 10% | 19% | 8% | 0% | 52% | ND | Up to 99,9% |
| Total PFAS conc. | 4000 ng/l | 6000 ng/l | 4000 ng/l | 15 000 ng/l | 4000 ng/l | 4000 ng/l | 100 000 ng/l | 100 000 ng/l | 2 000 000 ng/l |

But what about the short chains? Can we catch them too?

- Research about additives to enhance Foam Fractionation is carried out by many
- Several white papers produced and on the way
- Allonnia - US Biotech company, have come far, and have already several patents pending for additives that show enhanced removal efficiency's
- Envytech is proud partner to Allonnia, and our open door in to one of the worlds most modern and knowledgeable PFAS research centers

- At this point in time we work with 4 different additives for different waters.
 - Non toxic. All natural booster used for drinkingwater / groundwater
 - 3 additives made up of different surfactants.

ALL additives are removed in the SAFF process. Analyzing can, and is being done on treated water for documentation. This as they are surfactants, and made to create a foam.

For more information on the Booster products and process: www.allonnia.com



Case Study:

Treatment of PFAS Contaminated Surface Runoff Water at An Active Military Airport, Sweden



Site Description


- Active Military Airport
- Active fire fighting training
- Located in a rural area
- Surrounded by active farmland, actively applying nutrition
- Start December 2023
- Treatment by SAFF40 unit - ONLY
 - Flow rate capacity for specific water to be evaluated
 - Treatment efficiency to be evaluated
 - Possibility of short chain removal using additives to be evaluated
 - Amount of waste to be evaluated
 - Destruction on site option to be evaluated
 - Evaluation of cost of OPEX



Water characteristics

- Surface water runoff from active airport
- Target Criteria set by the Swedish Government:
 - Unit to prove ability of 95% PFAS11
 - Target values for site to be evaluated
- Total PFAS28 conc. 200 – 600 ng/l
 - PFAS4 ca 76%
 - PFAS 6 ca 79%
 - Other PFAS ca 21%

Inlet concentrations

|  | | Untreated Concentrations | Untreated Concentrations | Untreated Concentrations |
|--|------|--------------------------|--------------------------|--------------------------|
| Site | | | | |
| Date | | 2023-11-06 | 2023-12-12 | 2024-01-04 |
| Compund | Unit | | | |
| PFDA (Perfluordekansyra) | ng/l | <0,30 | <0,30 | <0,30 |
| 8:2 FTS (Fluortelomer sulfonat) | ng/l | 0,41 | <0,30 | <0,30 |
| 4:2 FTS (Fluortelomer sulfonat) | ng/l | <0,30 | <0,30 | <0,30 |
| PFNA (Perfluoronansyra) | ng/l | 0,52 | 0,46 | 0,43 |
| 6:2 FTS (Fluortelomer sulfonat) | ng/l | 6,7 | 4,8 | 1,4 |
| PFOA (Perfluoroktansyra) | ng/l | 16 | 35 | 18 |
| PFOS (Perfluoroktansulfonsyra) | ng/l | 160 | 210 | 130 |
| PFOSA (Perfluoroktansulfonamid) | ng/l | 0,5 | 2,1 | <0,30 |
| PFHpS (Perfluorheptansulfonsyra) | ng/l | 2,9 | 4,2 | 3 |
| PFHxS (Perfluorhexansulfonsyra) | ng/l | 100 | 180 | 150 |
| PFHpA (Perfluorheptansyra) | ng/l | 7,3 | 8,6 | 6,5 |
| PFHxA (Perfluorhexansyra) | ng/l | 18 | 25 | 16 |
| PFPeA (Perfluorpentansyra) | ng/l | 21 | 19 | 14 |
| PFBA (Perfluorbutansyra) | ng/l | 6,1 | 6,4 | 5 |
| PFBS (Perfluorbutansulfonsyra) | ng/l | 5,8 | 13 | 8 |
| Summa PFAS 4 | ng/l | 280 | 430 | 300 |
| Summa PFAS | ng/l | 360 | 530 | 350 |


Water characteristics

Other compound composition measured in the period December 2023 – February 2024

- TOC 8-16 mg/l
- DOC 8 – 16 mg/l
- Nitrogen 4000 – 6000 ug/l

Expected Possibilities and challenges from looking at the water data:

- Fairly low PFAS levels can be challenging as remediation is a contact sport
- Treatment time and energy levels will be important
- Low foaming water due to lower PFAS levels (PFHxS and 6:2 FTS)

|  | Enhet | Untreated water |
|---|-------|-----------------|
| Ammoniumkväve (NH4-N) | mg/l | 0.088 - 0,15 |
| DOC | mg/l | 7,8 - 16 |
| Kalcium Ca | mg/l | 13 - 19 |
| Magnesium Mg | mg/l | 3 - 4.0 |
| pH | | 7.1- 7,9 |
| Suspenderade ämnen | mg/l | 3 - 20 |
| TOC | mg/l | 8 - 16 |
| Total-kväve | µg/l | 4000 - 6000 |



Water characteristics – In Reality

- Tuning needed to be precise and move in patterns that we have developed for low contaminated waters
- High foamy water, generating large amounts of foam
 - Process amended by adding our developed foam handling treatment
 - System for external foam suppression
 - Collapsed foam are returned to SAFF
 - Volumes decreased by concentration in step 2 and 3



Treatment Results

- Removal rates as expected for non complex water with lower PFAS concentration
 - Non complex matrix and low PFAS concentrations gives “contact issue”
- ➔ Lower lower removal efficiencies then for complex high PFAS conc.
- PFAS4 91%
 - PFAS6 75%

Conclusion:

During winter periods, where organics and other natural surfactant levels are low, treatment target of 95% PFAS11 will be hard to meet.

Levels in treated water exceeds expected Swedish PFAS 4 and PFAS 11 drinking water guidelines

PFAS 4: 4 ng/l, PFAS11: 100 ng/l

| Date | envytech <small>Miljö & teknik</small> | | 2023-12-12 | 2023-12-12 | Removal Efficiency |
|----------------------------------|--|--|------------|------------|--------------------|
| Compound | Unit | | | | |
| PFDA (Perfluordekansyra) | ng/l | | <0,30 | <0,30 | ND |
| 8:2 FTS (Fluortelomer sulfonat) | ng/l | | <0,30 | <0,30 | ND |
| 4:2 FTS (Fluortelomer sulfonat) | ng/l | | <0,30 | <0,30 | ND |
| PFNA (Perfluornonansyra) | ng/l | | 0,46 | <0,30 | ND |
| 6:2 FTS (Fluortelomer sulfonat) | ng/l | | 4,8 | <0,30 | Up to 100% |
| PFOSA (Perfluoroktansulfonamid) | ng/l | | 2,1 | <0,30 | Up to 100% |
| PFHpS (Perfluorheptansulfonsyra) | ng/l | | 4,2 | <0,30 | Up to 100% |
| PFOS (Perfluoroktansulfonsyra) | ng/l | | 210 | 4,3 | 97,95% |
| PFOA (Perfluoroktansyra) | ng/l | | 35 | 1,6 | 95,43% |
| PFHxS (Perfluorhexansulfonsyra) | ng/l | | 180 | 33 | 81,67% |
| PFHpA (Perfluorheptansyra) | ng/l | | 8,6 | 5,6 | 34,88% |
| PFHxA (Perfluorhexansyra) | ng/l | | 25 | 25 | 0,00% |
| PFPeA (Perfluorpentansyra) | ng/l | | 19 | 19 | 0,00% |
| PFBA (Perfluorbutansyra) | ng/l | | 6,4 | 6,9 | 0,00% |
| PFBS (Perfluorbutansulfonsyra) | ng/l | | 13 | 13 | 0,00% |
| Summa PFAS 4 | ng/l | | 430 | 39 | 90,93% |
| Summa PFAS22 | ng/l | | 530 | 130 | 75,47% |

Waste production: 150 liters per 20 000 m3 treated - and decreasing !

... But can we increase reamoval efficiency using additives ?

Several trials are planned

- Plans were to have all 4 additives trialed at the time of this presentation...

But then reality / life happens

One trial performed so far using Allonnia booster no.1

Trial performed in our bench scale MiniSAFF unit, 60 L sample size

Mini SAFF Bench scale testing unit

Want to trial your water?

Just contact us and we will perform a bench scale trial



Mini SAFF trial for Military Aurfield Surface water Runoff

First trial: SAFF only



Mini SAFF trial for Military Aurfield Surface water Runoff

Second trial: Allonnia Booster no 1

:

Tests performed in US show great results for complex, co-contaminated waters such as leachate and waste water

Surfactant

Labeled as toxic for water organisms in high concentrations

Test performed in US confirms additive removal by process, very low to non detect levels in treated water.

Our results are pending...

Low dosing concentrations

Dose concentrations for treatment, a few mg/l



Upcoming trial is Allonnia Booster nr 2 - A non toxic fully natural additive. Trials planned in April 2024

Surface water runoff

– initial trials

First trial show:


- Important increase of removal rates for "long chained" PFAS PFOA, PFHxS
- Complete removal of short chain PFAS PFBS" PFAS PFBS
- Major increase in removal rates for PFHpA, PFHxA and PFPeA

Conclusion:

Great potential for SAFF with additive to reach Target 95% treatment of PFAS 11

Great potential for reaching PFAS4 and PFAS11 Drinking water guidelines

Removal efficiency of the lab scale miniSAFF has been proven to ca 90% of a full scale SAFF unit

|  <i>Miljö & teknik</i> | Removal rate using SAFF | Removal Rate Using Patent Pending Additive (Allonnia) |
|--|-------------------------|---|
| PFBA (Perfluorbutansyra) | 5,6% | 3,85% |
| PFPeA (Perfluorpentansyra) | 9,1% | 20,51% |
| PFHxA (Perfluorhexansyra) | 0,0% | 53,00% |
| PFBS (Perfluorbutansulfonsyra) | 0,0% | 94,51% |
| PFHpA (Perfluorheptansyra) | 26,0% | 96,74% |
| PFOA (Perfluoroktansyra) | 90,4% | Upp till 99,9% |
| PFOS (Perfluoroktansulfonsyra) | 96,2% | 99,25% |
| PFHxS (Perfluorhexansulfonsyra) | 99,81% | 99,81% |
| PFNA (Perfluornonansyra) | Upp till 99,9% | Upp till 99,9% |
| PFDA (Perfluordekansyra) | Upp till 99,9% | Upp till 99,9% |
| PFHpS (Perfluorheptansulfonsyra) | Upp till 99,9% | Upp till 99,9% |
| 6:2 FTS (Fluortelomer sulfonat) | Upp till 99,9% | Upp till 99,9% |
| 8:2 FTS (Fluortelomer sulfonat) | Upp till 99,9% | Upp till 99,9% |
| PFOSA (Perfluoroktansulfonamid) | Upp till 99,9% | Upp till 99,9% |
| PFDS (Perfluordekansulfonsyra) | ND | ND |
| 4:2 FTS (Fluortelomer sulfonat) | ND | ND |

Immediate Application Possible

SAFF Surface Active Foam Fractionation

- Ready for the future

All Full scale SAFF units are equipped with a Chemical dosing tank and pump system

Possibility to add of solvents / additives or other type of amendments to increase efficiency of the foam fractionation process

Injection is performed straight into the Foam Fractionation process, no extra treatment steps or treatment system needed.



Figure 20: Dosing tank and pump

Contact



Helena Hinrichsen (Passionista, PFASionista)

Founder, Chief Commercial Officer PFAS, Envytech Solutions AB

Talks about #pfas, #leachate, #horizon2020, and #watertreatment

PFAS Specialist

+46 (0)70 408 24 80

helena.hinrichsen@envytech.se

