Soil Washing
In combination with Foam Fractionation

PFAS in water

SURFACE ACTIVE FOAM FRACTIONATION (SAFF)

The SAFF process utilizes the physio-chemical properties of PFAS compounds to attach to fine air bubbles as a result of its hydrophobic and hydrophilic properties. When accurately controlled bubbles are introduced and allowed to rise in a narrow column of water, the bubbles become exceptionally effective in collecting PFAS compounds that are loosely bound to the water molecules. Once at the surface, PFAS can easily be removed by separation and concentration through a passive ”spill over weir” system, and an active vacuum system. Treated (aerated) water can then be released to the recipient. The collected PFAS concentrate is passed on to further fractionation steps to become a high concentration liquid of relatively small volume suitable for destruction via permanent destruction techniques such as high temperature thermal combustion, Super Critical Water Oxidation (SCWO) or Electrochemical Oxidation (EO).

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*
- *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 1 000 000 m³ treated*

USING ADDITIVES

It has been proven that the ability of PFAS molecules to be removed by foam fractionation is depending on the specific adsorption coefficient of each PFAS. Long chained PFAS has been shown to have greater surface activeness then shorter chain PFAS.

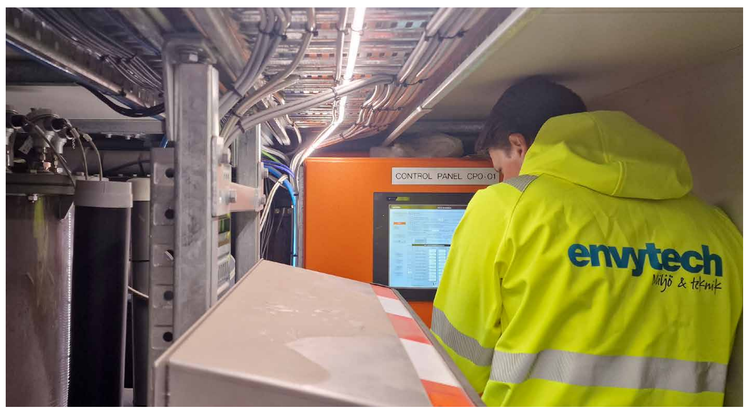
Allonnia US, a biotech company chosen by EPOC Enviro as sole SAFF distributors for US, have performed extensive research within the field of additives. Allonnia are at this moment evaluating +30 additives with the potential to enhance the SAFF removal process for short chain PFAS. Three additives have been proven to increase removal efficiency for several of these short chain PFAS so far, see *table 1*.

Table 1: Pink column presents removal efficiency for SAFF treatment unit without pre-treatment, filter medias or other consumables. Blue colums presents expected removal rates for SAFF with additives, researched and tested in full scale by Allonnia, added to the primary fractionation process.

Substance	Expected Removal % using full scale SAFF	Possible increase in removal efficiency % using new patended additive (Allonnia US)	Possible increase in removal efficiency % using CTAB (removed in the process)	Possible Removal % using full scale SAFF and patent pending additive
PFDA	>99,9%	Up to 99,9%	Up to 99,9%	Up to 99,9%
8:2 FTS	>99,9%	Up to 99,9%	Up to 99,9%	Up to 99,9%
4:2 FTS	>99,9%	Up to 99,9%	Up to 99,9%	Up to 99,9%
PFNA	>99,9%	Up to 99,9%	Up to 99,9%	Up to 99,9%
6:2 FTS	>99,9%	Up to 99,9%	Up to 99,9%	Up to 99,9%
PFOA	>99,9%	Up to 99,9%	Up to 99,9%	Up to 99,9%
PFOS	>99,9%	Up to 99,9%	Up to 99,9%	Up to 99,9%
PFOSA	>99,9%	Up to 99,9%	Up to 99,9%	Up to 99,9%
PFHpS	>99,9%	Up to 99,9%	Up to 99,9%	Up to 99,9%
PFHxS	>99,9%	Up to 99,9%	Up to 99,9%	Up to 99,9%
PFPeA	>99,9%	Up to 93%	>99,9%	Up to 99,9%
PFHpA	70-99,9%	Up to 95%	Up to 99,9%	Up to 99,9%
PFHxA	30-60%	Up to 90%	Up to 99%	80%
PFPeA	0-25%	No effect	Up to 89%	40%
PFBA	0-20%	No effect	Up to 40%	40%
PFBS	0-20%	Up to 80%	Up to 96%	Up to 80%

TREATMENT CONTROL

SAFF is remotely surveillanced by producers EPOC Enviro 24/7. The Envytech staff can also watch, process and change settings for fine tuning of foam control remotely. We can ”live” guide local staff for service, sampling or questions on the performance etc. The system is completely automatic and have work health and safety measures for minimizing possible contact with PFAS aerosols.



PFAS in soil

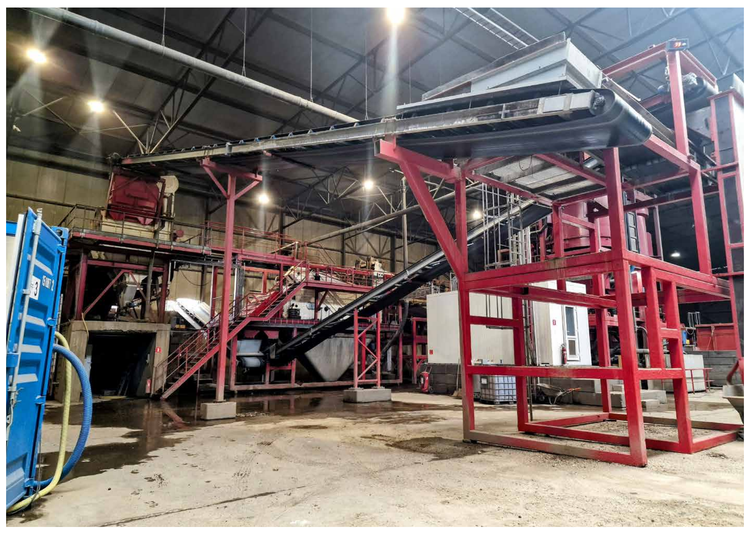
LEACHING

As water is passed through the soil, PFAS is desorbed from the particles, peeling of PFAS molecules. Lechability of PFAS from soil can be measured by performing column tests or a two step shake test. Due to the soluble nature of short chain PFAS, long chain PFAS (>C6) are prevalently found in soils. See results in *table 2* from a 2-step leachability test of weathered soil at an airport.

Table 2: Pink column show PFAS concentrations in soil collected from an airport site in Sweden. Blue columns present results achieved from performing a 2-step lechability test on this soil.

Substance	Silty sandy soil µg/kg Ts	TYP1 L/S=2 ng/l	TYP1 L/S=8 ng/l
6:2 FTS	3,9	1900	97
PFBA	0,11	57	<20
PFBS	<0,10	33	<10
PFDA	0,51	120	23
PFHpA	0,29	140	<10
PFHxA	0,48	240	12
PFHxS	2,4	930	42
PFNA	0,37	140	12
PFOA	2,2	910	42
PFOS	220	60 000	11 000
PFPeA	0,66	400	<20
PFOSA	13	2600	720

We then got the question, is SAFF a suitable option for treating PFAS contaminated soil washing process water? And the answer is YES!



Results

TREATMENT COMMISSIONED IN MARS 2023

To date, a total of 50 000 tons of PFAS contaminated soil has been treated full scale in Belgium. The first three soils are presented in *table 3* below.

Soil 1

Low PFAS contaminated soil, Sum PFAS28 concentrations of <10ug/kg. Soil wash process water concentrations, up to 500 ng/l.

Soil 2

Low PFAS contaminated soil, Sum PFAS28 concentrations of <25ug/kg. Soil wash process water concentrations, up to *3800* ng/l.

Soil 3

Low PFAS contaminated soil, Sum PFAS28 concentrations of <10ug/kg. Soil wash process water concentrations, up to 4000 ng/l.

Table 3: PFAS concentrations in process water from the soil wash plant before and after tratment with SAFF.

Substance	Unit	Soil 1		Soil 2		Soil 3	
		Untreated	Removal rate %	Untreated	Removal rate %	Untreated	Removal rate %
PFNA	ng/l	BDL	BDL	BDL	NA	BDL	NA
PFOA	ng/l	46	Up to 99%	49	Up to 99%	100	Up to 99%
PFOS	ng/l	BDL	NA	600	95%	670	95%
PFHxS	ng/l	BDL	NA	640	83%	120	83%
Sum PFAS 4	ng/l	**46**	**Up to 99%**	**1289**	**89%**	**890**	**98%**
PFDA	ng/l	BDL	BDL	BDL	NA	BDL	NA
PFHpA	ng/l	37	Up to 99%	93	39%	120	71%
Sum PFAS 6	ng/l	**83**	**Up to 99%**	**1382**	**86%**	**1010**	**98%**

WASTE DESTRUCTION - CREATING A CLOSED LOOP

In total, approx. 15 000 m³ of process water have been treated using a SAFF20, offering a 2-step fractionation process. A total of 10 000 liters of waste have been generated. The project is about to upgrade to a SAFF40 system, offering a 3-step fractionation process, and amounts of waste produced is expected to decrease to >500 liters/15 000 m³.

The waste from the 2-step fractionation has been sent for a destruction trial by Aclarity, a company performing destruction of PFAS contaminated waters, with a patented Electrochemical Oxidation system. The trial shows that one treatment cycle in the Aclarity EO unit is efficiently destroying more than 90% av the PFAS for PFAS4. Applying another treatment cycle would leave only low residual PFAS levels in the limited amount of waste, and this liquid can be fed into the start of the SAFF process, as the added PFAS will be caught in the treatment, creating a zero waste solution.

Table 4: Destruction efficiency of PFAS contaminated waters using one cycle in the Aclarity EO unit.

Substance	Removal % @132.75 W-hr/gal
PFHpA	40.89
PFOA	93.58
PFNA	>93.44
PFDA	>68.51
PFHxS	75.99
PFOS	97.33
PFHpS	>94.83
6:2 FTS	93.47
8:2 FTS	>88.22

Contact us!

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