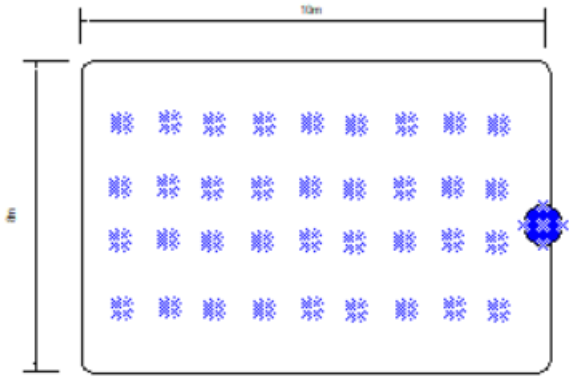
Testing phytoremediation at a fire drill site (hotspot)

Materials & Methods

During the summer of 2024, a research trial was conducted on a site heavily contaminated with Pfas (5000ng/g) as a result of fire extinguisher drills. This trial assessed the uptake of PFAS by Willow (variety Wilhem), which is one of the higher yielding varieties in Europe

Soil Type : Old lake bed which is very wet with standing water in winter/spring. The soil is peaty with high organic matter content.

Area: The willow area was 80m2 (10x8m) planted with 0.5m spacing

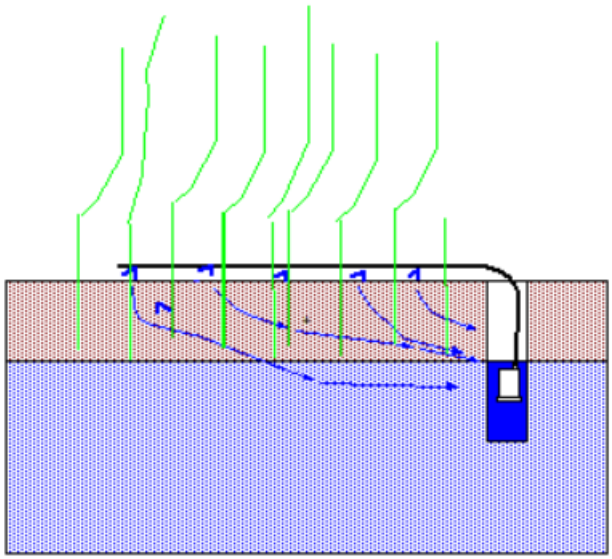


During the summer/autumn, the groundwater level is around 0.5-0.8m below the surface.

A pump sump (diameter of approx. 0.4m and a depth of 1.3m) was installed in one corner of the test site containing a submersible pump with a capacity of $3m^3/h$.

The pump can therefore empty the sump in in about 2-3 minutes as the inflow is much slower.

The pump is controlled by a timer enabling its operation for 15 minutes every two hours.



The sump is therefore emptied regularly with the water being spread on the ground surface around the Salix, creating a localised water recycling system

Water samples were collected from the sump at there different occasions (between June and September 2024) as well as from the standing water when present.

In September the willow was harvested and chemically analysed. The willow was also incinerated at (850'C) to simulate a waste combustion system, with the ash residuals analysed for Pfas.

Summary of this summer test

At this stage of the project the data is still relatively limited however some interesting trends are potentially visible indicating that pfas is being relocated from the soil and water, into the willow biomass.

Early estimates suggest a reduction total pfas of about 30% in the groundwater. Pfos concentrations fluctuate however the trend is still a reduction

The reduction in total PFAS is most likely a result of a number of processes which include stabilization within the soil/plant matrix,, absorption and uptake into the plant materials and a number other factors.

Below is the reduction in the groundwater we extract from the pit and spread onto the willow.

Table 1: Concentration of PFAS compounds between 14th June 2024 and 10th September 2024

Pump pit (Concentrations ng/l)				
	24 06 14	24 07 17	24 09 10	Start-End
PFBA	7 400	5 100	3 800	-49%
PFPeA	43 000	34 000	21 000	-51%
PFBS	2 500	1 700	1 500	-40%
PFHxA	23 000	21 000	12 000	-48%
PFPeS		2 500		
PFHpA	6 200	6 900	4 300	-31%
PFHxS	26 000	25 000	24 000	-8%
6-2 FTSA	20 000	21 000	16 000	-20%
PFOS	170 000	81 000	120 000	-29%
PFOA	8 200	8 700	8 100	-1%
Total	306 300	206 900	210 700	-31%

There are various factors which are likely to influence the uptake of Pfas. The biggest single factor is the concentration of Pfas in the water irrigated to the willow/plant system. The plant will uptake a specific volume of water depending on the evapotranspiration rate (heat, light, wind, plant age, leaf density and integrity etc). Research is starting to indicate that the molecular size of the PFAS molecule will determine its mobility within the rhizosphere and the plant system (reference). It is possible also that the PFAS molecular size may also determine its movement within the soil / water profile and more specifically within the rhizosphere We can't say for sure this is a determining factor from this work however it would be a legitimate avenue for further research with consequences of nature based filtration systems with even higher PFAS removal.

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Table 2 illustrates the higher PFAS concertation in soil/groundwater the higher uptake in the willow:

Table 2: PFAS concentrations within the plant material, the soil and the irrigated groundwater.

Uptake by Willow a mix of trunk branches, leaf's

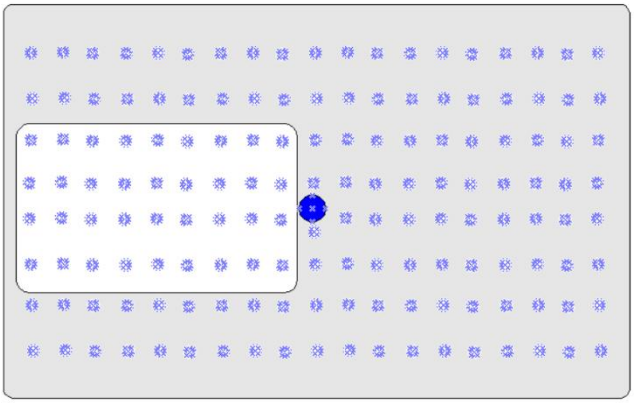
	Mix of stem branshes, leafs ng/g	In soil ng/g	In groundwater ng/l
PFBA	126	12	5 100
PFPeA	138	74	34 000
PFBS	6	11	1 700
PFHxA	18	71	21 000
PFPeS	9	--	2 500
PFHpA	2	22	6 900
PFHxS	89	300	25 000
6-2 FTSA	284	71	21 000
PFOS	163	5 000	81 000
PFOA	4	59	8 700
Tot	*838*	*5 620*	*206 900*

Potential uptake by willow

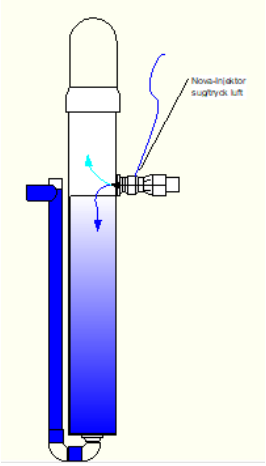
A concentration 838 ng/g of PFAS in willow biomass corresponds to a removal *10-20g/ha/year in the biomass.*

Further trial for 2025

As willow growth in 2024 was harvested to approx. 10cm above ground levels, these stools will regrow. As the root system will be even more developed the shoots will be bigger and stronger during the 2025 growing season. Furthermore, the trial site will be enlarged, resulting in the sump being central in the trial site protecting the trial from any external influences to a greater degree.



An extra addion to treatment trial in 2025 will be the introduction of a fume fractionation system to speed up PFAS treatment time as 70% of Pfas $_{11}$ and 90% of Pfas $_{4}$ could be easily separated from the recycled irrigation water prior to willow irrigation. A simple separator based on pluming pipes is proving to be an affordiable system, even for small sites. Trials have shown a reduction from 300 000ng/l to 13 000ng/l.



Test of FF reduction (pump pit) ng/l			
	Befor	After	Reduktion
PFBA	7 400	6 500	-12
PFPeA	43 000	36 000	-16
PFBS	2 500	2 100	-16
PFHxA	23 000	18 000	-22
PFHpA	6 200	1 100	-82
PFHxS	26 000	2 000	-92
6-2 FTSA	20 000	1 300	-94
PFOS	170 000	13 000	-92
PFOA	8 200	590	-93
Total	306 300	80 590	-74

Some pictures from season 2024

Fig 1: Willows planted in standing water 24 04 16

Fig 2: Willow buds appearing 24 04 23

Fig 3: willow growth 24 06 12

Fig 4: Sump with pump 24 06 16

Fig 5: Simple irrigation pipe to willow

Fig 6: Strong willow growth 24 09 10

Fig 7: Some of the harvested willows to be analysed for PFAS content. Growth nearly 4m 24 09 10