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# New developments and advances in treating PFAS-contaminated soil and water

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WORK ON PROGRESS

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# Our PFAS treatment plants for water and soil

- Efficient and economical
- Over 60 plants since 2009



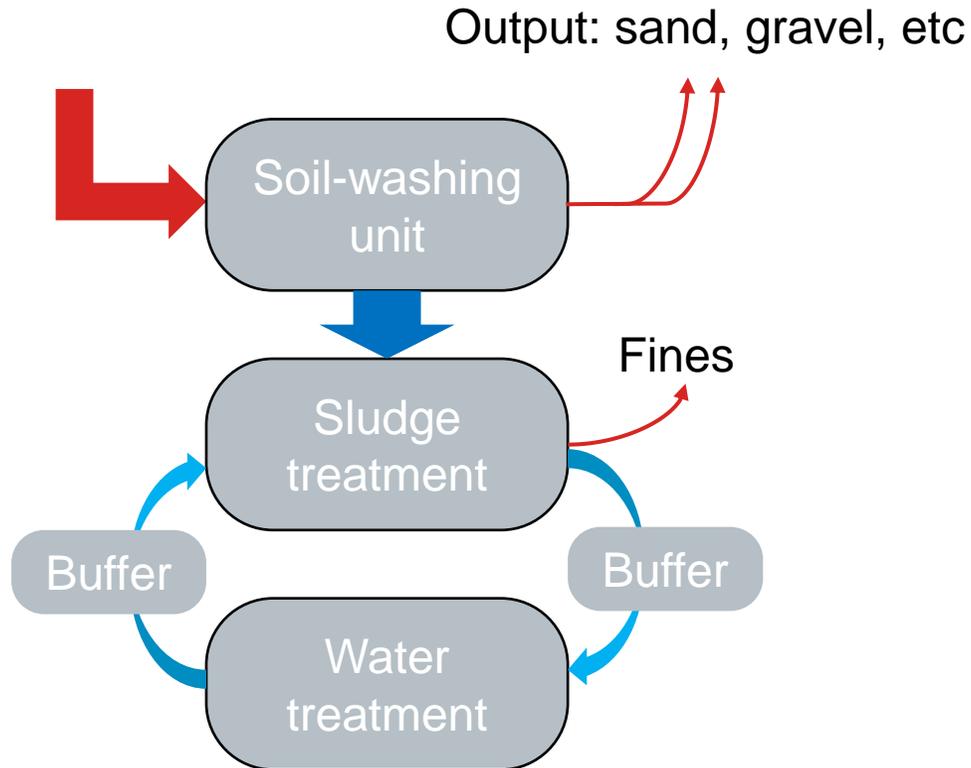
Former refinery – hydraulic barrier, 200 m<sup>3</sup>/h



Airport – soil washing plant, 2.000 t/day

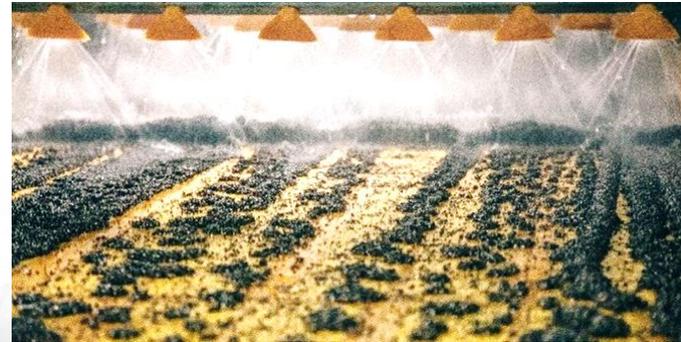
# PFAS soil treatment

# PFAS soil washing – at a glance



# Soil washing – core element 1/3

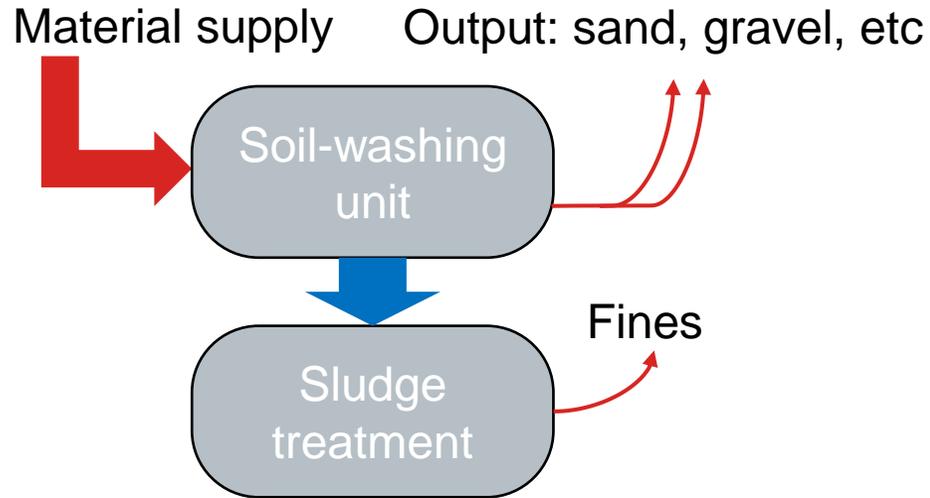
Material supply      Output: sand, gravel, etc



## Soil-washing unit

- Classification (screens, hydrocyclones, etc)
- Transfer of PFAS to the washing water

# Soil washing – core element 2/3



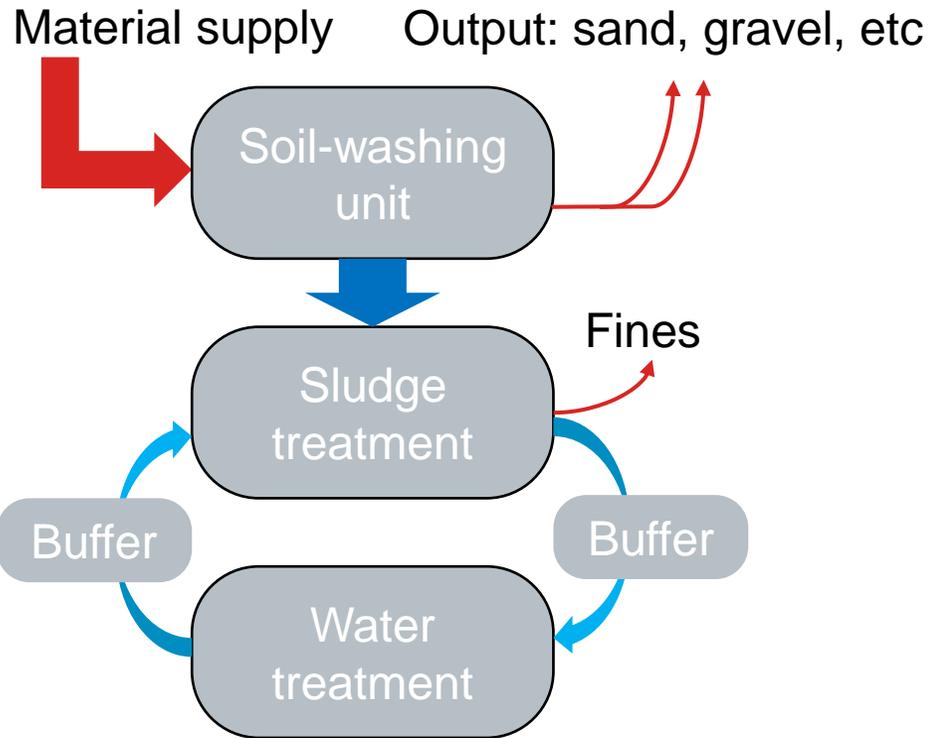
## Soil-washing unit

- Classification (screens, hydrocyclones, etc)
- Transfer of PFAS to the washing water

## Sludge treatment

- Dewatering & washing fine fraction

# Soil washing – core element 3/3



## Soil-washing unit

- Classification (screens, hydrocyclones, etc)
- Transfer of PFAS to the washing water

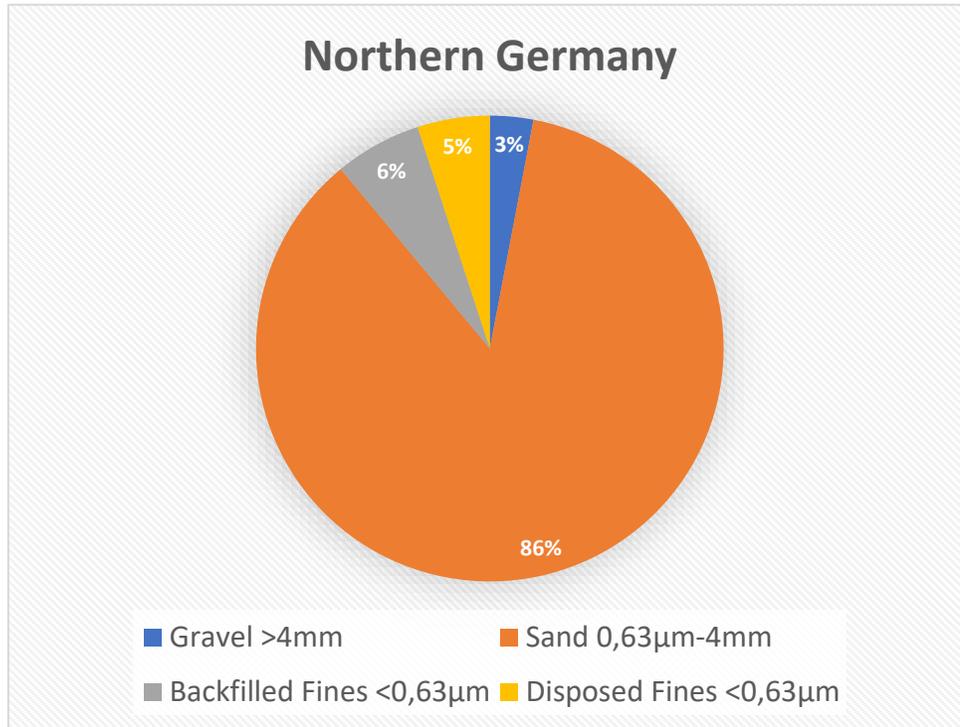
## Sludge treatment

- Dewatering & cleaning fine fraction

## Water treatment

- Removal of PFAS by activated carbon
- Buffer tanks

# Interim balance (status: May 2024)



## Optimised soil treatment

- 50-75% of the fines are treatable  
→ increased backfilling rate 90% → 95%

## Output-material

- Soil washed, 02/23 – 05/24 220.000 t (100%)
- Backfilled on-site 209.000 t (95%)
  - Gravel (> 4 mm) 6.600 t (3%)
  - Sand (< 0,63 µm - 4 mm) 189.200 t (86%)
  - Fines (< 0,63 µm) 13.200 t (6%)
- Landfill
  - Disposed Fines (< 0,63 µm) 11.000 t (5%)

## Operation data

- Throughput soil: 2.000 t/d
- Flow rate washing water: 200 m<sup>3</sup>/h
- Costs: 60 EUR/t
- Output C<sub>PFAS</sub> (2:1 eluate): <0,1 µg/L  
<1,0 µg/L

# Operation is optimisation



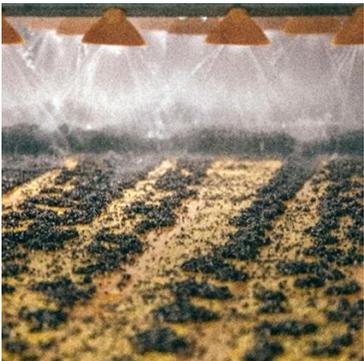
## Reduce complexity

- PFAS-Analysis:  
focus on main substances  
Identification of critical factors  
of the input material
- Adapted operation



## Use laboratory experiments

- Selection & dosage of  
precipitation & flocculation aids
- Optimisation of the washing  
result



## Reduce water demand

- Degrees of freedom
- Water: the more, the better...  
but the higher the costs

# Soil washing test – technical scale



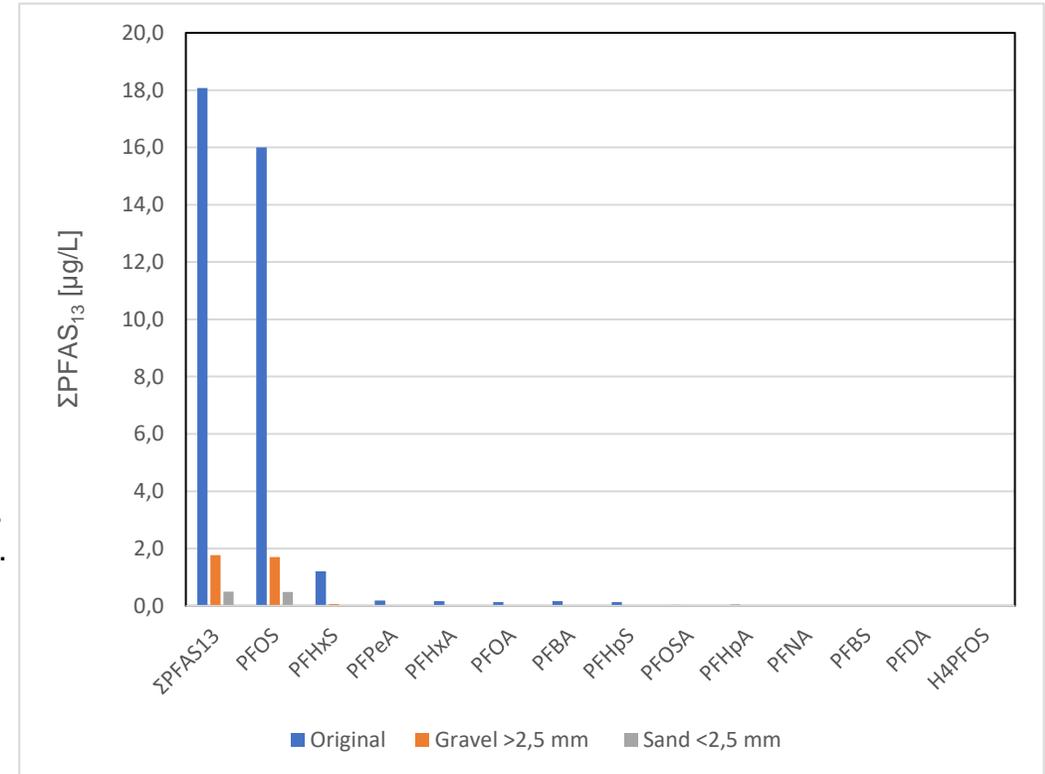
Soil washing plant, multi-stage, technical scale



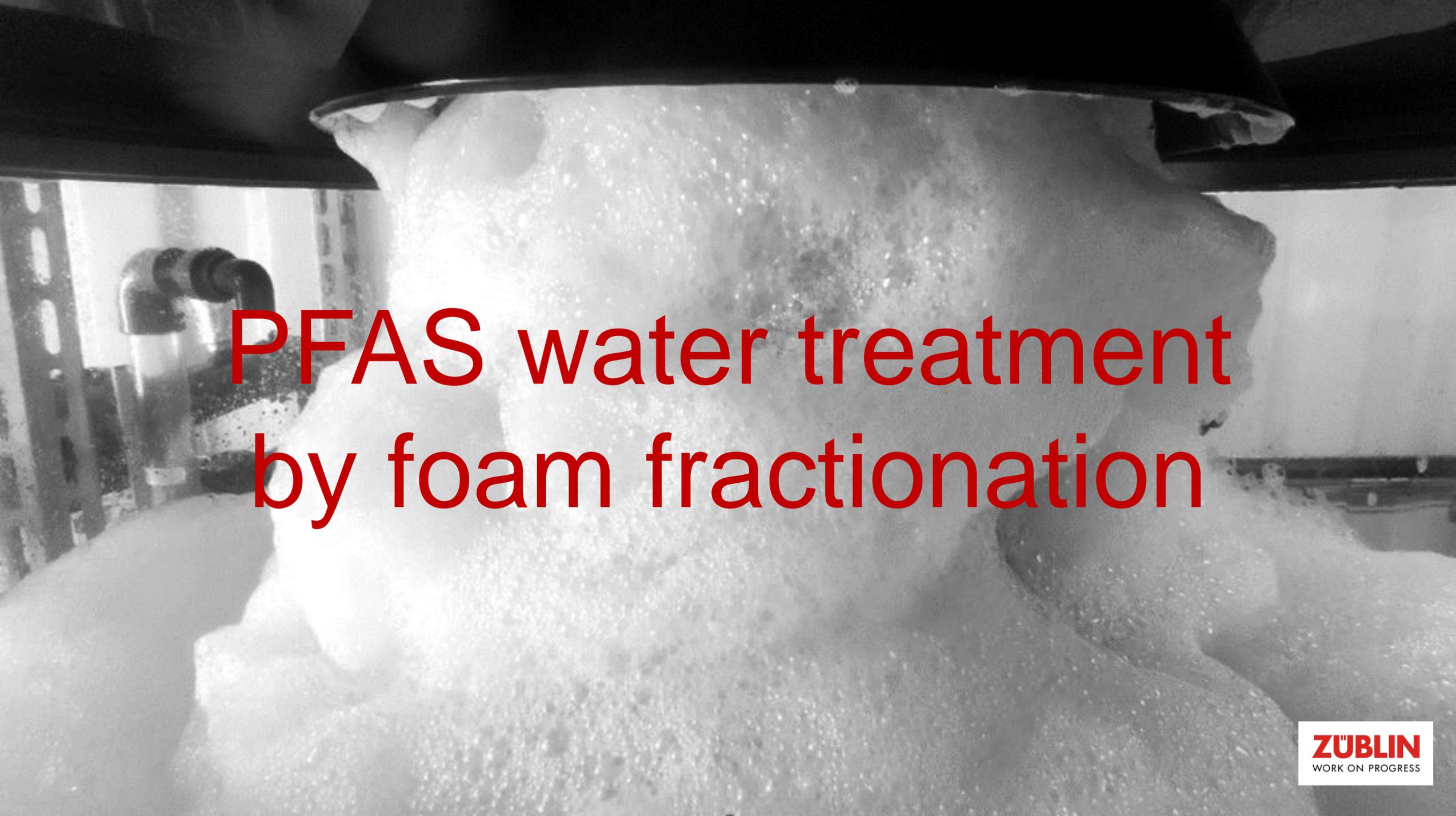
Gravel (> 2,5 mm), 11.0% wt. Sand (< 2,5 mm): 63.8% wt. Fines (< 0,63 µm): 24.5% wt.



Organics: 0.7% wt.



→ This soil material is very easy to wash



# PFAS water treatment by foam fractionation

# Relevant water treatment methods



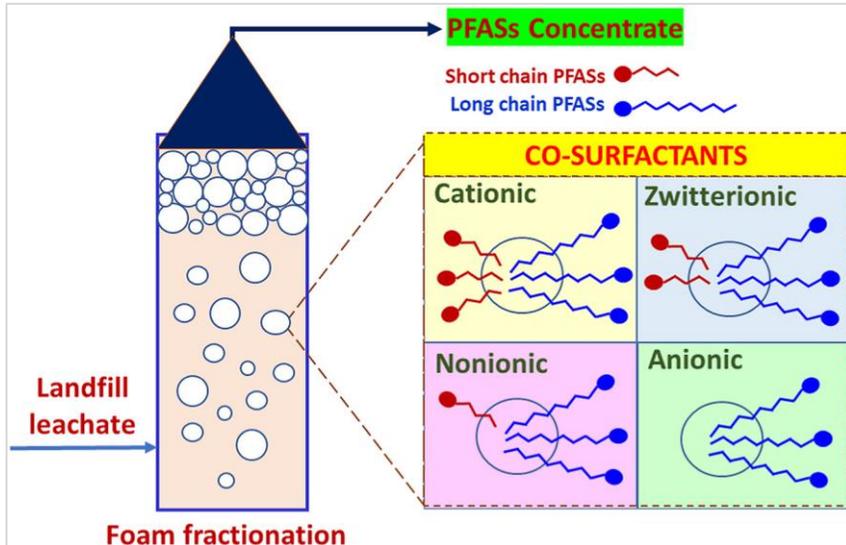
## Treatment methods

- Activated carbon adsorption
- Ion exchange
- **Foam fractionation**
- Membrane process

## Aqueous media

- Groundwater
- Leachate
- Extinguishing water
- Process water

# Foam fractionation - basics



Source: Vo P et al. (2023)

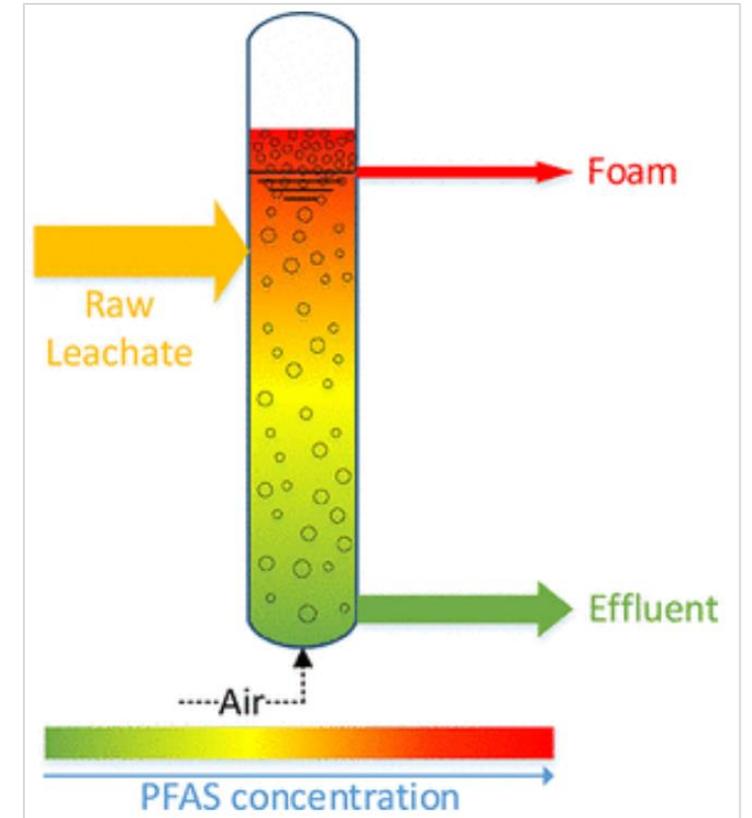
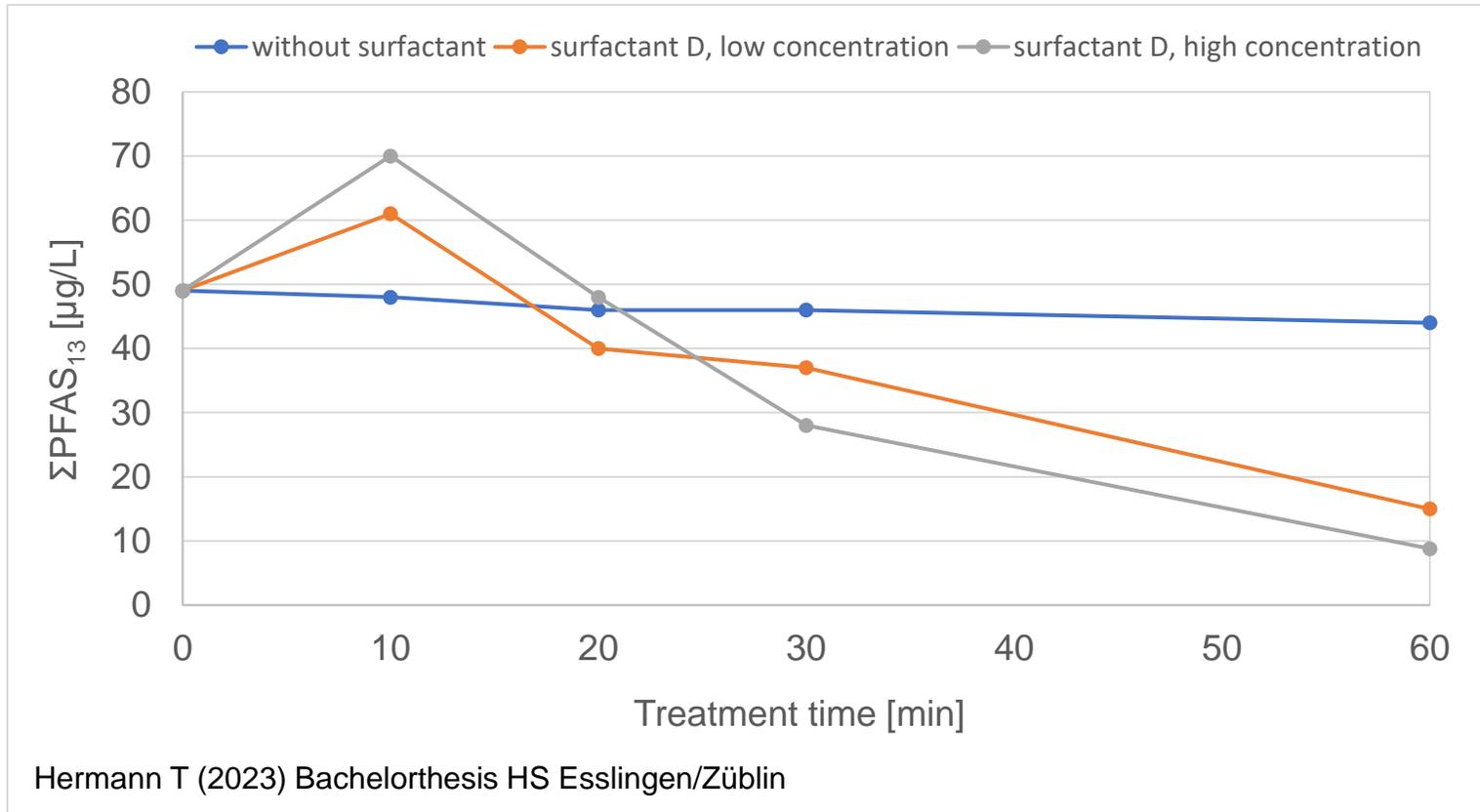
## Foam fractionation

- First patent in 1918, Wilhelm Ostwald
- Adsorption of surface-active compounds on the hydrophobic surface of gas bubbles
- Separation of the foam, removal of the surfactants

## Application

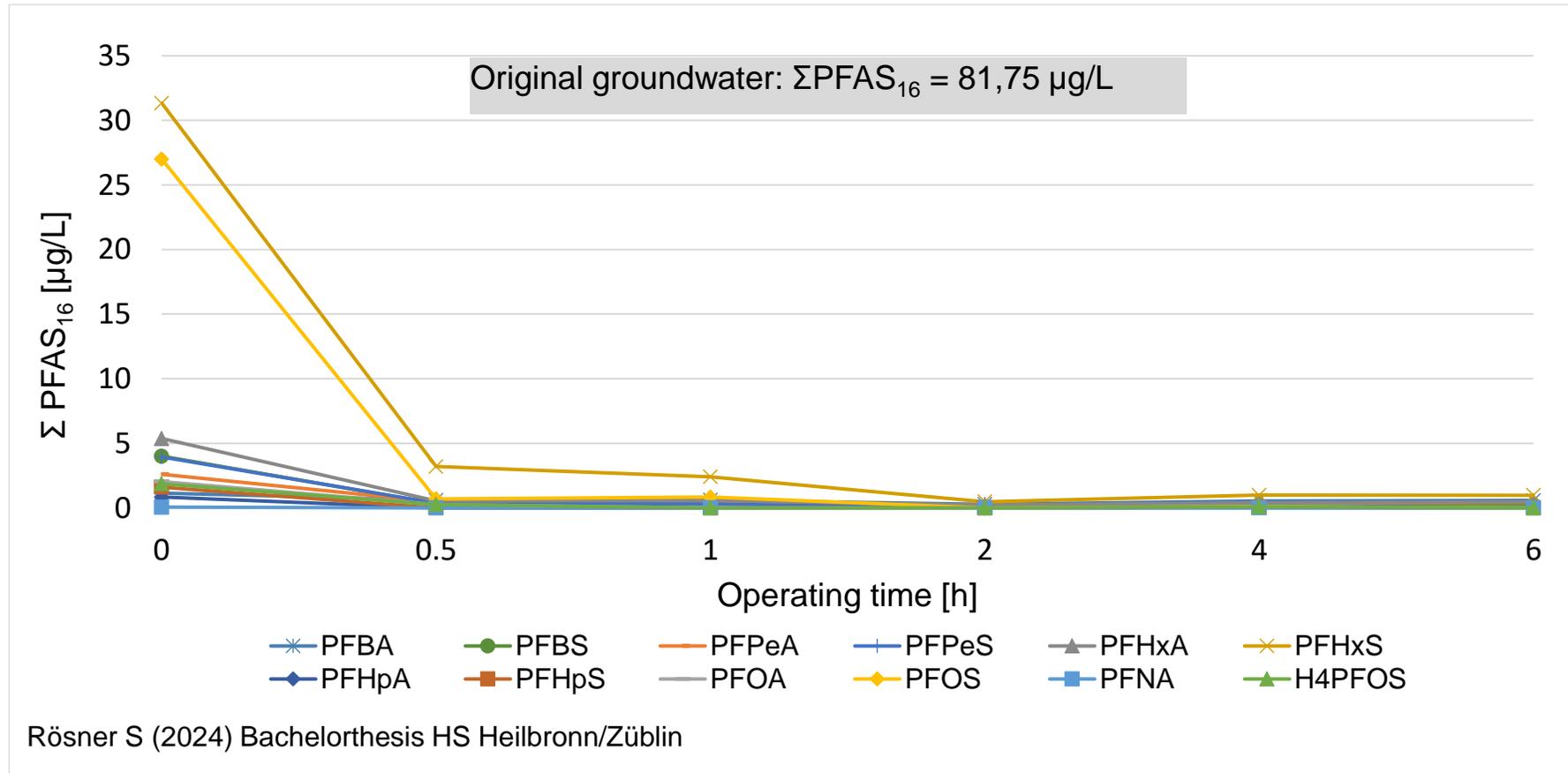
- Protein separation
- Fish farming
- PFAS removal

# Foam fractionation - leachate



Source: Smith SJ et al. (2022)

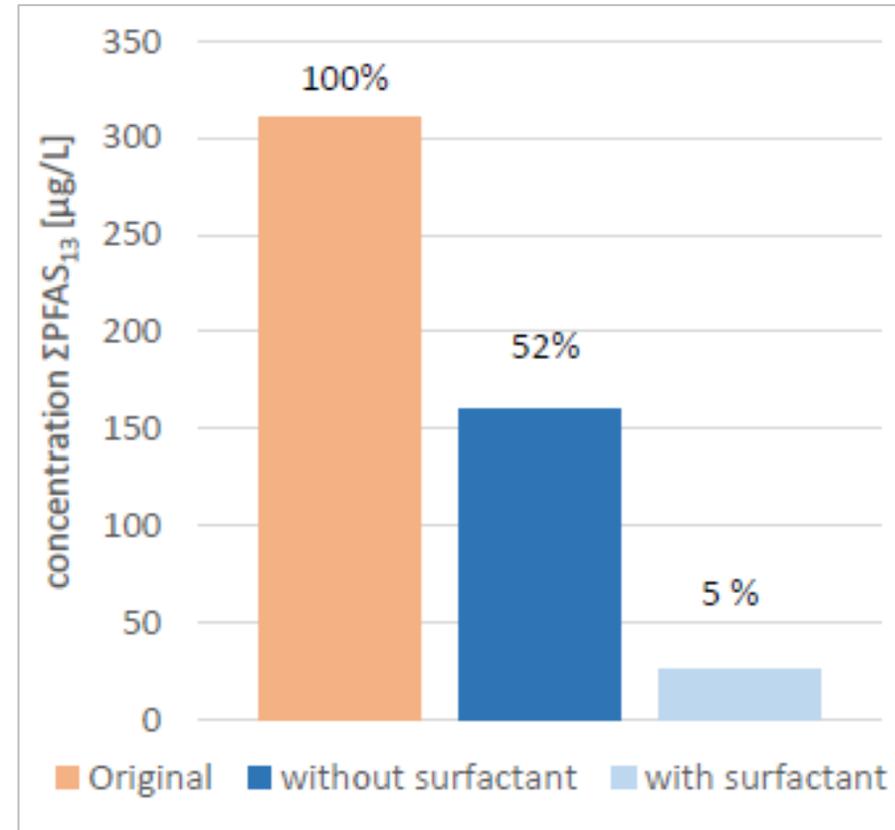
# Foam fractionation - groundwater



# Foam fractionation – extinguishing water

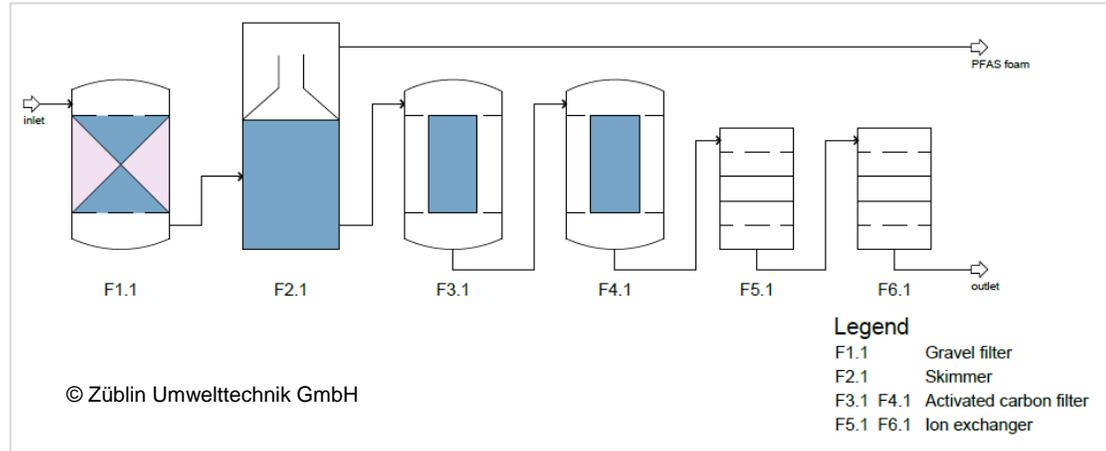


Sprinkler system - foam fractionation unit



Foam fractionation - treatment performance

# Combined treatment procedure



## Foam fractionation

- high PFAS concentrations  
→ PFAS load reduction

## Activated carbon adsorption

- low PFAS concentrations  
→ polishing

## Ion exchange (option)

- low PFAS concentrations, short-chain PFAS  
→ polishing



# Summary and outlook

## PFAS soil washing

- The only economically feasible cleaning method on large scale
- Even a viable tool treating the fine fraction
- Heterogeneous input material with varying contaminant load and soil structure requires constant optimisation of operation
- Tests on laboratory and technical scale serve for reliable planning

## PFAS foam fractionation

- Suitable and reliable method for removing high PFAS concentrations
- Application for aqueous media:
  - leachate
  - groundwater
  - extinguishing water
  - process water
- Combination with GAC adsorption and/or IEX
  - economical operation
  - low target values in the nanogram range

→ Ongoing research/development leads to further advances in PFAS treatment technologies

# Any questions?

Thank you for your attention!

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