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REMEDIATION OF PFAS IN SOIL & GROUNDWATER

Biopolymer based remediation of PFAS contaminated soils - on-site treatment in leaching piles

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REMEDIATION OF PFAS IN SOIL & GROUNDWATER

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  - electroad/desorption modules
- Pilot Tests
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ABOUT ME / SENSATEC

- Anja Wilken
- environmental engineer
- since 2017 with Sensatec GmbH (www.sensatec.de)
  - current position: co-branch manager – Kiel office
  - responsible for PFAS remediation projects
- Sensatec = technology provider for in-situ soil and groundwater remediation
  - drilling technology
  - laboratory for feasibility studies & cultivation
  - custom-made remediation units
  - execution of in-situ remediation

THE RESEARCH PROJECT

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- joint research project funded by the German Federal Ministry of Education and Research
- project duration: 03/2021 – 02/2024
- partners:
  - GEOlogik Wilbers & Oeder GmbH – Münster
  - Mull und Partner Ingenieurgesellschafts mbH – Osnabrück
  - Sensatec GmbH – Kiel
  - Helmholtz-Centre for Environmental Research (UFZ) – Leipzig
- Aim: Adaptation of the biopolymer-based in situ PFAS elution for on-site piles AND establishment of electroad/desorption modules for water treatment

RECAP: BIOKON PRELIMINARIES

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- series of column tests with PFAS contaminated soil
  - biopolymer screening
  - varying BP concentration
  - pH-value adaptions

- verification of biopolymer elution system in a lysimeter test

- in-situ pilot test in Southern Germany
  - paper sludge contaminated site
  - 80% removal

ON-SITE REMEDIATION PROCESS

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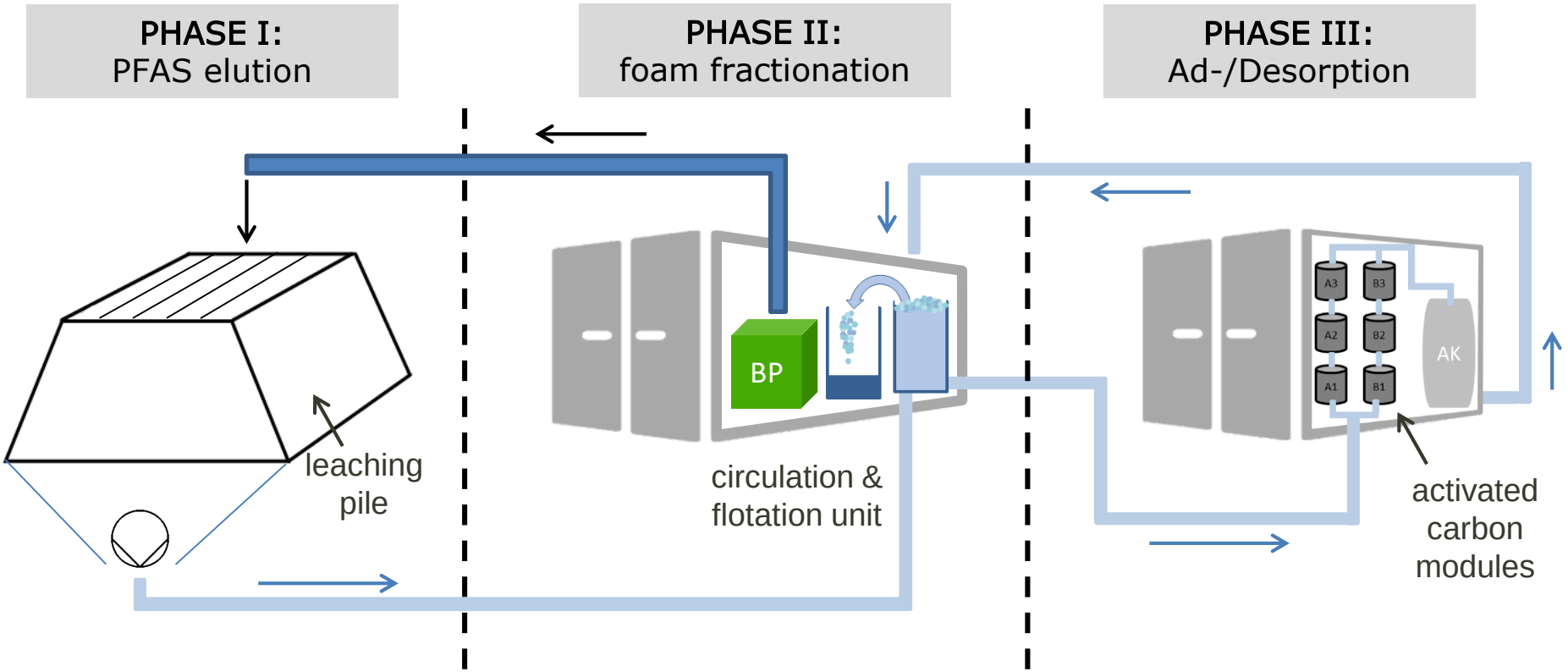
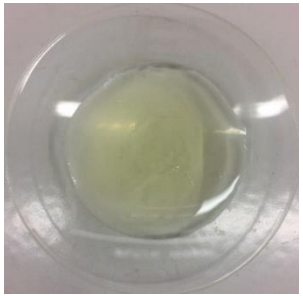
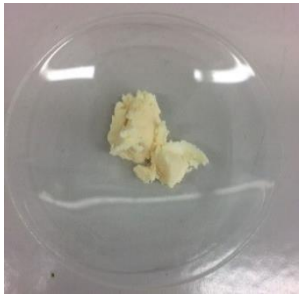
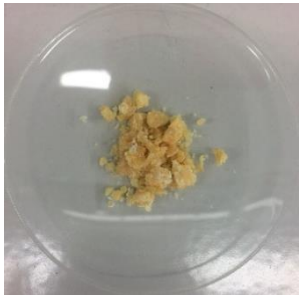


BIOPOLYMERS

- biopolymer selection in previous research project - BioKon
- biopolymer characteristics
  - consisting of amino acids, fatty acids & lipids
  - readily biodegradable
  - amphiphilic
- formation of biopolymer-PFAS-complexes
- biopolymer use enables improved PFAS elution in contaminated soils

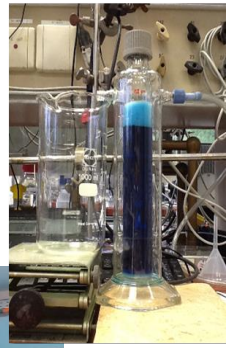






FLOTATION

- treatment of PFAS contaminated water
  - adding biopolymer
  - air injection
  - tranfer of PFAS into concentrate
- 95 % removal on lab scale
- field application as a sequential batch
  - 2 m³/h
- 75% removal in pilot
- optimization in progress



ELECTROAD-/DESORPTION MODULES

- use of flat, fine-fibre activated carbon felts
  - high PFAS sorption selectivity
  - specially activated
- Regeneration
  - by applying a negative potential
  - flush-back
  - several flush-back cycles possible

- promising removal rates on lab scale (95% PFDA, 70% PFBA with residence times of < 5 min.)
- transfer to pilot cell with 0.25 m^3/h

Laborzelle ca. 200 ml

Pilotzelle ca. 25 l

PILOT SCALE

- Southern Germany
- ∑ PFAS $_{soil}$ ≈ 300 µg/kg
- contaminant origin: paper sludges
- Main contaminant: PFDA

SITE 1
agricultural site

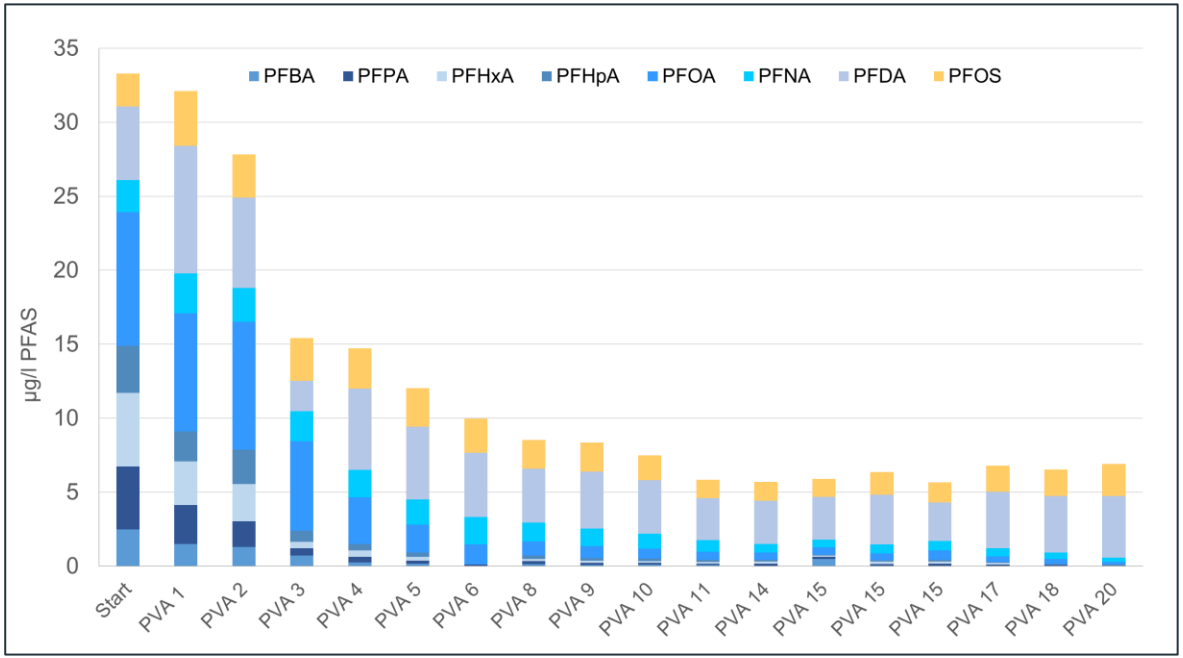
- Northern Germany
- ∑ PFAS $_{soil}$ ≈ 340 µg/kg
- contaminant origin: AFFF
- Main contaminants: PFOS, PFUnA

SITE 2
airport site

PILOT 1 – RESULTS PERCOLATE

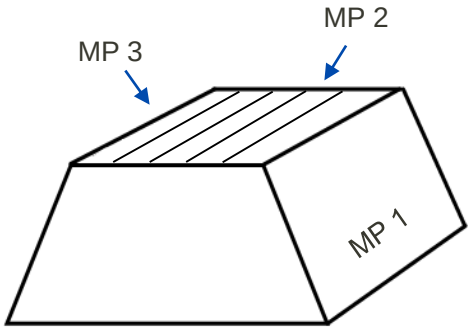
- continuous analysis of the percolate
- decreasing elution over time
- short-chain PFAS only detected in the beginning
- data for process control
- Elution data used for modelling

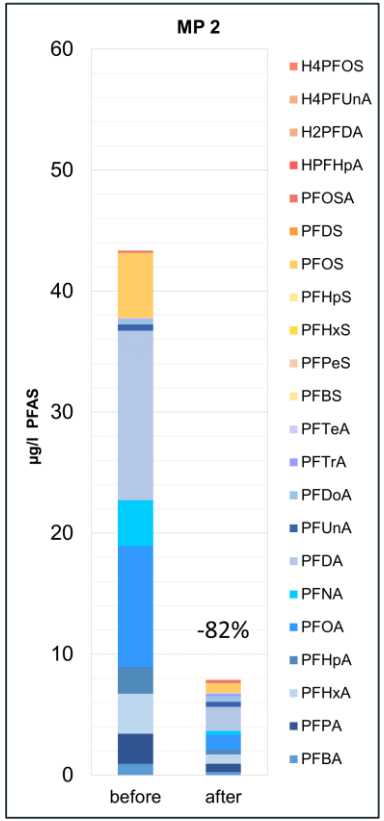
  → site assessment tool



PILOT 1 – RESULTS SOIL REMOVAL

- collection of several mixed samples
- soil analysis and 2:1 eluate analysis
- **82% removal in MP 2**
- removal of perfluorinated sulfonic & carboxylic acids
- no PAP removal
  - transformation processes stimulated





PILOT 2 – RESULTS PERCOLATE

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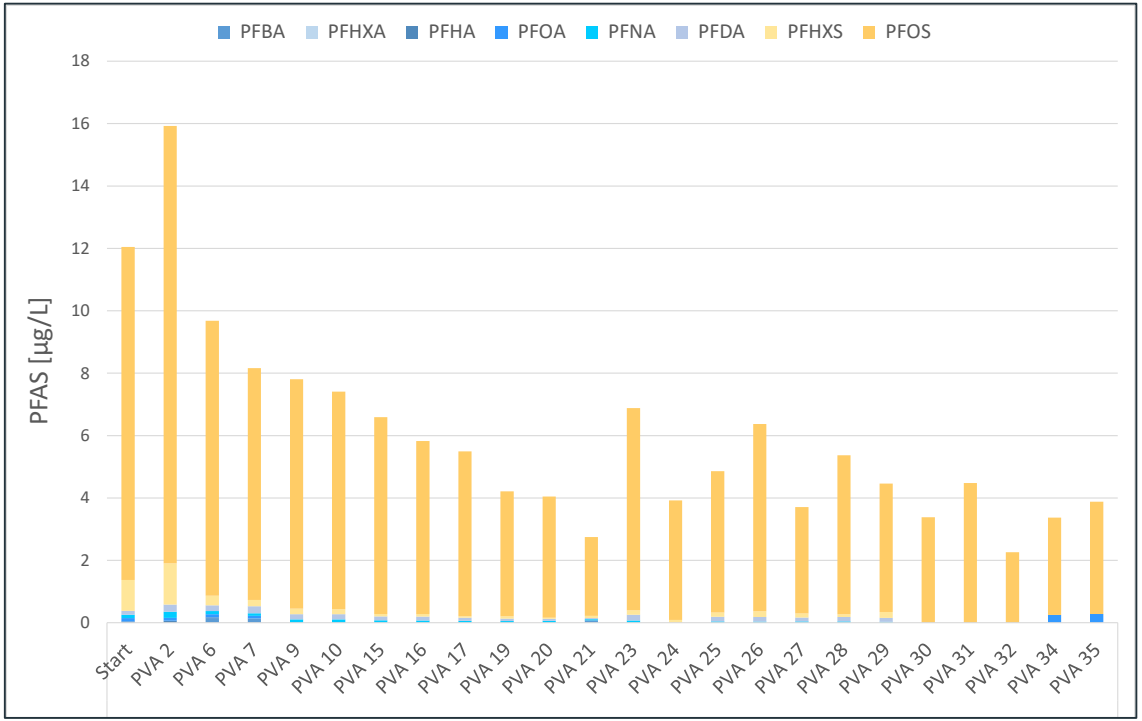
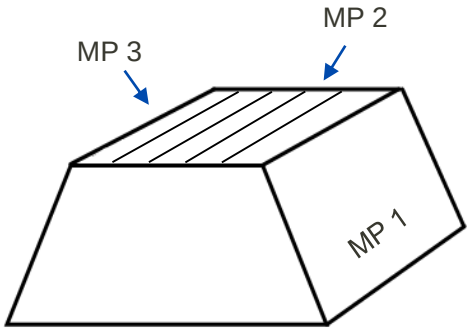
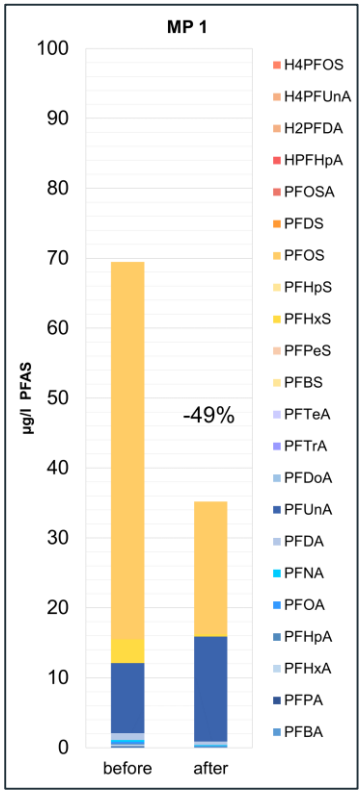
- continuous analysis of the percolate
- decreasing elution over time
- in comparison, lower PFAS concentration
- mainly PFOS
- biopolymer added in second half of pilot



PILOT 2 – RESULTS SOIL REMOVAL

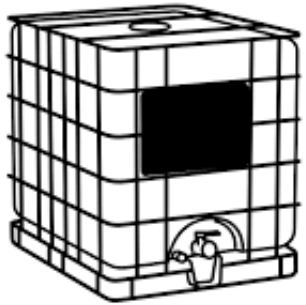
- collection of several mixed samples
  - sample sampling strategy as in Pilot 1
- soil analysis and 2:1 eluate analysis
- 49% removal in MP 1
- removal of perfluorinated sulfonic & carboxylic acids
- consistent saturation in pile necessary

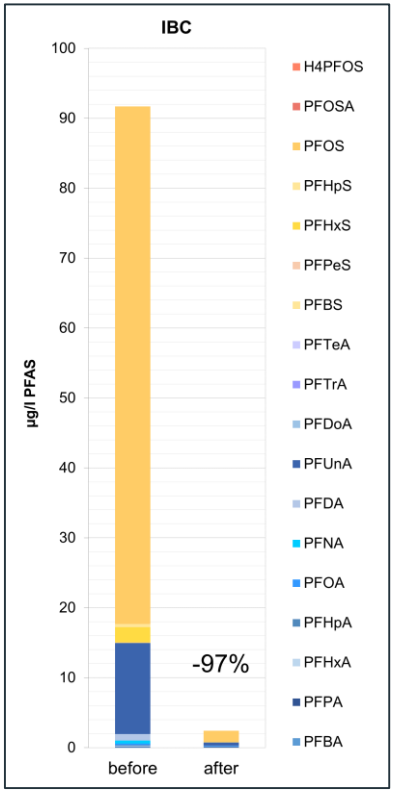




PILOT 2 – RESULTS FULLY SATURATED SOIL

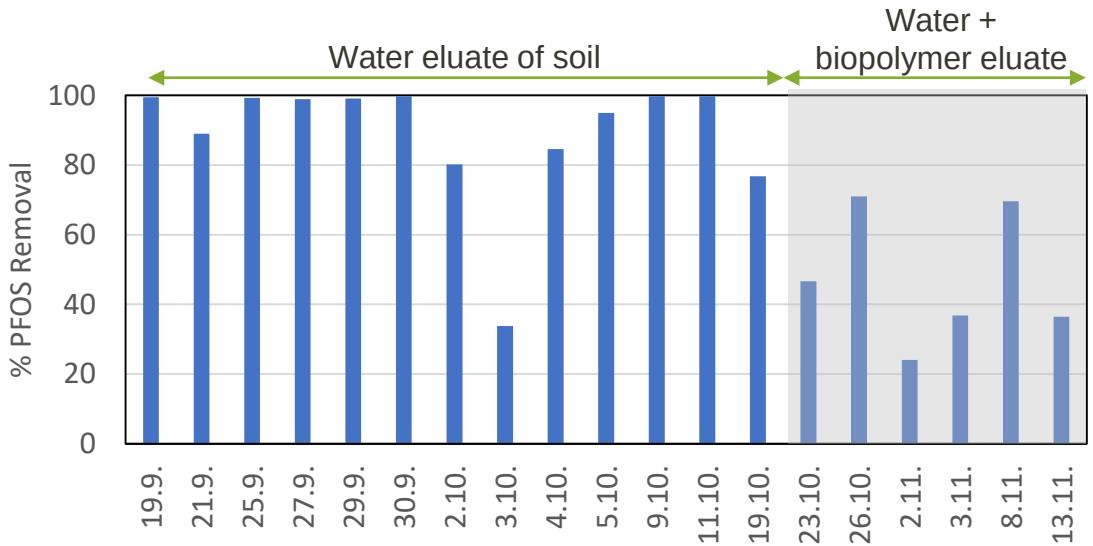
- additional test with AFFF contaminated soil
  - 1m³ soil in IBC container
  - fully saturated conditions
- collection of mixed sample
- soil analysis and 2:1 eluate analysis
- **97% removal in IBC container**





PILOT 2 – RESULTS AD-DESORTION MODULES

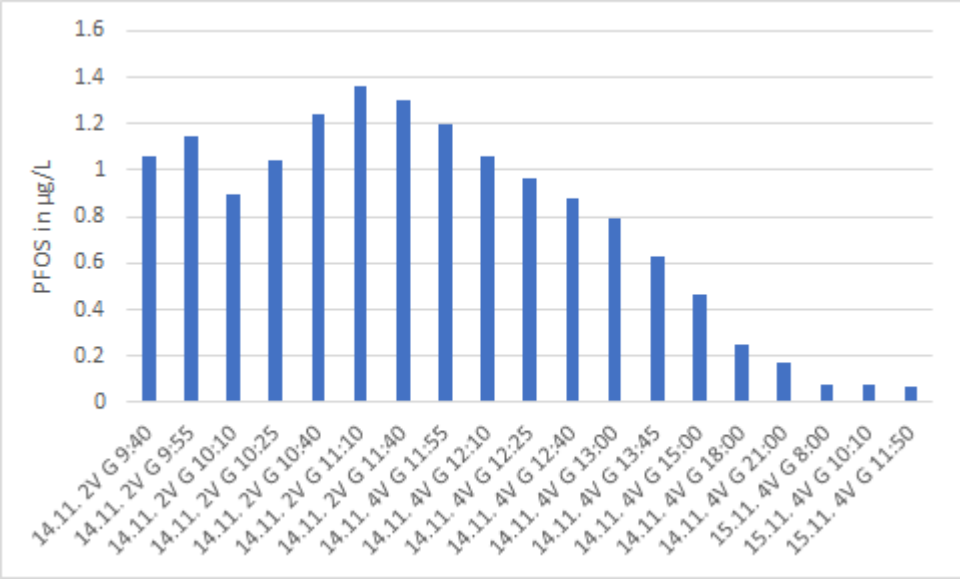
- high removal degree for PFOS in water despite high flow rate, reduced removal for water + biopolymer
- biopolymer is reducing adsorption → optimize biopolymer removal by flotation



- 3 modules in sequence
- 4 kg activated carbon in total
- ca. 500 L/h
- ca. 7 min residence time
- up to 99% removal (w/o biopolymer)

PILOT 2 – RESULTS AD-DESORTION MODULES

- e-desorption was realized with 2 to 4 V cell voltage over 24 h
- adsorbing ACF = cathode
- safe operation, no water electrolysis
- recovery of PFOS still low in field test desoprtion (24 h, 1.2 m³)
- PFOS prediction: treat > 4000 m³ and desorb into 130 m³ (conc. factor = 10)
- PFBA e.g. 80% recovery in E-desorption with 0.3 m³ water achieved



CONCLUSION

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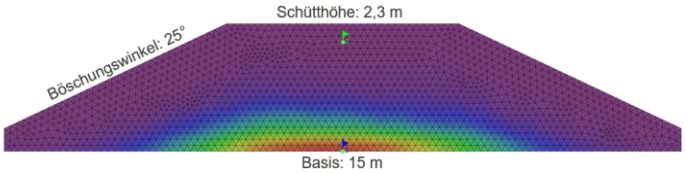
- biopolymer based PFAS elution is applicable in leaching piles
  - up to 97% removal
- removal efficiency in the soil strongly depends on
  - soil type
  - saturation in leaching pile
  - biopolymer system applied
- electrostimulated activated carbon adsorption/ desorption modules show up to 99% removal
  - desorption works better for short-chain PFAS than long chain PFAS

OUTLOOK

- developed technology is available for field application
- site-specific feasibility study on lab scale is a prerequisite
- feasibilty strongly depends on
  - PFAS source component
  - soil type

- on-site and in-situ approach possible depending on site conditions
- site assessment tool based on BioKon & FABEKO results is being set up



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