From Waste to Recyclable Material

New Approaches to Dealing with Soil with PFAS Contamination

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BATTELLE

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What you can Expect from this Presentation

- Fraport, Terminal 3 – project background
- New approaches to dealing with soil with PFAS contamination
  - Soil washing
  - Immobilization in soil material
  - Implementation of PFAS sorbing geotextiles

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Fraport, Terminal 3 – Project background

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Construction Measures Terminal 3, Fraport

1990

First discussions between city of Frankfurt and Fraport about the extension of the Airport Frankfurt Main

2015

Begin of construction measures (main building)

2026

Planned commissioning of Terminal 3

Design Study Terminal 3, Frankfurt

History of the Site

1945 - 2005

US-AirBase

- PFAS-spills due to AFFF usage

2006

Transfer of the area to Fraport

2008

First detection of PFAS concentrations at the site

Aerial photograph from 1960

Aerial photograph from 2005

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Mass Balance

Excavation mass

- About 1.14 million meters cubed (m^3)

Refilling mass

- About 680 000 m^3

Excess mass

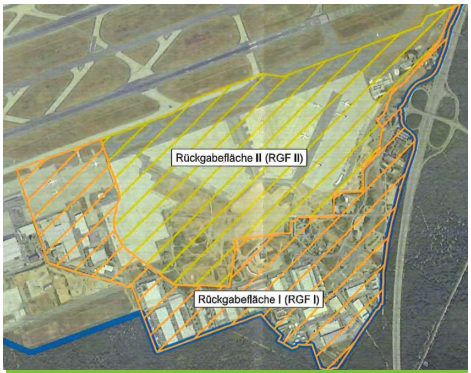
- About 460 000 m^3

Excavation pits main building

Legal Provisions for the Site

May 2010

Remediation notice issued by local authority for handling PFAS in soil – on basis of solid concentrations



Former US-Airbase Areas

November 2018

Amendment of remediation notice by local authority for handling PFAS in soil – on basis of leachate concentrations

Legal Regulations for Excavated Soil, Germany

- Regulations for **waste** classification
  - >50 milligrams (mg) PFOS/ kilogram (kg) –> hazardous waste
- No further legally binding threshold values, only guiding values for soil
- **Reuse of soil** based on leachate concentrations
  - 13-14 individual parameters, depending on state regulation
  - So far state-level guide values [often 1:10 solid-liquid ratio]
  - Only recently nation-wide guidelines [1:2 solid-liquid ratio]

Guidelines for PFAS assessment

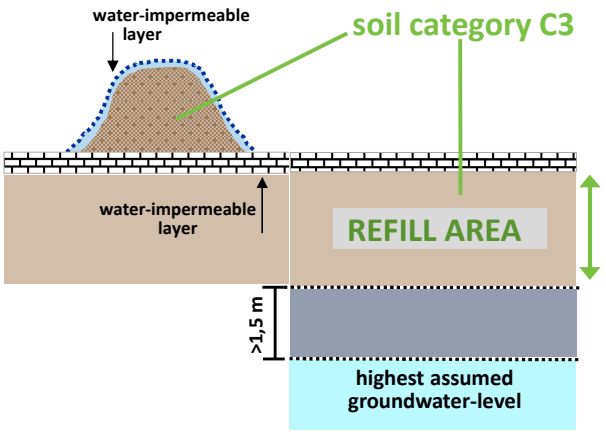
Recommendations for the uniform nationwide assessment of soil and water contamination and for the disposal of soil material containing PFASs

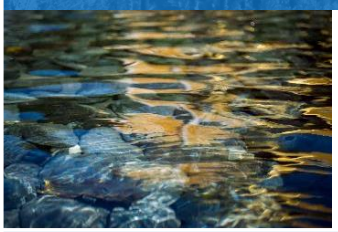
Released Feb 21st 2022

Guidelines for Reuse of Soil

Three scenarios for reuse of material

- **Category C1**: Reuse without safety measures, “open”
- **Category C2**: Reuse without safety measures under specific conditions [areas with high PFAS concentrations; above saturated zone]
- **Category C3**: Reuse with safety measures against leaching [capping; above saturated zone]





New Approaches to Dealing with Soil with PFAS Contamination

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Soil Washing

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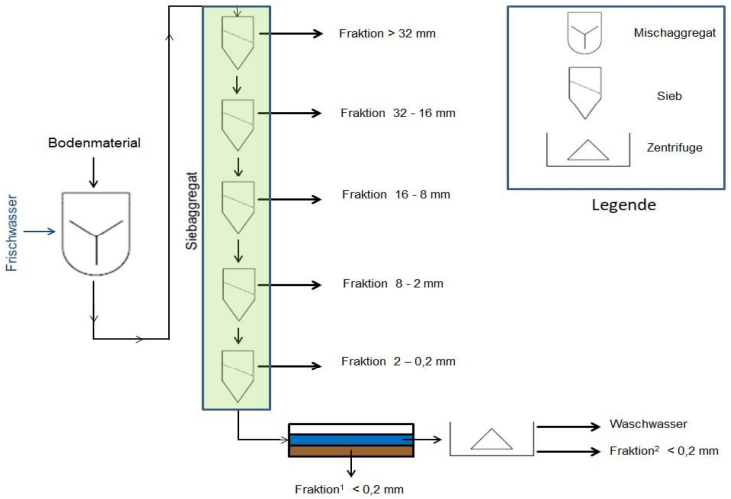
Soil Washing – Lab Scale

Dry sieving



Flow chart washing process

Results: Soil Washing

Sieve fraction [mm]	Dry sieving		Soil washing 1:1		Soil washing 2:1		Soil washing 3:1	
	∑ PFAS [µg/l]	wt-% (app.)	∑ PFAS [µg/l]	wt-% (app.)	∑ PFAS [µg/l]	wt-% (app.)	∑ PFAS [µg/l]	wt-% (app.)
>32	--	1.2	n.d.	1.1	0.02	0.4	0.56	1.6
>16	0.07	3.1	0.32	2.7	2.96	2.3	7.58	2.6
>8	0.14	5.3	0.07	4.3	0.05	4.6	0.05	4.1
>2	0.12	14.3	0.10	9.9	0.05	10.0	0.06	9.4
>0.2	0.26	76.0	0.06	67.2	0.04	64.5	0.05	61.0
<0.2			0.62	14.8	0.47	18.3	0.23	21.2
loss	--	--		12.4	--	14.1	--	3.9
Washing water	--	--	3.47	--	1.84	--	1.23	--

* According to Bavarian EPA preliminary guidelines for PFAS contamination of water and soil, Status: April 2017 [1:10 solid-liquid ratio for analysis]

Category C3 and >C3
Category C2
Category C1

Soil Washing – Large Scale

Soil washing facility

Sand fraction

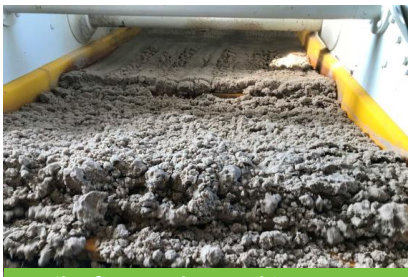
Filter cake

Soil Washing – Large Scale

Large scale trials

Treatment 1: Sand 0 – 2 mm >> C 3 material

Treatment 2: Sand 0 – 2 mm > C 3 material



Silty fine sand at washing street

Σ PFAS concentration	pre-treatment sand fraction 0-2 mm	after treatment sand fraction 0.2-2 mm	after treatment sand fraction <0.2 mm
Treatment 1	8.44 µg/l	0.09 µg/l	9.40 µg/l
Category	>C3	C2	>C3
Treatment 2	0.88 µg/l	0.07 µg/l	0.13 µg/l
Category	>C3	C2	C3

Immobilization in Soil Material

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Immobilization in Soil Material

RemBind®-Material

- Powdered Sorbens
- Environmental neutral composition
  - Activated carbon
  - Aluminum hydroxide
  - Aluminum oxide
- Stable for storage, stable against temperature
- No hazardous materials

Concept of effectiveness RemBind®

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Immobilization in Soil Material

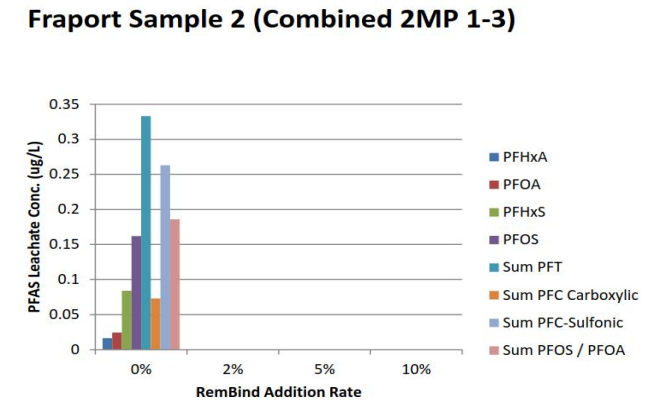
Bench test with Fraport soil

Added ratio RemBind®

- 2%
- 5%
- 10 %

Results

- No amendments:
  up to 0.35 micrograms per liter (µg/L) Σ PFAS in leachate
- No proof of PFAS for amended samples



Immobilization study results

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Implementation of PFAS Absorbing Geotextiles

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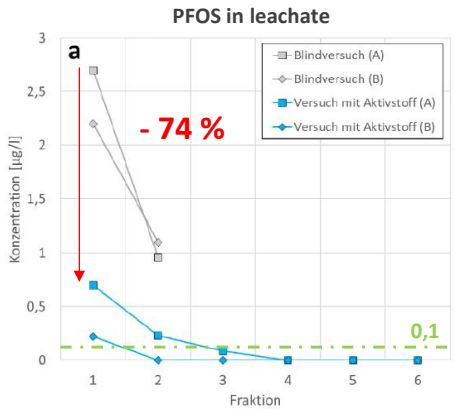
Implementation of PFAS Absorbing Geotextiles

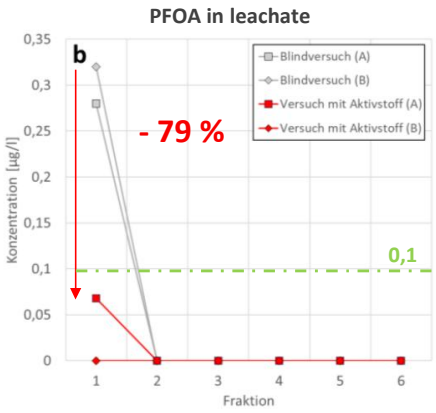
Lab studies

- Column experiments according to DIN 19528
- Leaching behavior determined in setups without absorbing matrix
- Six rounds of percolation, 10 liter water in total, 891 cm^3 soil
- Column experiments with Tektoseal Active as absorbing matrix

Ion exchange resin as sorbing material

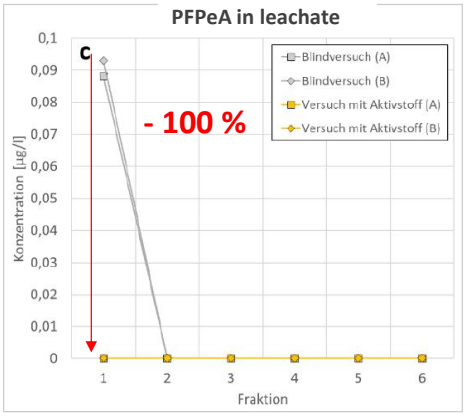
Results Column Experiments PFOS, PFOA

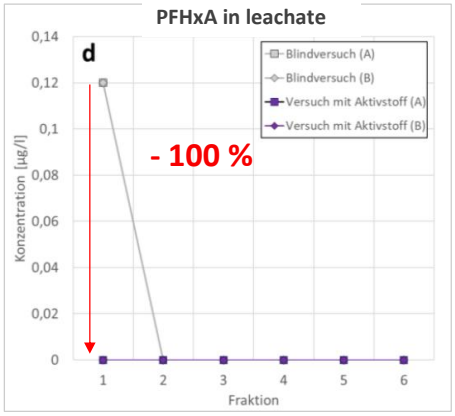




Column experiment (DIN 19528)

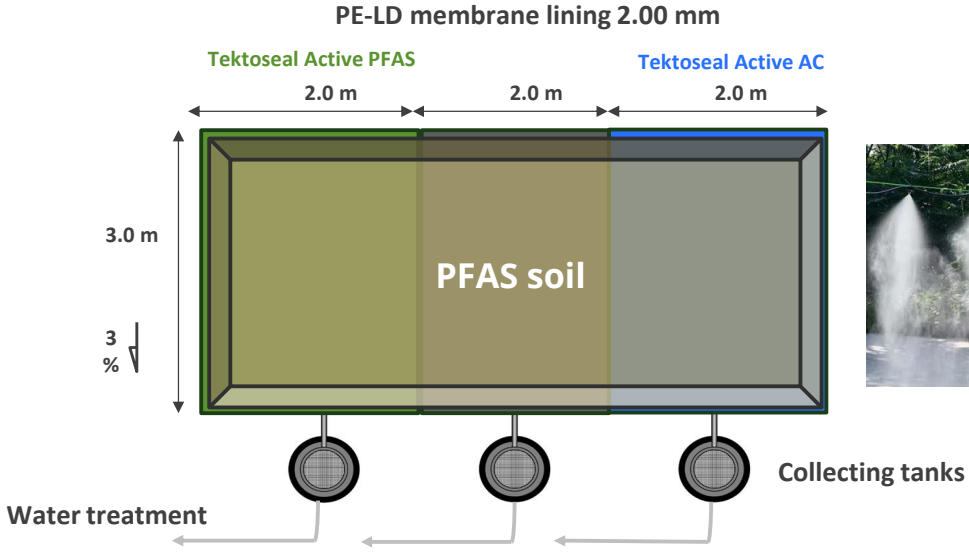
Results Column Experiments PFPeA, PFHxA





Column experiment (DIN 19528)

Pilot Field – Top View



Pilot Field – Installation

Pilot Field – Monitoring

Precipitation

Collecting leachate

Temperature

Soil humidity

Take Away Messages

- PFAS load of soil is crucial for large construction measures at aqueous film forming foam (AFFF) impacted areas
- Legal regulations are developing
- Treatment alternatives
  - Soil washing
    - Improvement of PFAS content
    - Reduced waste fraction
    - Geotechnical properties to be determined
  - Immobilization by sorbent mixing-in
    - Improvement of leaching behavior
    - Long-term stability?
    - Additional material costs
  - Sorbing geotextile
    - Promising results
    - Further tests needed, runtime 1 year

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