THE HYBRID SOIL WASHING PROCESS FOR THE TREATMENT OF PFAS CONTAMINATED SOILS

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Content

Origin of PFAS in Contaminated Soils

PFAS Cycle through the Environment
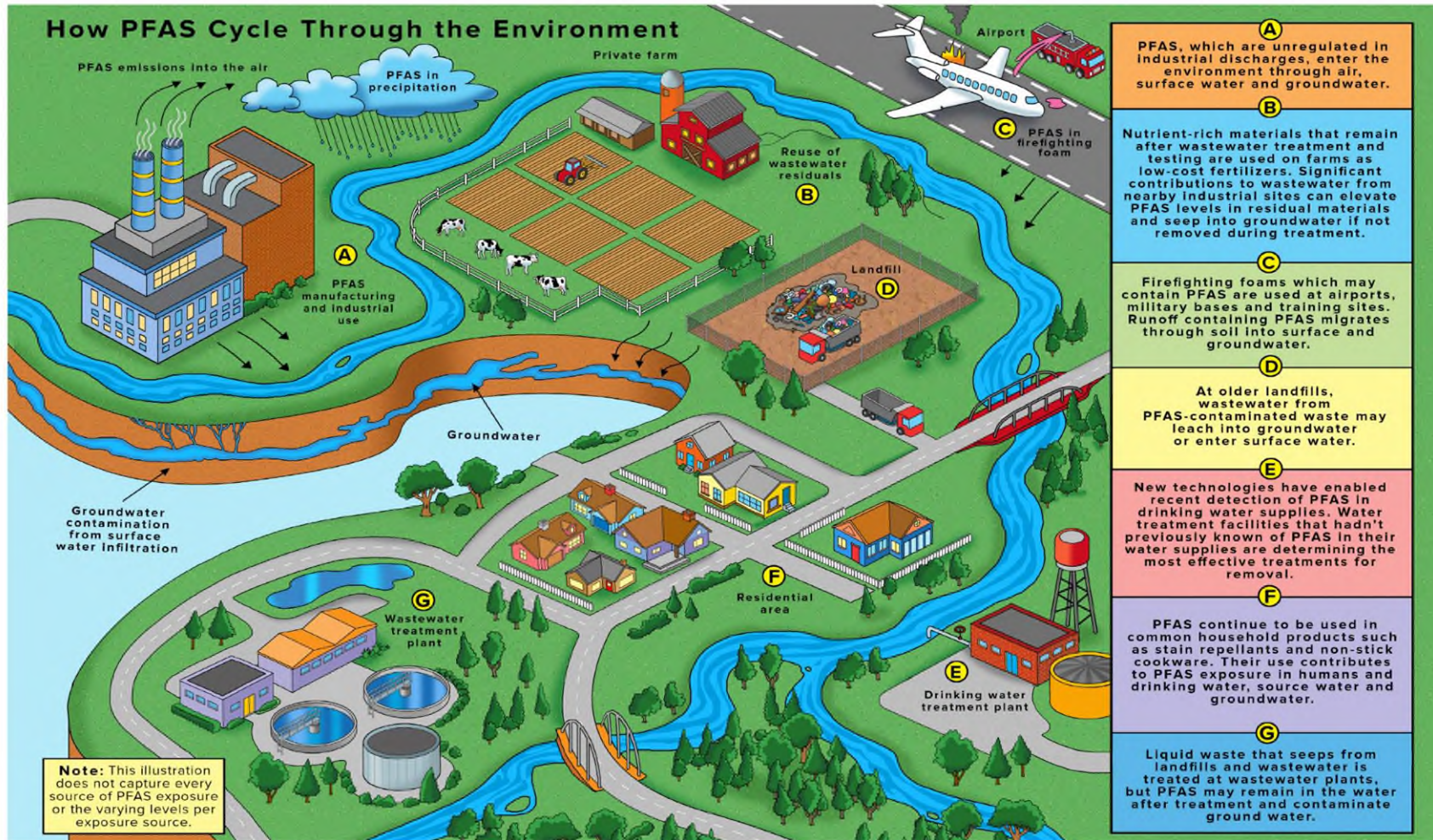
Hotspot Areas

➤ Airports: fire fighting areas
  ➤ PFOS major compound

➢Production sites
  ➢PFOS, Gen-X, fluorotelomers,…

Soil Treatment Experience
Pioneer since 1993

- Pioneer in soil treatment: since 1993 - first soil washing plant in Belgium.

- 200.000 tons/year of mineral waste streams including contaminated soils, spent blasting grit and sweeping waste

- Preferred solution provider for major players in the petrochemical industry in the Port of Antwerp

- Extensive experience with the remediation of emerging contaminants and non-standard chemical parameters

- Own R&D laboratory for washing tests and treatment tests
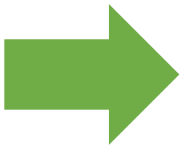
Soil Washing for PFAS

Difference with other contaminants
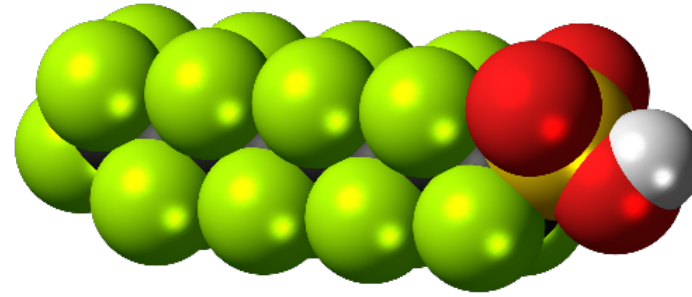
› PFAS in contaminated soils are mainly longer chain molecules and in particular PFOS.

› PFAS are quite soluble in water (e.g. PFOS 520-570 mg/l)

› PFAS adsorb very well to organic matter

› PFAS levels and treatment standards are 1000 to 10000 times lower compared to classic contaminants.

Soil washing of PFAS contaminated soils is based on

▶ Optimizing transfer of PFAS to the process water

▶ Thorough removal of organic matter from the soil as it is a sink for PFAS

▶ Continuous process water treatment to remove contaminant mass from the process.

▶ Secondary washing step of gravel and sand with ultrapure water to remove PFAS traces.

Soil Washing for PFAS

Hybrid Soil Washing Process

Contaminated Soil (PFAS) → **DEME Soil Washing Plant**

DEME Soil Washing Plant → **Residue (fines and organic compounds)**

Process Water Treatment ⇄ **DEME Soil Washing Plant**

Process Water Treatment ⇄ **Process Water Ultra Treatment**
1. Pretreatment
2. GAC

Process Water Ultra Treatment ⇄ **Pretreated Sand (and Gravel)**

DEME Soil Washing Plant → **Pretreated Sand (and Gravel)**

Reactivate GAC → **PFAS destruction**

Pretreated Sand (and Gravel) → **Clean Sand (and Gravel)**

Chemical Stabilisation (optional)

Clean Sand (and Gravel) → **REUSE**

Residue (fines and organic compounds) → **Landfill**

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Soil Washing for PFAS
Typical PFAS Mass Balance

Soil Washing for PFAS
Activated Carbon Consumption

Contaminated Soil (PFAS) — 10000 ton @ 100 µg/kg, DM = 1 kg PFAS

Process Water Treatment

DEME Soil Washing Plant

Residue (fines and organic compounds)

0,75 kg PFAS = 750 kg GAC — **Process Water Ultra Treatment** 1. Pretreatment 2. GAC

Pretreated Sand (and Gravel)

Reactivate GAC

Clean Sand (and Gravel)

Chemical Stabilisation (optiona)

PFAS destruction

<0,01 kg PFAS — **REUSE**

0,25 kg PFAS — **Landfill**

Treatment Standards

- Mostly focus on PFOS and PFOA, combined with ∑PFAS

- Concentration targets in most countries. In some countries leaching standards.

- Standards evolve with time…

- Examples:

Flanders:

▶PFOS < 3 µg/kg DM

▶PFOA < 3 µg/kg DM

▶∑ other PFAS < 8 µg/kg DM

▶1/1/2025: leaching $\sum_{20}$PFAS < 0,1 µg/l DM

Netherlands:

▶PFOS < 3 µg/kg DM

▶PFOA < 7 µg/kg DM

▶∑ other PFAS < 3 µg/kg DM

Design & Validation

Lab Testing: PFAS washing protocol

Flowchart:

Initial sample →

(1) STEP 1 Wet sieving
- > 2 mm → Gravel
- < 63 µm → Settling/dewatering → Fines, Process water 1

→ Sand 1

(2) STEP 2 Upstream classifier → Organic Matter, Process water 2
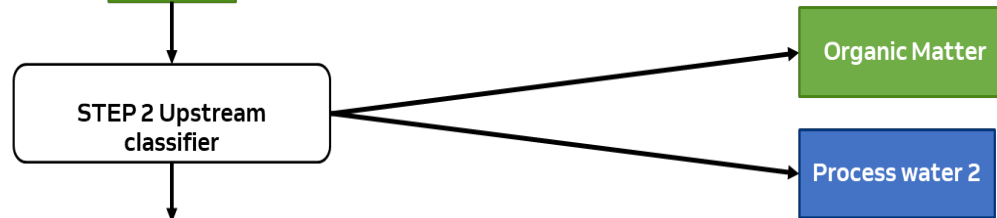
→ Sand 2

(3) STEP 3 Additional step → Residue, Process water 3
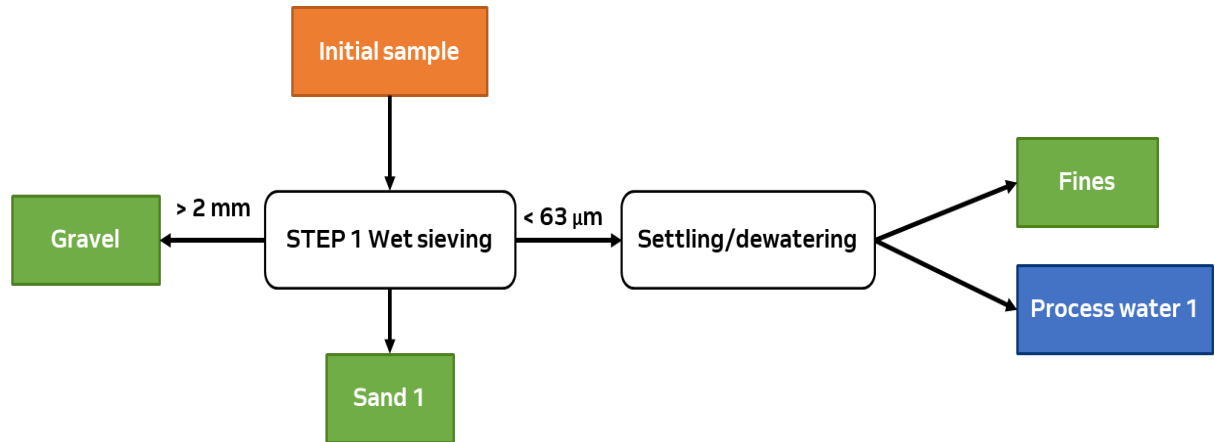
→ Sand 3
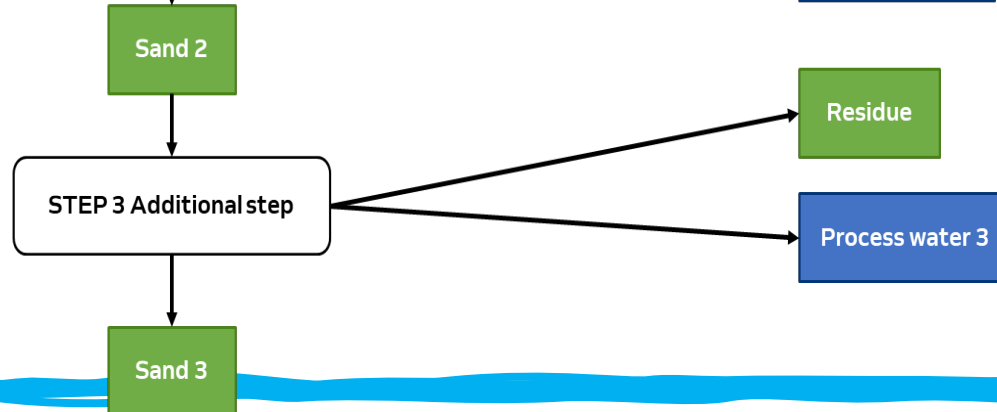
- ▶ PFAS washing protocol focus on sand and process water treatment
- ▶ Full PFAS mass balance, TOP Assay optional
- ▶ Kinetics of PFAS dissolution
- ▶ Contribution of organic matter adsorption
- ▶ Attrition scrubbing and froth flotation optional extra steps

Case Studies

Lab Studies

▶ Airport authorities: Belgium, Netherlands, Sweden, Norway, UK

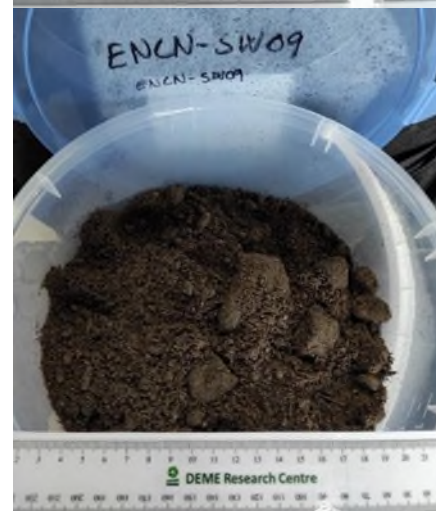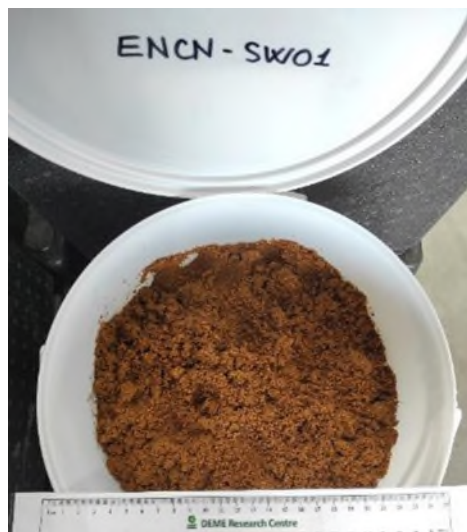▶ Private companies: PFAS producers

▶ Public authorities

Full Scale Projects

▶ Former General Motors factory Antwerp-Belgium (2021): 35.000 tons

▶ Oosterweel Link project: 300.000 tons

▶ Various clients Port of Antwerp: 150.000 tons

▶ Design, build, operate bespoke soil washing plant at a major European airport: 200.000 tons (2024-2027)

Relative leachability versus OMC

Washing Results

	SW01	SW02	SW03	SW04	SW05	SW06	SW07	SW08	SW09	SW10
■ Initial PFAS in soil	420	2600	1200	1600	130	8,7	5,4	1500	380	190
■ PFAS in sand after step1	32	560	240	350	18	2,4	0,48	290	120	24
■ PFAS in sand after step 2	11	59	100	55	8,5	0,55	0	63	47	6,2
■ PFAS in sand after step 3		1,9	11	6,8				15	21	
— Reuse target (30 µg/kg DM)	30	30	30	30	30	30	30	30	30	30
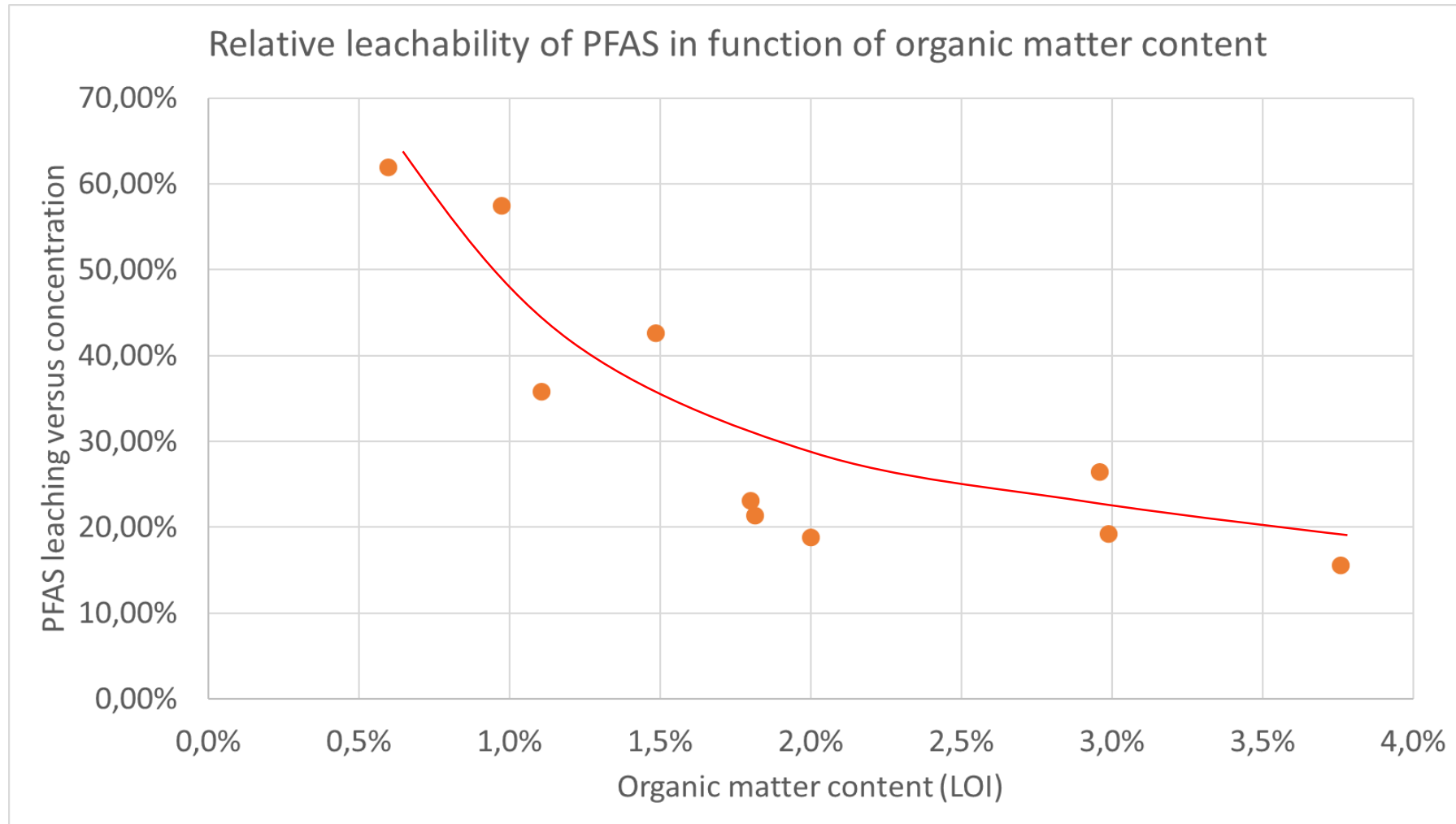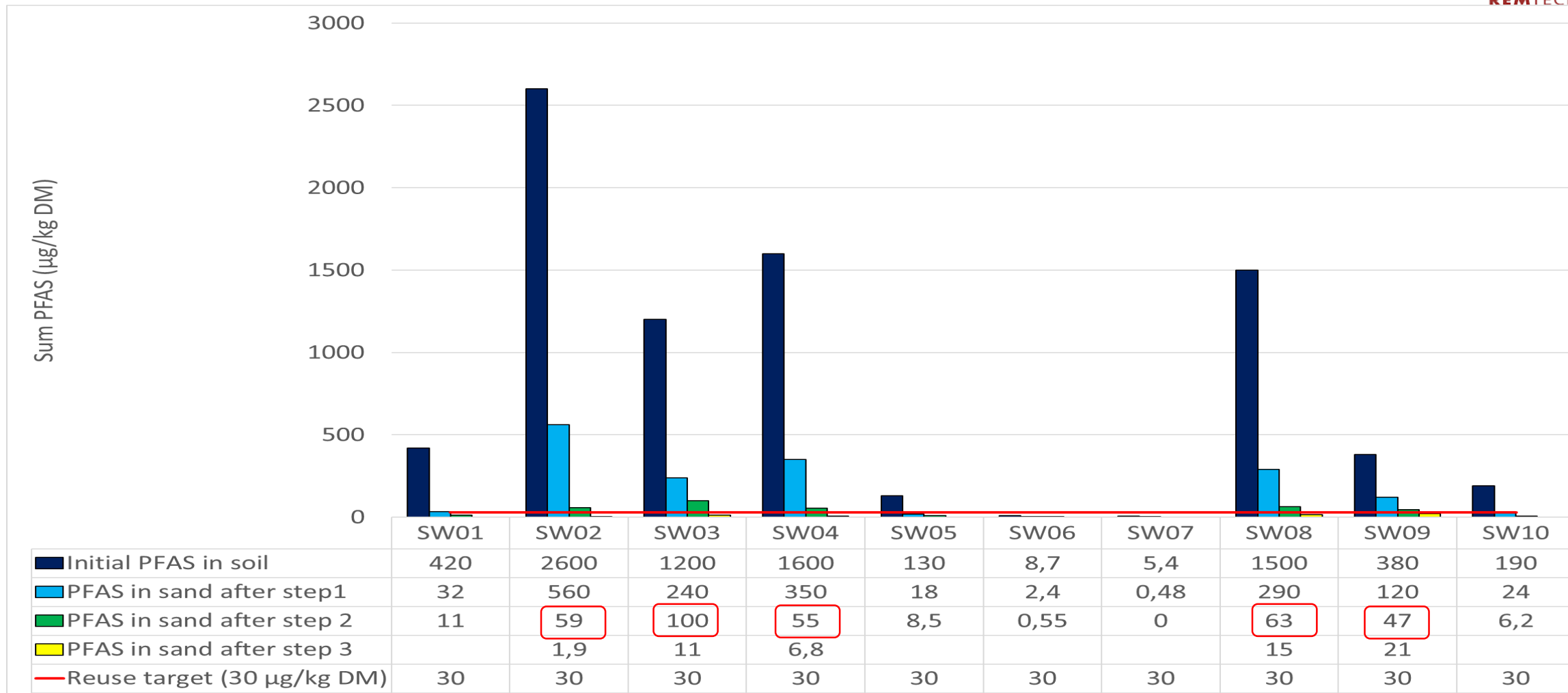
Visual Assessment Washed Fractions

Mass Balances

- **87 to 99% (based on DM) of the soil can be recovered** for reuse in the form of sand and some gravel

- **91 to 97% of the PFAS can be removed** in two washing steps

- **Additional scrubbing results in > 99% removal**

SW01	Initial
dry mass vs input (%)	100%
PFAS (µg/kg DM)	420
PFAS vs input (%)	100%

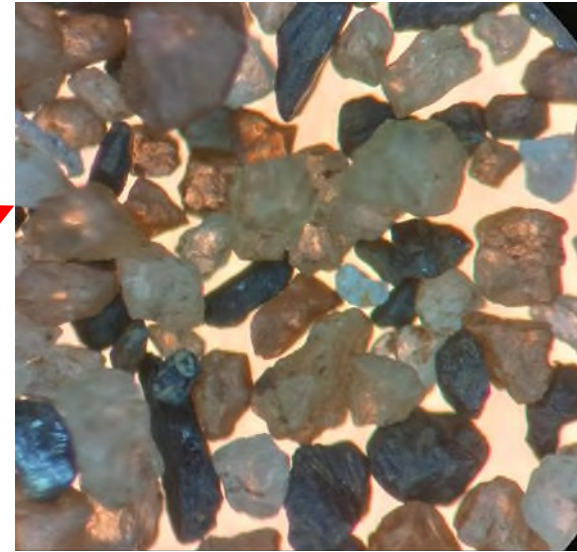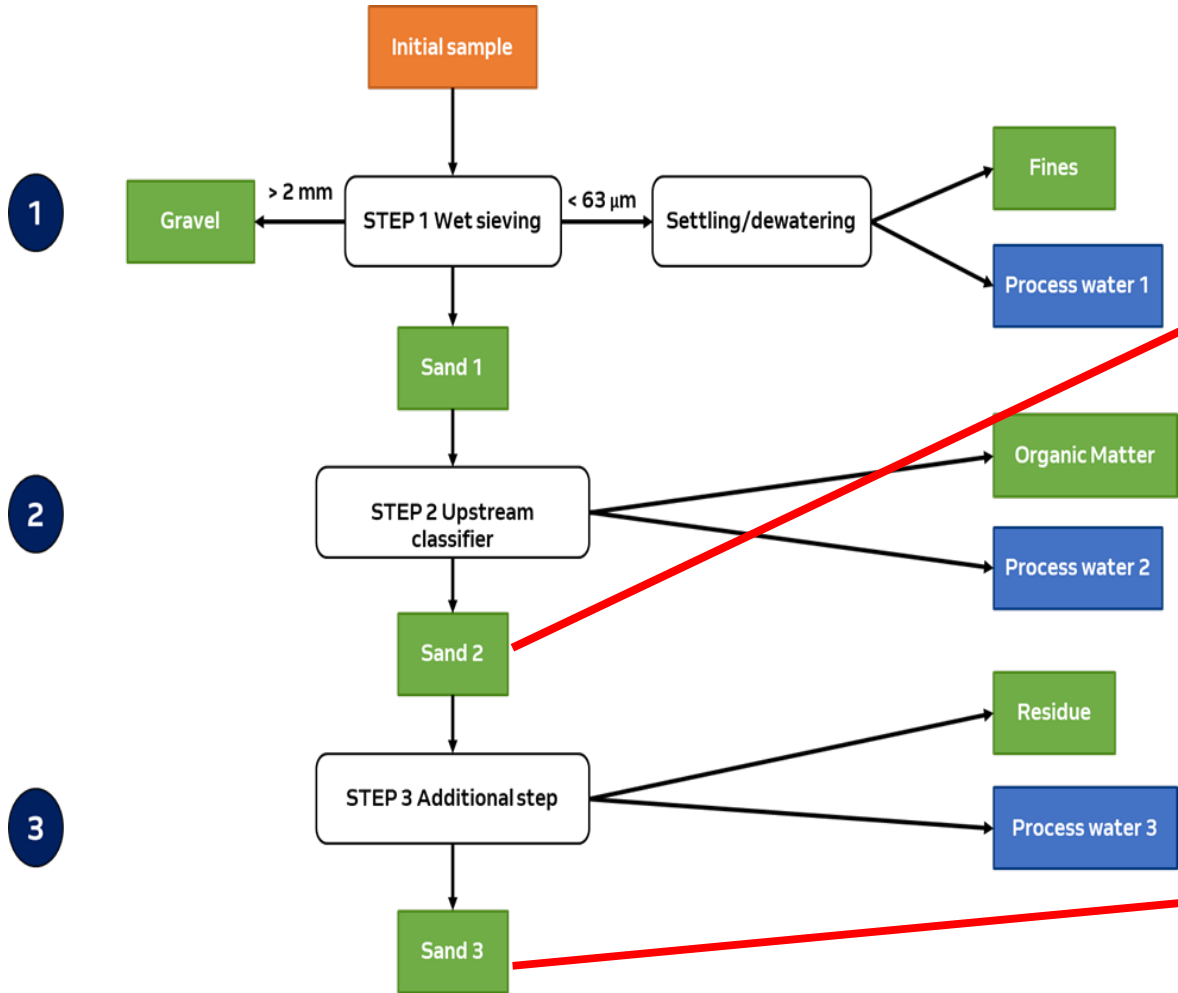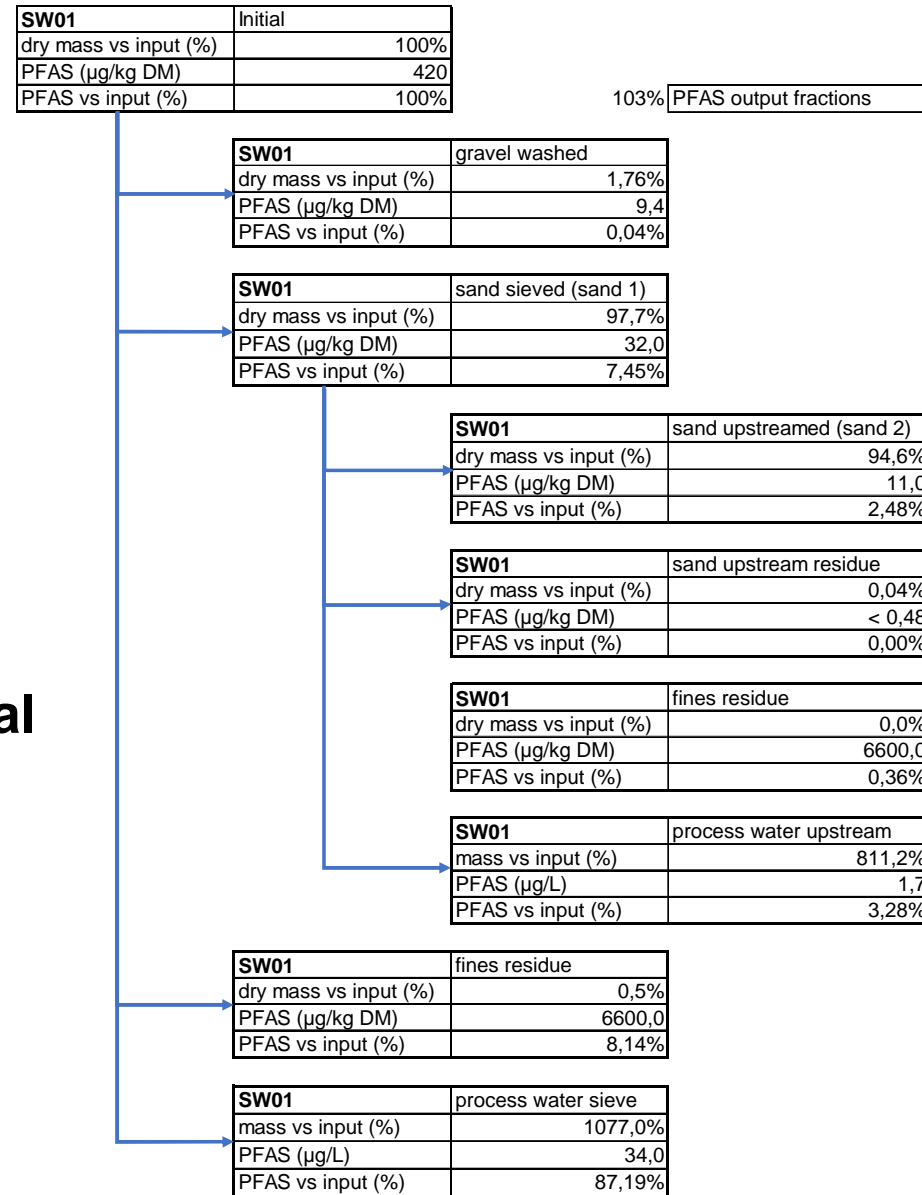103% PFAS output fractions

SW01	gravel washed
dry mass vs input (%)	1,76%
PFAS (µg/kg DM)	9,4
PFAS vs input (%)	0,04%

SW01	sand sieved (sand 1)
dry mass vs input (%)	97,7%
PFAS (µg/kg DM)	32,0
PFAS vs input (%)	7,45%

SW01	sand upstreamed (sand 2)
dry mass vs input (%)	94,6%
PFAS (µg/kg DM)	11,0
PFAS vs input (%)	2,48%

SW01	sand upstream residue
dry mass vs input (%)	0,04%
PFAS (µg/kg DM)	< 0,48
PFAS vs input (%)	0,00%

SW01	fines residue
dry mass vs input (%)	0,0%
PFAS (µg/kg DM)	6600,0
PFAS vs input (%)	0,36%

SW01	process water upstream
mass vs input (%)	811,2%
PFAS (µg/L)	1,7
PFAS vs input (%)	3,28%

SW01	fines residue
dry mass vs input (%)	0,5%
PFAS (µg/kg DM)	6600,0
PFAS vs input (%)	8,14%

SW01	process water sieve
mass vs input (%)	1077,0%
PFAS (µg/L)	34,0
PFAS vs input (%)	87,19%

Conclusions

- The hybrid soil washing process is capable of removing more than 99 % of PFAS from a sandy soil.

- PFAS upconcentrated in GAC can be destroyed

- PFAS in fines residue safely landfilled

- The washing efficiency seems to be more dependent on the nature of the soil (PSD, OMC,…) than on the PFAS composition.

- Each soil requires testing !

OSPITI:

- *Guido Bonfedi,* Environmental Engineering & Market Development | **Eni Rewind**

- *Giuseppe Bortone,* Direttore Generale | **ARPA Emilia-Romagna**

- *Andrea Chiorboli,* Direttore Generale | **Acque del Chiampo**

- *Michele Fratini,* Resp. Area Caratterizzazione e Protezione dei Suoli e Siti Contaminati | **ISPRA**

- *Federica Scaini,* Primo Ricercatore Dipartimento Ambiente e Salute | **ISS**

- *Roberta Vallacchi,* Consigliera regionale | **Partito Democratico della Lombardia**