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Immobilised PFAS vs. weather effects – resistant & durable enough?

Jürgen Bühl, Cornelsen Umwelttechnologie GmbH, sales director

ENSOr Conference Brussels 2024

Immobilised PFAS vs. weather effects - resistant & durable enough?

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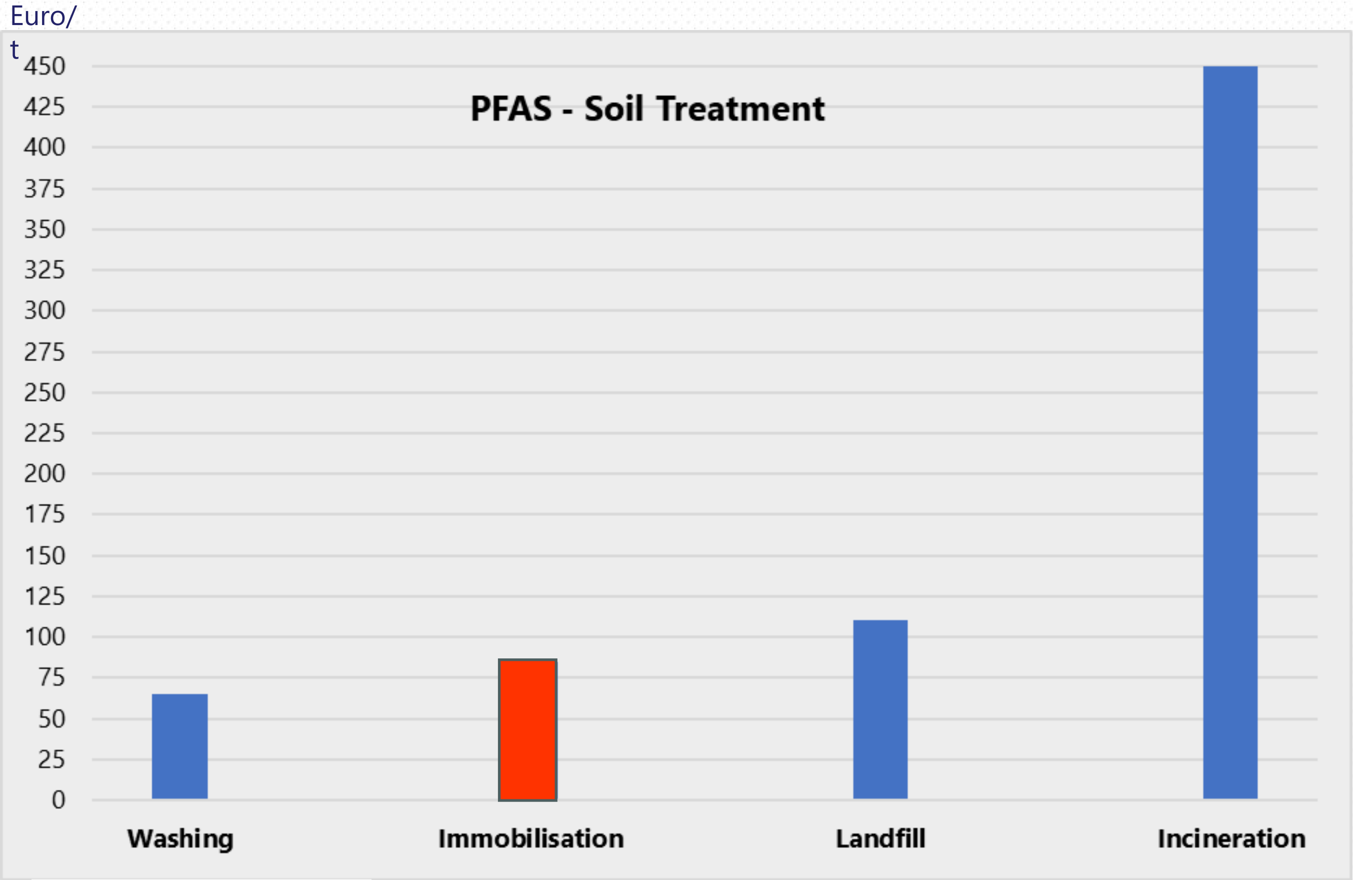
Cornelsen & PFAS business

Cleaning of fire-fighting trucks

Cleaning of fire-fighting systems

Cleaning of fire-fighting water

Treatment Options & Cost



Price level for Germany in 2021

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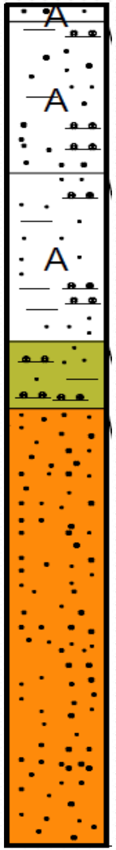
Remediation Approach

- about 3.000 t excavated
- limited space on site
- landfill preferred
- Subset of 200 t used for study
    - ✓ Sorption with RemBind
    - ✓ Target achievable
    - ✓ Durable? - Stress Test



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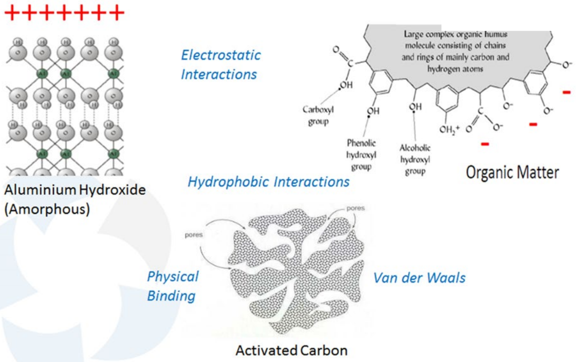
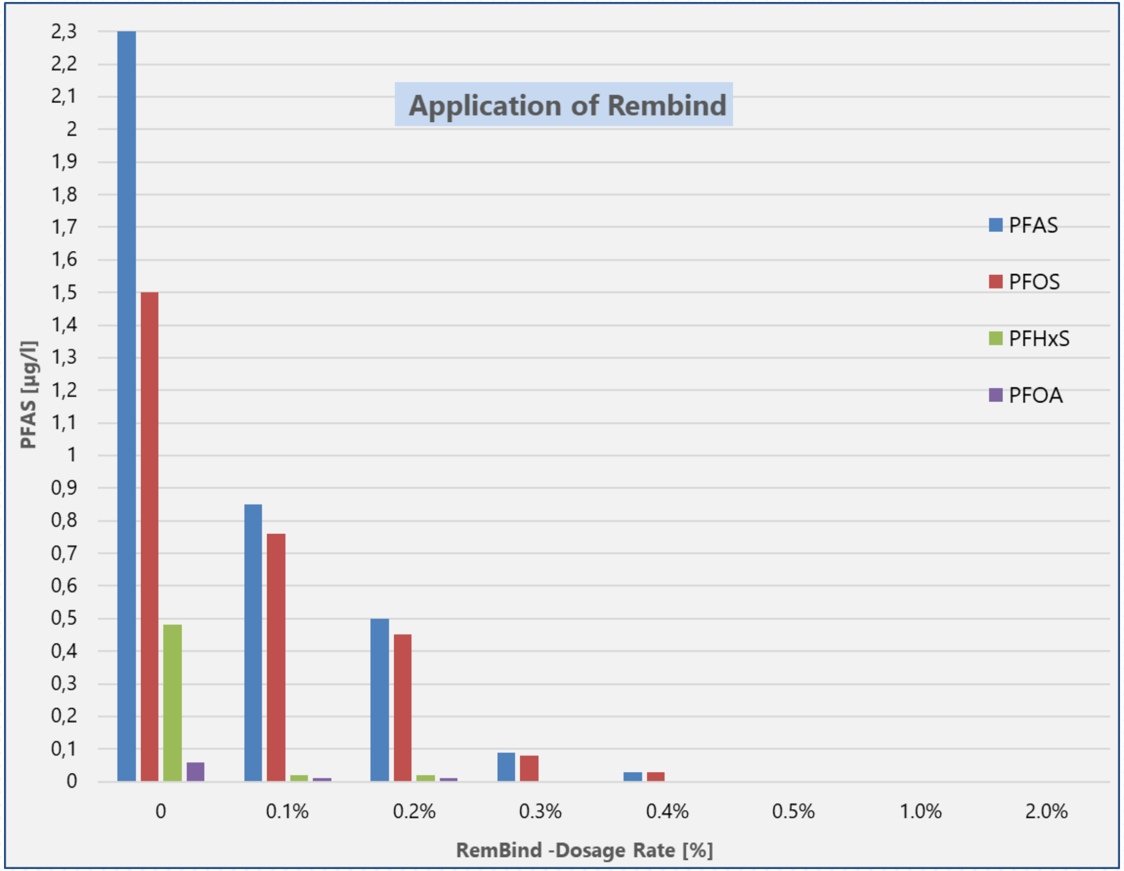
RemBind – Key Facts

- powdered adsorbens
  - + activated carbon
  - + Aluminium hydroxide
  - + Kaolin
  - + Additives
- Dosage adjustable
- 1 to 2,5% (w/w)
- 24 hrs fixation
- Bench Test in advance



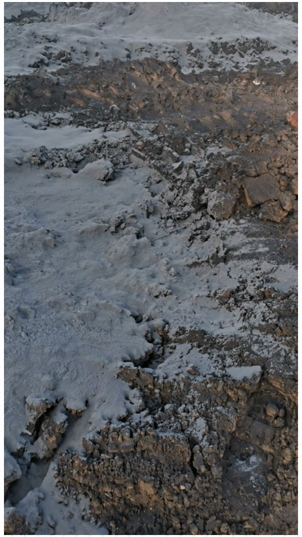
Result of Bench Test

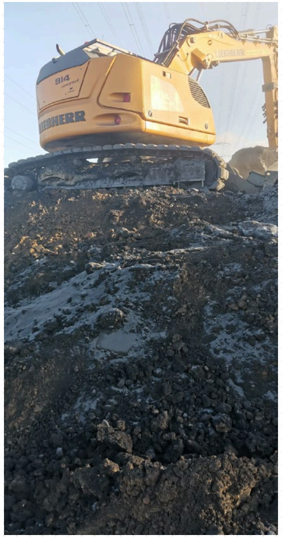


0,05 ppb PFHxA + PFHpS each / 0,04 PFBS / 0,03 PFOSA + PFPeS + 6:2 FTS each / 0,02 PFPeA / 0,01 PFHpA

Application in the Field

- Dosage rate is adjustable
- Mixing is easy
- PFAS no longer soluble
- CO_2 footprint low





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Stress Test at Eurofins/D

- Durability of sorption process
- Idea: check weathering / simulate landfill
- Eluates 2:1 & 10:1

Freeze – Thaw

Wet – Dry

Activated Sludge

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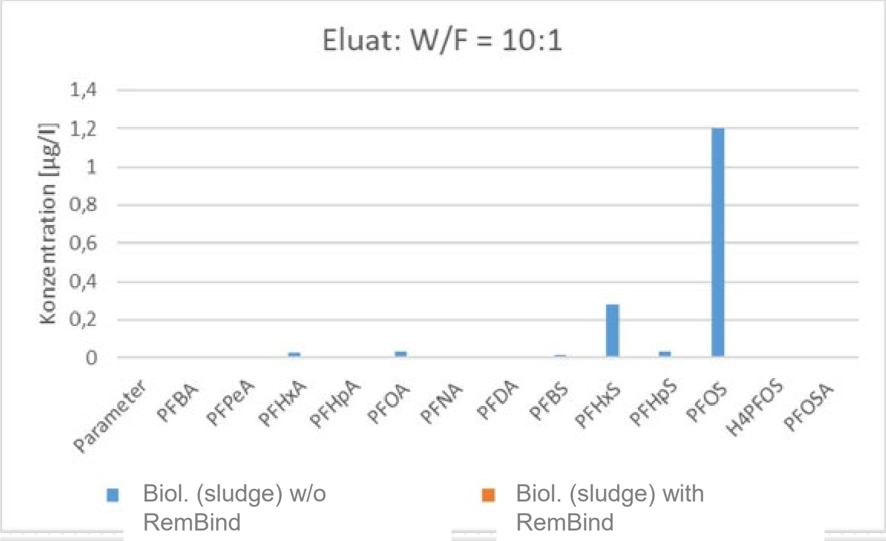
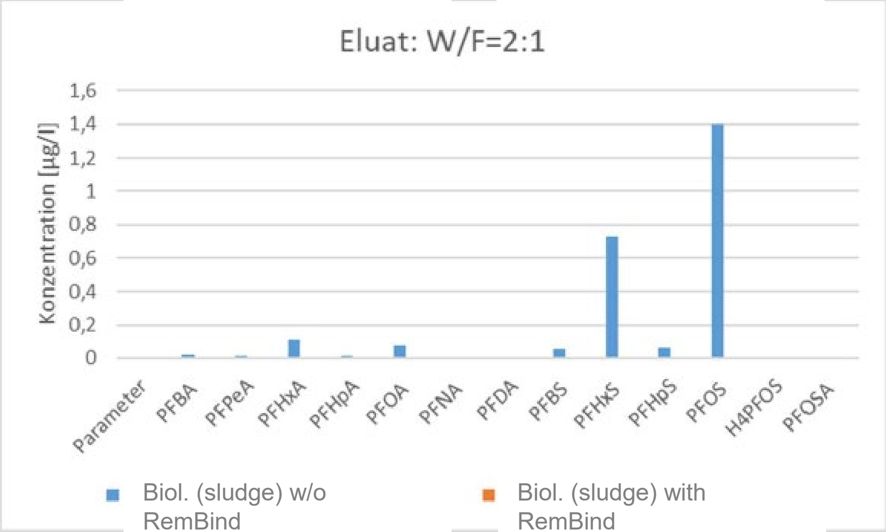
Biol. Stress (Sludge)

eurofins





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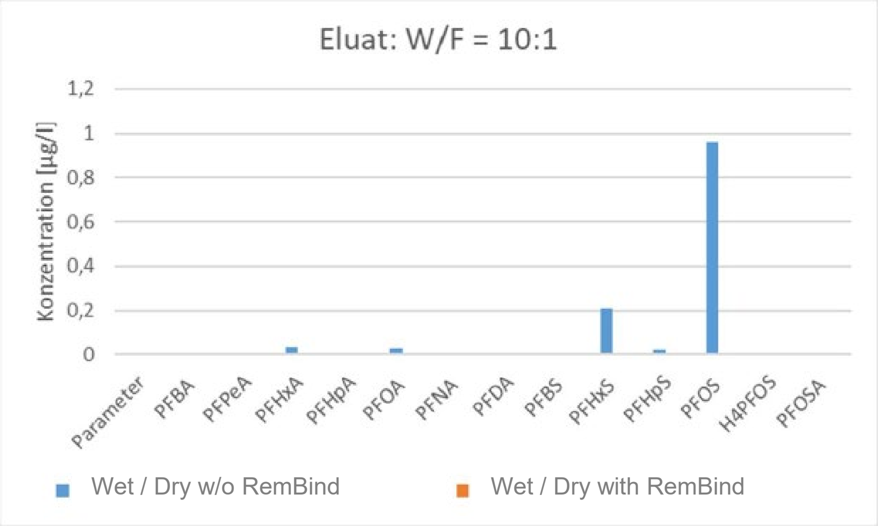
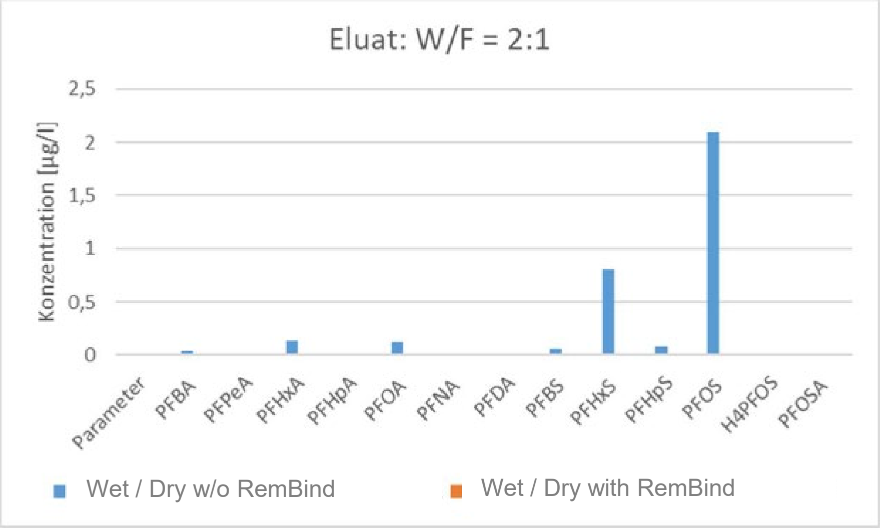
Wet-Dry-Changes





Conclusions

- RemBind binds PFAS (even reduced uptake by plants)
- withstands normal exposure
- Simulation confirms papers (2021 & 2024)
- Literature⁺: durability, long term, comparison, etc.…

Influence of a commercial adsorbent on the leaching behaviour and bioavailability of selected perfluoroalkyl acids (PFAAs) from soil impacted by AFFFs
Jennifer Bräunig, Christine Baduel and Jochen Mueller

Application of soil amendments for reducing PFAS leachability and bioavailability☆
Albert L. Juhasz[a,*], Farzana Kastury[a], Carina Herde[b], Wayne Tang[a]

Field-Scale Demonstration of PFAS Leachability Following In Situ Soil Stabilization
Jeffrey T. McDonough,* Richard H. Anderson, Johnsie R. Lang, David Liles, Kasey Matteson, and Theresa Olechiw

Stabilization and solidification remediation of soil contaminated with poly- and perfluoroalkyl substances (PFASs)
Mattias Sörengård[a,*], Dan B. Kleja[b], Lutz Ahrens[a]

Durability of sorption of per- and polyfluorinated alkyl substances in soils immobilised using common adsorbents: 1. Effects of perturbations in pH
Shervin Kabiri[a,*], Marc Centner[b], Michael J. McLaughlin[a,*]

Durability of sorption of per- and polyfluorinated alkyl substances in soils immobilized using common adsorbents: 2. Effects of repeated leaching, temperature extremes, ionic strength and competing ions
Shervin Kabiri*, Michael J. McLaughlin*

Both Apr 2021

RemBind®

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Many Thanks!

- Questions or more information??

brand-new

Assessing the impact of immobilisation on the bioavailability of PFAS to plants in contaminated Australian soils

Sali Khair Biek[1,2] · Leadin S. Khudur[1,2] · Laura Rigby[2] · Navneet Singh[3] · Matthew Askeland[3] · Andrew S. Ball[1,2]

Received: 23 October 2023 / Accepted: 12 February 2024

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EmConSoil
a Multi-stakeholder Network for Emerging Soil Contaminants

Pilot and full-scale treatment of PFAS-contaminated ground water by means of different types of (innovative) adsorbents

Tiza Spit, Witteveen &Bos, Process engineer wastewater

be EU
belgium24.eu

PFAS removal in Doetinchem

Ground water treatment

Tiza Spit & Ruben Oost

14-3-2024

Programme

1. Background Doetinchem
2. Pilot Voltastraat:
    1. Adsorbents
    2. Research set-up
    3. Results
3. Full-scale Iseldoks
4. Conclusion

1. Background Voltatraat

- Rutgers Milieu BV, fire extinguisher recycling
- Aqueous Film Forming Foam (AFFF)
- 1300 IBC's in 10 years

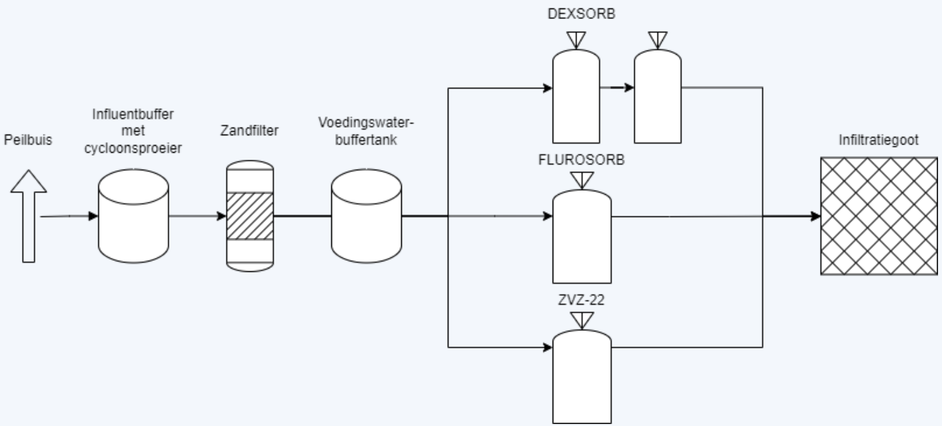





2.1 Adsorbents

	Producer	Capacity	Single use
Activated carbon	Norit	+	X
DEXSORB	Cyclopure	++	
FLUOROSORB	Cetco	+++	X
ZVZ-22	Viritec	++	X

2.2 Research set-up Voltastraat



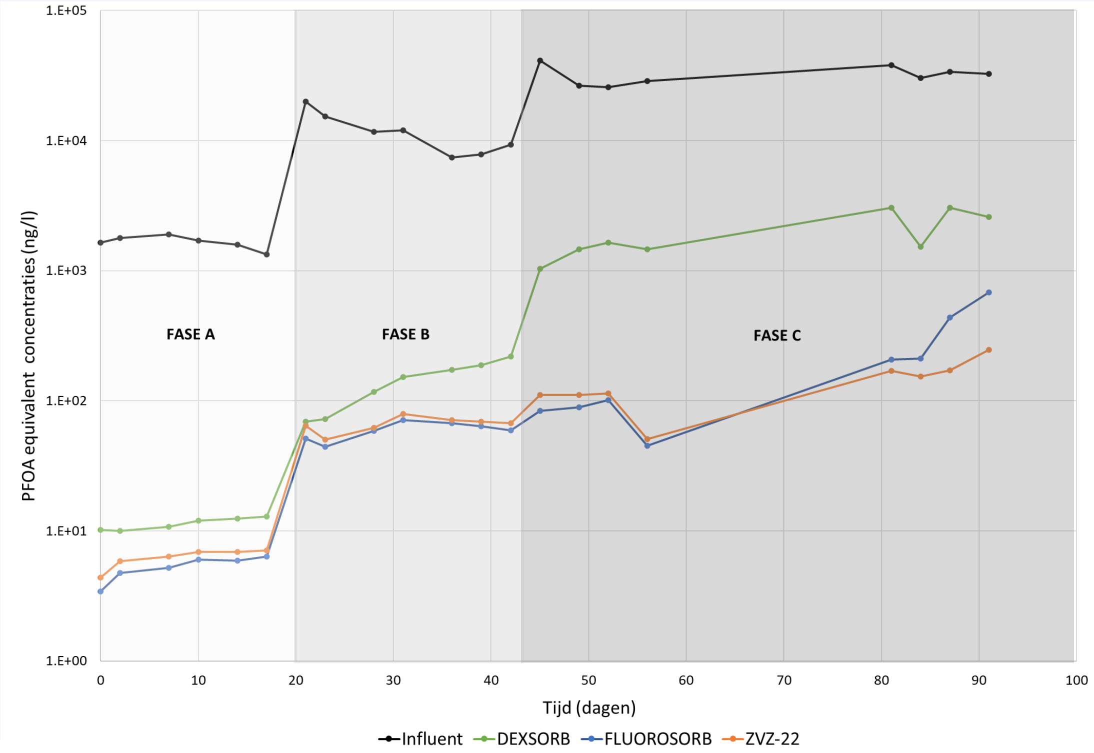
- Difference in medium capacity
- 3 phases of 3 weeks
- Each phase a different extraction location with a higher PFAS concentration

Witteveen + Bos

2.2 Incoming concentrations per phase

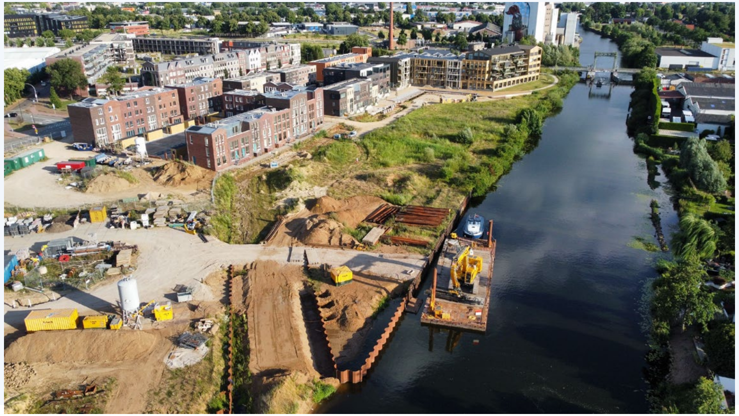
PFAS	Unit	Phase A (low)	Phase B (medium)	Phase C (high)
PFOA total	ng/l	123	719	3100
PFOS total	ng/l	580	2500	5700
6:2 FTS	ng/l	247	7076	34250
PFBA	ng/l	59	419	2750
PFPeA	ng/l	178	1886	4500
PFHxA	ng/l	168	2143	13000
PFHpA	ng/l	75	549	2650
PFNA	ng/l	1	2	17
4:2 FTS	ng/l	1	36	155

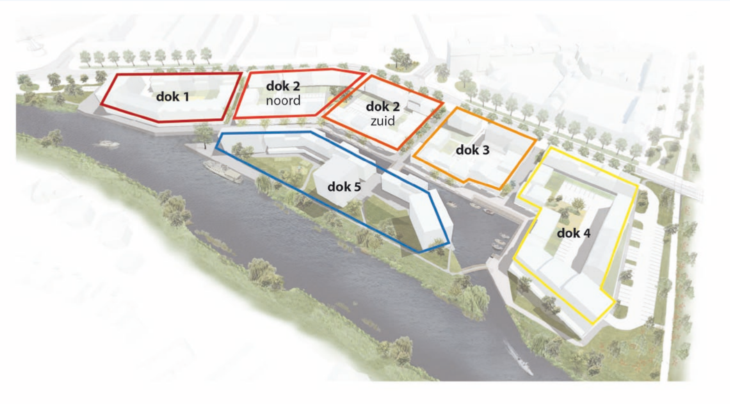
2.3 Results PFAS-concentrations



3.1 Background Iseldoks

- Former fire station contaminated groundwater with PFAS
- Construction site → groundwater drainage from construction pits
- PFAS removal from drainage water before discharge in river



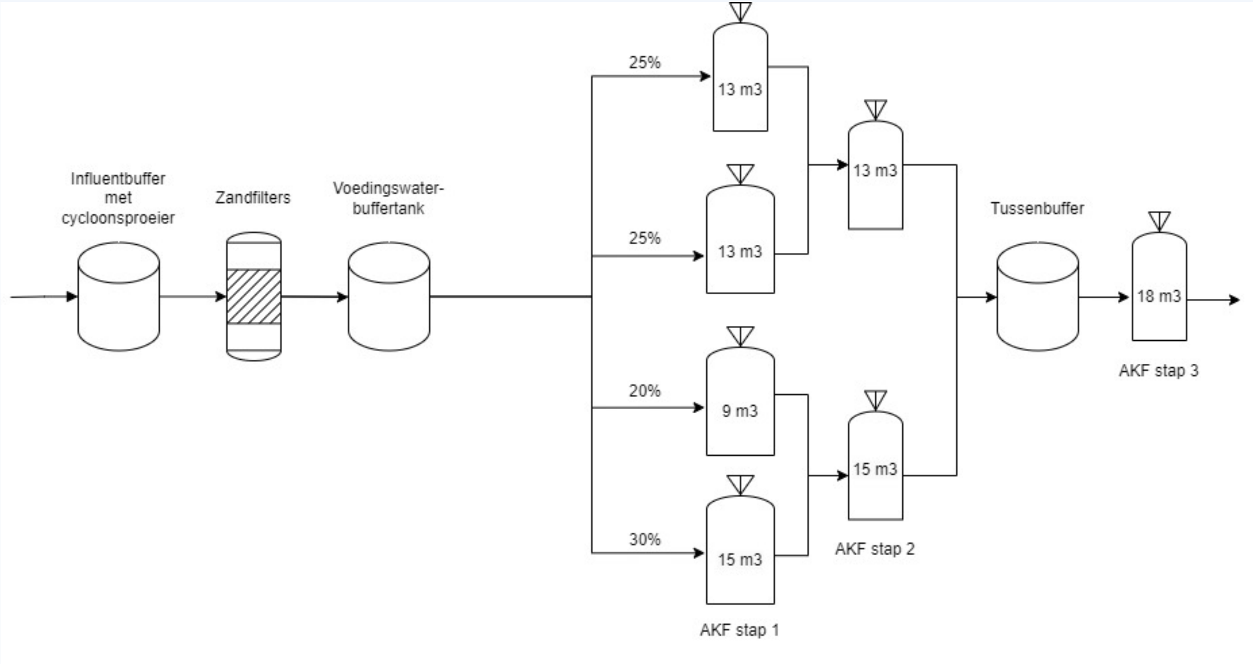


Witteveen + Bos

3.2 Project dimensions

	DOK2	DOK5	DOK1 (ongoing)
Drainage duration	2 weeks	5 months	5 months
Drainage flow (m^3/h)	50	100	240
Treatment flow (m^3/h)	50	100	100

3.3 Treatment set-up



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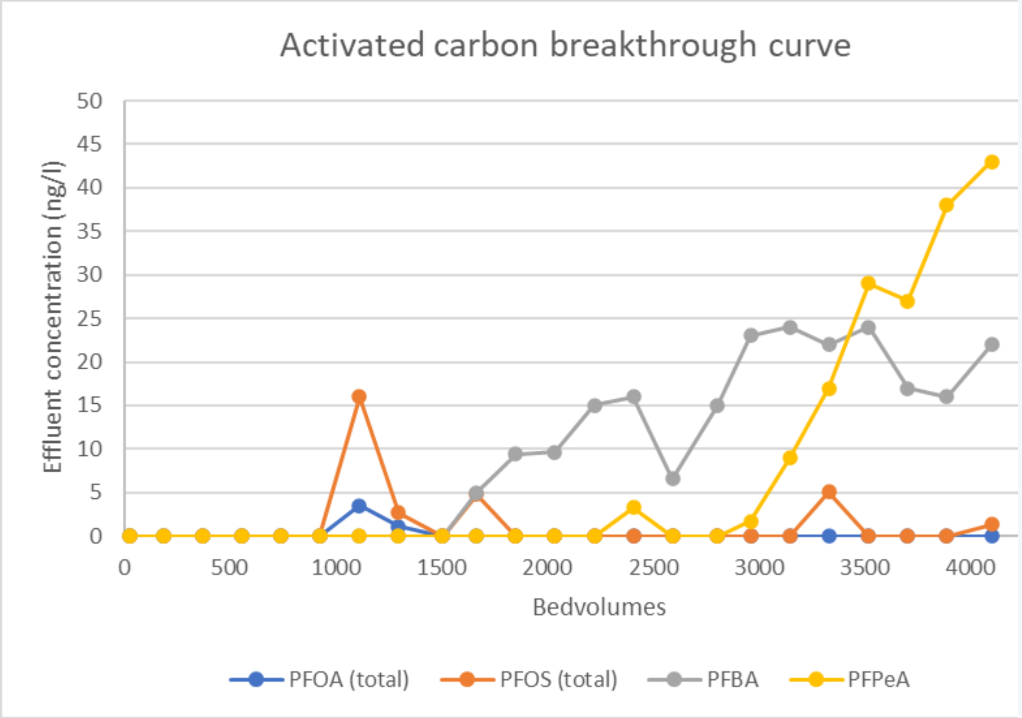
3.4 Incoming concentrations (DOK5)

PFAS	Unit	Min	Average	Max
PFOA total	ng/l	4,5	32,9	138
PFOS total	ng/l	6,3	173,7	840
6:2 FTS	ng/l	1,3	76,1	440
PFBA	ng/l	4,8	21,5	73
PFPeA	ng/l	2	73,7	380
PFHxA	ng/l	2,5	52,2	250
PFHpA	ng/l	1,6	17,7	71
PFNA	ng/l	<0,50	-	2,4
4:2 FTS	ng/l	<0,50	-	<2,8
Total*	ng/l	24	448	2194

3.5 Results

- Activated carbon filtration has proven to be suitable for the removal of PFAS
- Breakthrough of short chain PFAS up to 3 times faster than long chain PFAS



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4. Conclusions

1. Successful removal of PFAS with different types of adsorbents
2. Short chain PFAS removal is limited
3. Combination of different adsorbents could be cost efficient
4. Technique and material selection depends on project specifications

Questions?

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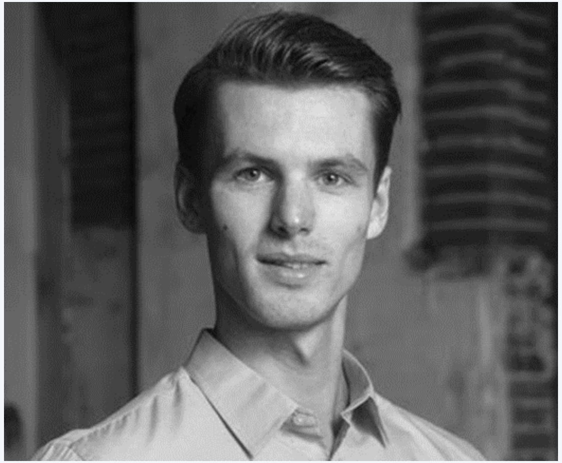

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Bio-flushing for in situ decontamination of saturated and unsaturated soil

Cosimo Masini, DND Biotech, CEO

be EU
belgium24.eu

BIO-FLUSHING for in situ decontamination of saturated and unsaturated soil

Cosimo Masini, CEO cosimo@dndbiotech.it

14th March 2024 – ENSOr 2024

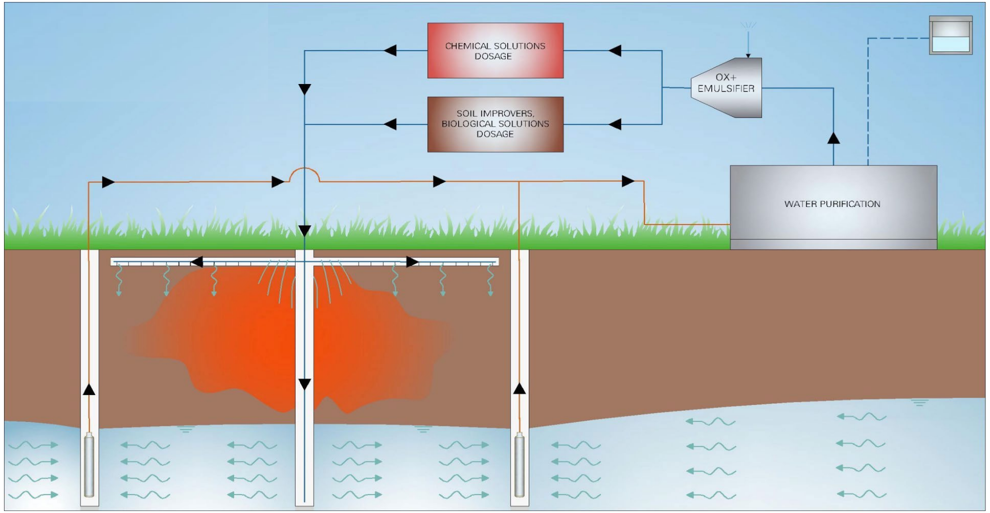
DnD biotech
Discover New Directions

A G E N D A

- TECHNOLOGY CONCEPT
- PLANT LAYOUT
- PROTOTYPES
- PILOT TESTING & RESULTS

BIO-FLUSHING
Technology Concept

A technological system that brings into the subsoil chemical and biological solutions, thereby promoting the removal of contaminants.



- A system of injection and extraction wells/pipes, engineered for geochemical modification, soil conditioning, flushing, biostimulation, bioaugmentation
- Effective in both saturated and unsaturated layers
- Integrated mobile treatment plant for purification of extracted contaminated flushing water and groundwater
- Chemicals dosing units for addition to recirculated injecting water
- Water-based formulations for injections

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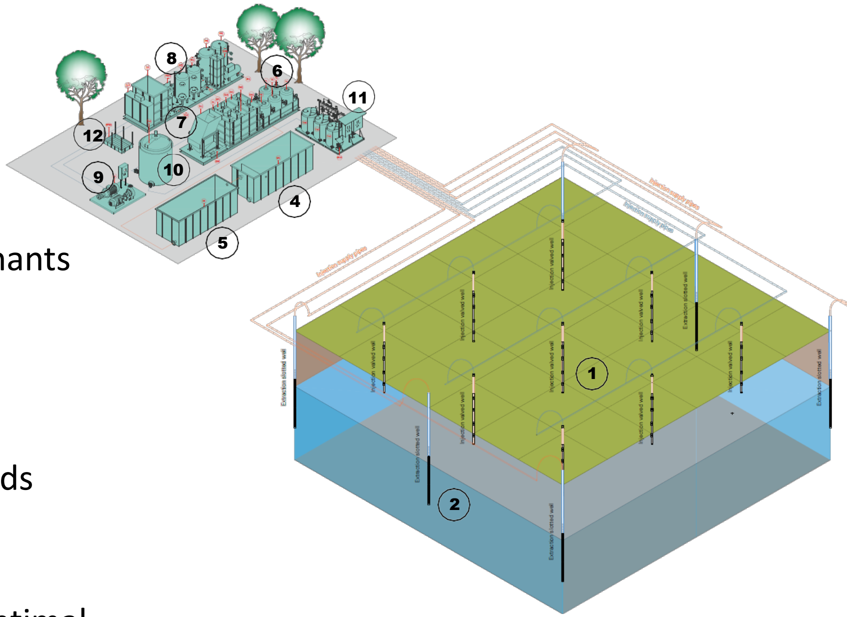
BIO-FLUSHING

Technology Concept

Subsequent or parallel application of *in situ* interventions:

- Physical-chemical soil conditioning (geochemical modification)
- Flushing of subsoil by leaching solutions, for the transformation/desorption/solubilization of inorganic contaminants
- Extraction and purification of contaminated flushing water and groundwater
- Bio-stimulation *in situ* by nutrients and oxygen (injection of fluids enriched with air nano-bubbles)
- Bio-augmentation *in situ* with microbial cultures selected for optimal biodegradation



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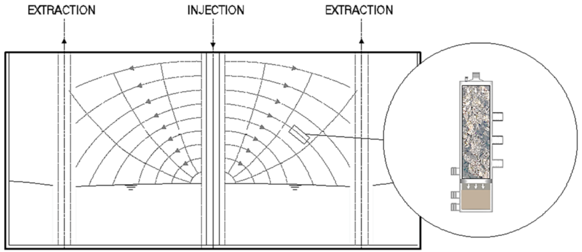
BIO-FLUSHING

Prototypes: flushing solutions

- Model the flushing flow that is established in soil
- Columns representative of portions of soil to be flushed
- Determine the kinetics of abatement/removal of the contaminants from the matrix
- Simulate the flushing with solutions for biostimulation, bioaugmentation, leaching and/or oxidation-reduction
- Equipped with dosing units, production and injection of air nano-bubbles, leachates purification unit



BIO-FLUSHING

Prototypes: injection modes

- Two hydraulic circulation modes: **Jetting and Dispersion**
- Establish a filtration flow that engages the entire volume being treated
- Simulate the injection in different lithological layers
- Calibrate the mathematical model (flow rates, trajectory of the water particles, hydraulic load and pressure).

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BIO-FLUSHING Plant

BIO-FLUSHING Plant

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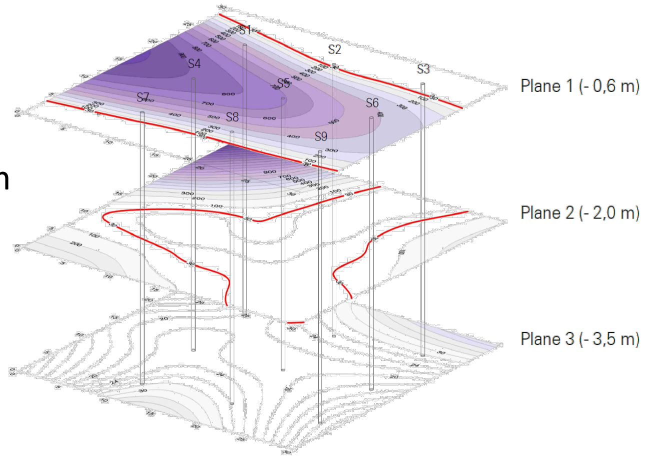
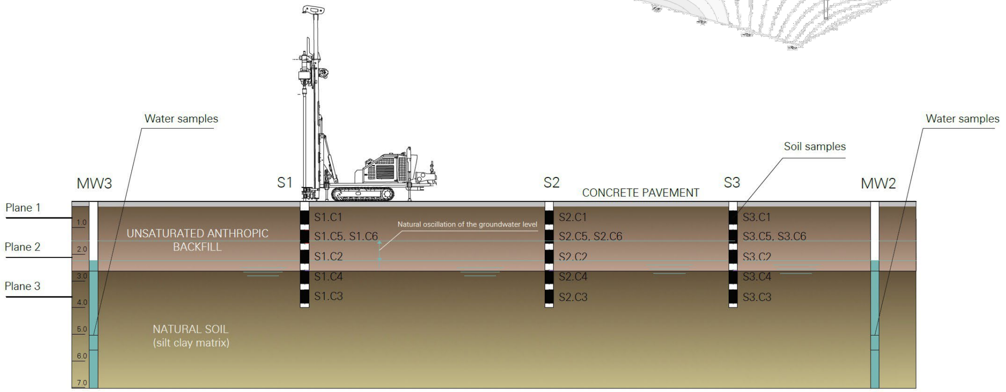
BIO-FLUSHING

Pilot Testing

- Former industrial site in the north of Spain
- Three layers of soil: 0.6 m, 2 m and 3.5 m depth



- Hydrocarbons C10-C40, up to 690 mg/kg
- Heavy hydrocarbons, up to 104 mg/kg
- PAHs, up to 38 mg/kg
- Arsenic, up to 900 mg/kg
- Cadmium and chromium, up to 13 kg/kg
- Lead, up to 2768 mg/kg
- Copper, up to 2485 mg/kg
- Zinc, up to 4494 mg/kg



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BIO-FLUSHING

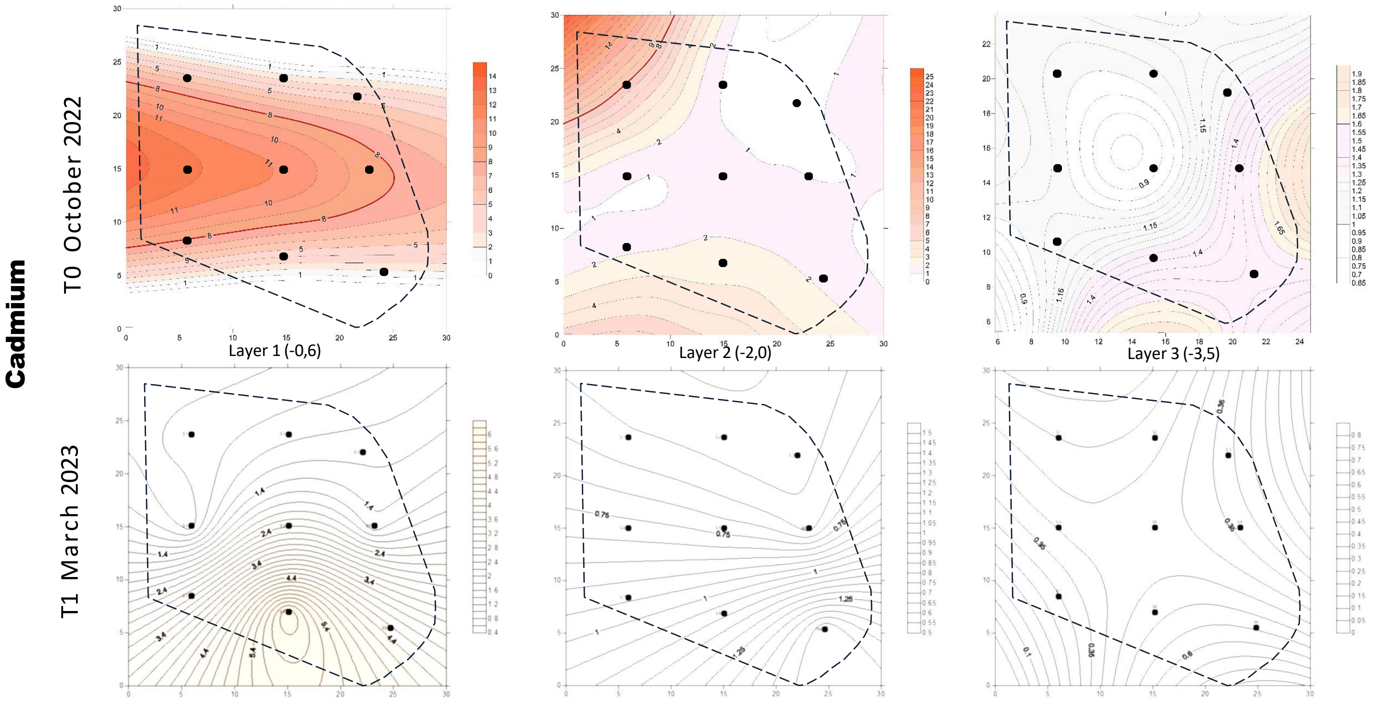
Results

- Effectiveness of the process and of the plant for **the degradation of petroleum and polycyclic aromatic hydrocarbons**, as well as for **the removal of heavy metals**.

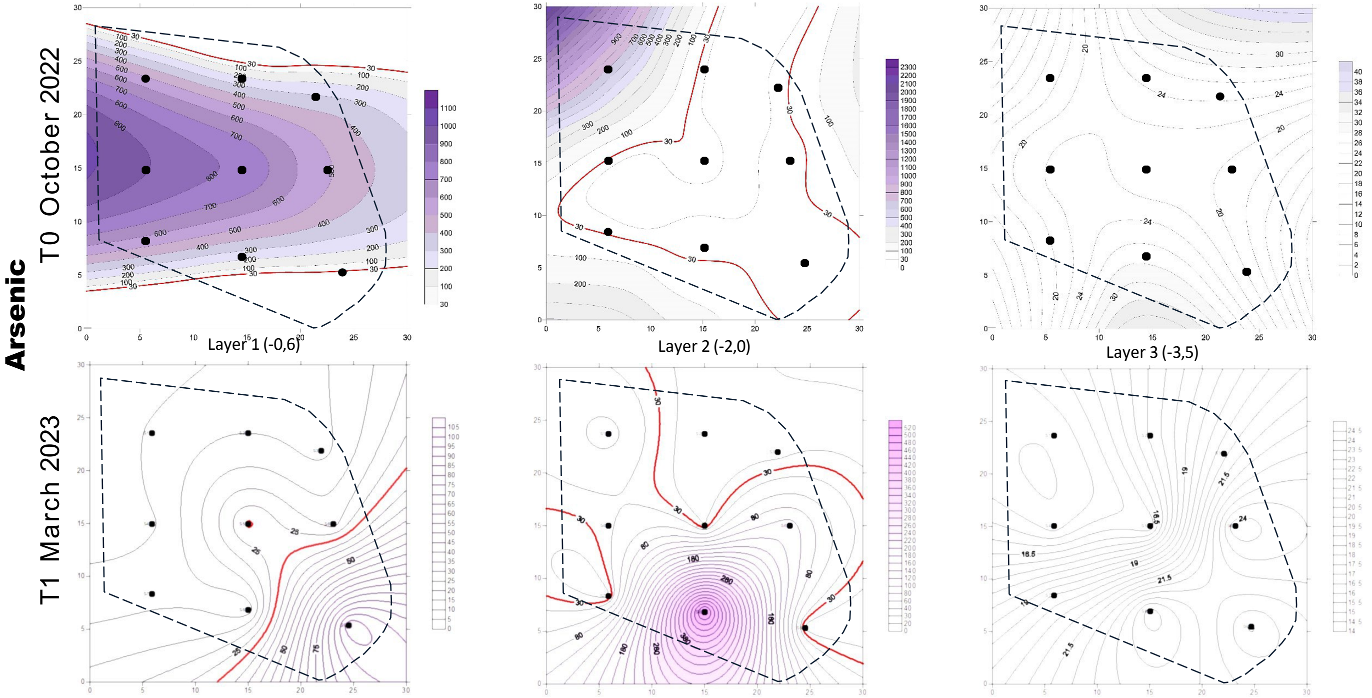
In approximately **5 months of operation of the plant:**

- Inorganic contaminants: Arsenic -97%, Cadmium -82%, Chromium -31%, Nickel -56%, Lead -95 %, Copper -96% and Zinc -94%
- Organic contaminants: Hydrocarbons (TPH) C10-C40 -85%, PAHs (EPA 16) -97%

BIO-FLUSHING Results



BIO-FLUSHING Results



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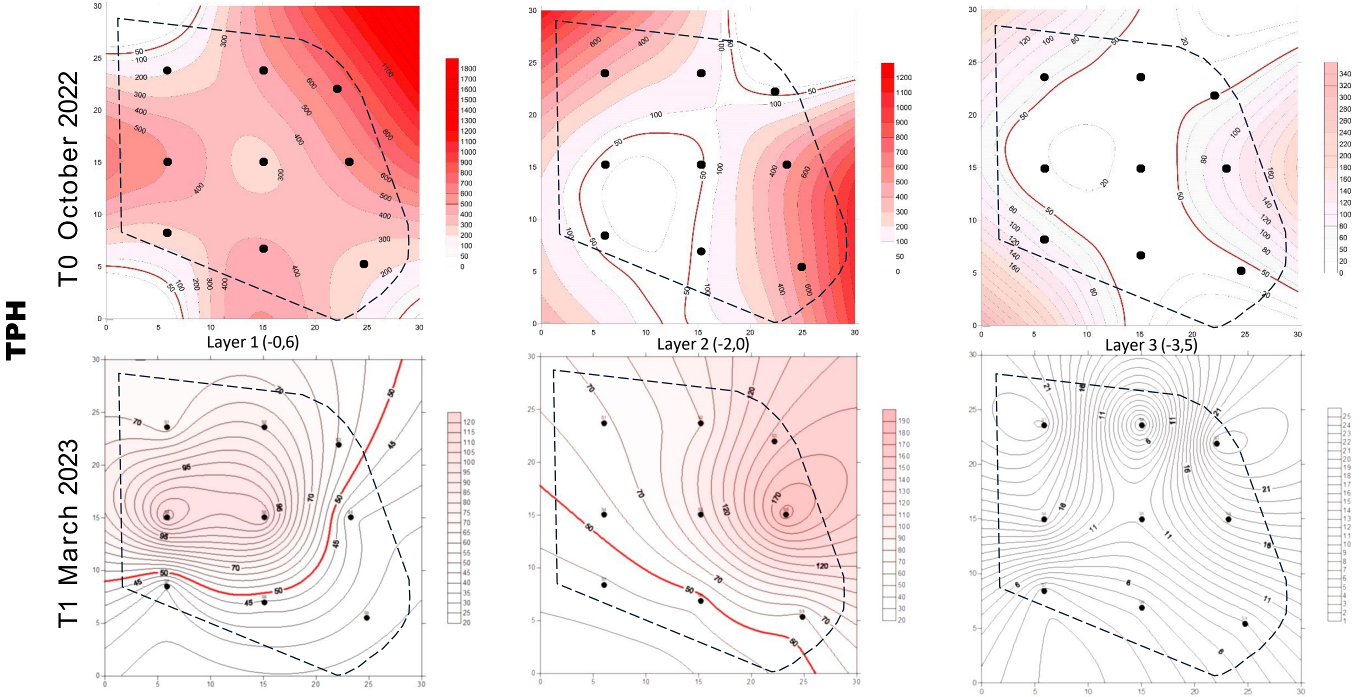
BIO-FLUSHING Results



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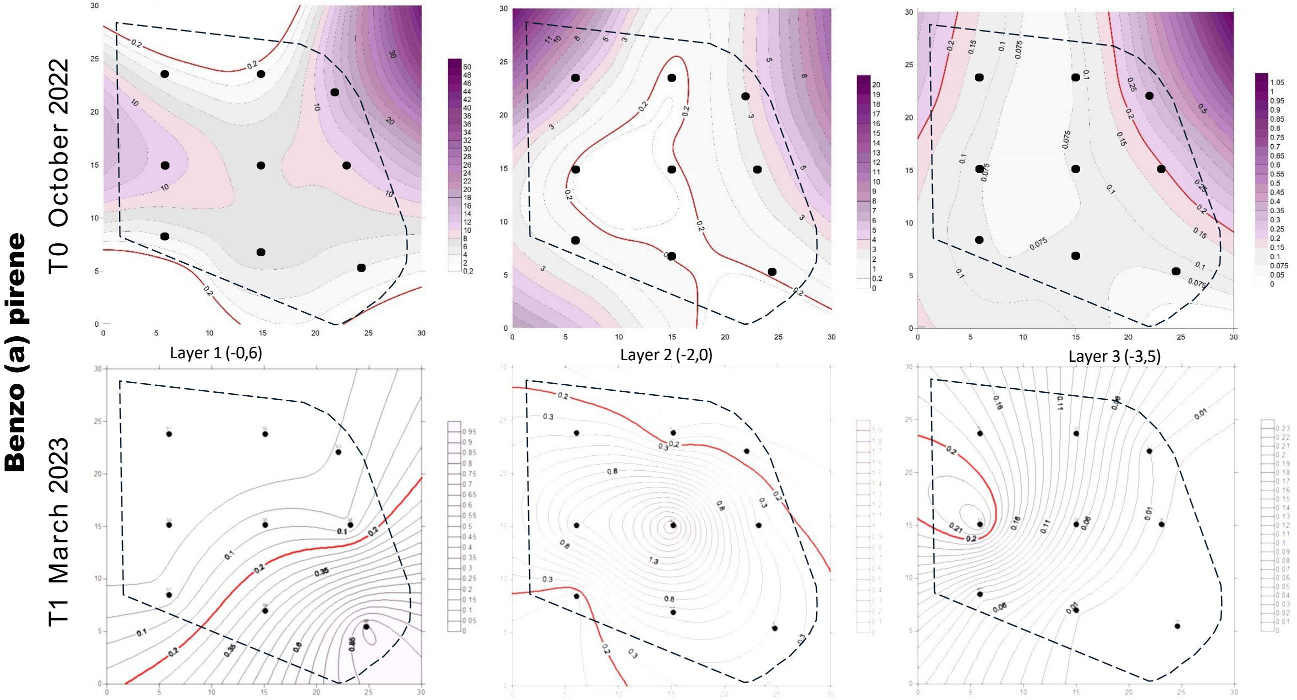
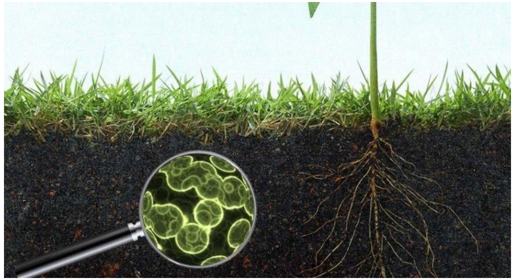
BIO-FLUSHING Results



BIO-FLUSHING Results

The bio-flushing was able to recover soil:

- With increased bacterial indexes of bacterial biodiversity efficient in soil recovery
- Characterised by microbiological traits indicating a recovery of resilience and capacity to eventually offer ecosystemic services
  - An increment of metabolic activity associated to the capacity to transform the organic carbon in soil and to promoting plant growth
  - An increment of metabolic activity involved in the degradation of the organic contamination, indicating a memory effect for the cointanement of similar contaminant spillage



Soil capability of offering **ecosystemic services**

Humification of the organic matter, synthesis of soil humus
Nitrogen fixation
Promoting plant growth

DnD biotech Discover New Directions

**We have not inherited the Earth from our parents,
we have borrowed it from our children.**

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Cosimo Masini
cosimo@dndbiotech.it

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Sustainable in situ solutions for PFAS source-plume systems using colloidal activated carbon

Kris Maerten, REGENESIS, Technical Manager Europe

be EU
belgium24.eu

REGENESIS®

Sustainable in situ solutions for PFAS source-plume systems using colloidal activated carbon

Kris Maerten MSc Eng
Technical Manager, Europe
REGENESIS

ENSOr, March 14th 2024

How can we treat PFAS?

➔ **PFAS are EVERYWHERE!**

➔ Available technologies

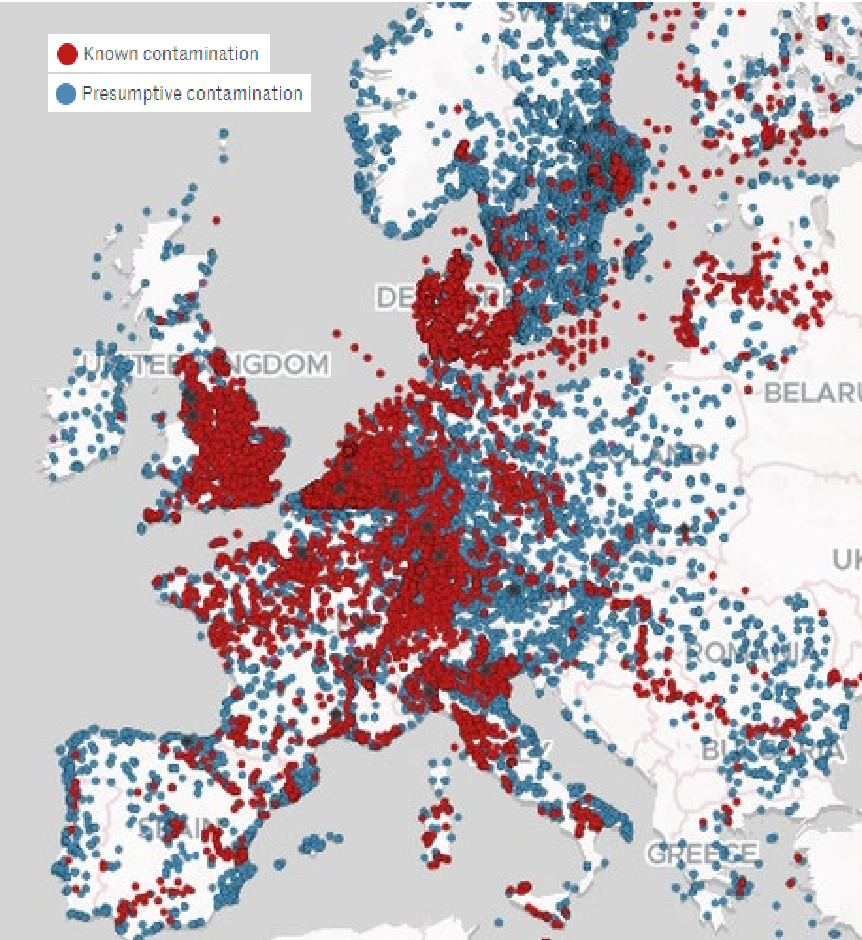
- Feasibility and costs
- Risk for secondary sources
- Sustainability?

(ISO 18504:2017) definition:

Sustainable Remediation is the

‘elimination and/or ***control*** *of unacceptable* ***risks*** *in a safe and timely manner* ***whilst optimizing the environmental, social and economic value*** *of the work.´*

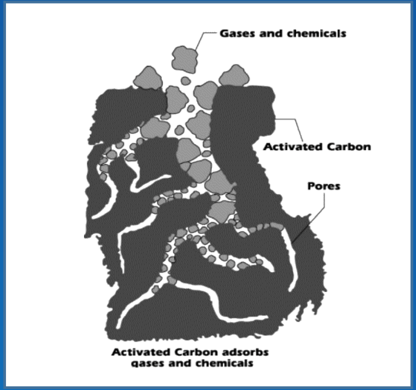
➔ Can we treat PFAS in a sustainable way?



https://www.lemonde.fr/en/les-decodeurs/article/2023/02/23/forever-pollution-explore-the-map-of-europe-s-pfas-contamination_6016905_8.html

Colloidal Activated Carbon: SourceStop and PlumeStop

REGENESIS



Wide area distribution

- No high-pressure fracturing needed

Coats aquifer surfaces

- Creates subsurface activated carbon filter

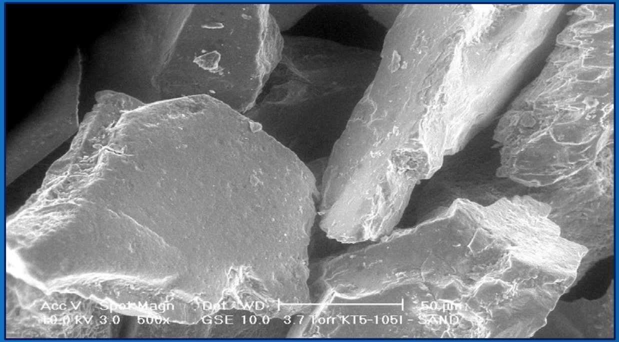
Extremely fast sorption of PFAS

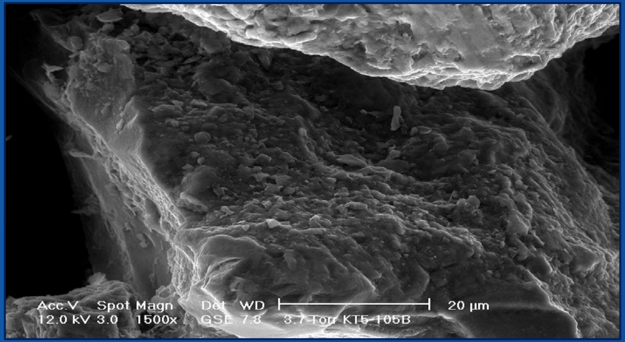
- Smaller particles provide more exterior surface
- Shorter distance to all the sorption sites compared to GA

Xiao, Ulrich, Chen & Higgins. Environ. Sci. Technol. 2017, 51, 6342-6351

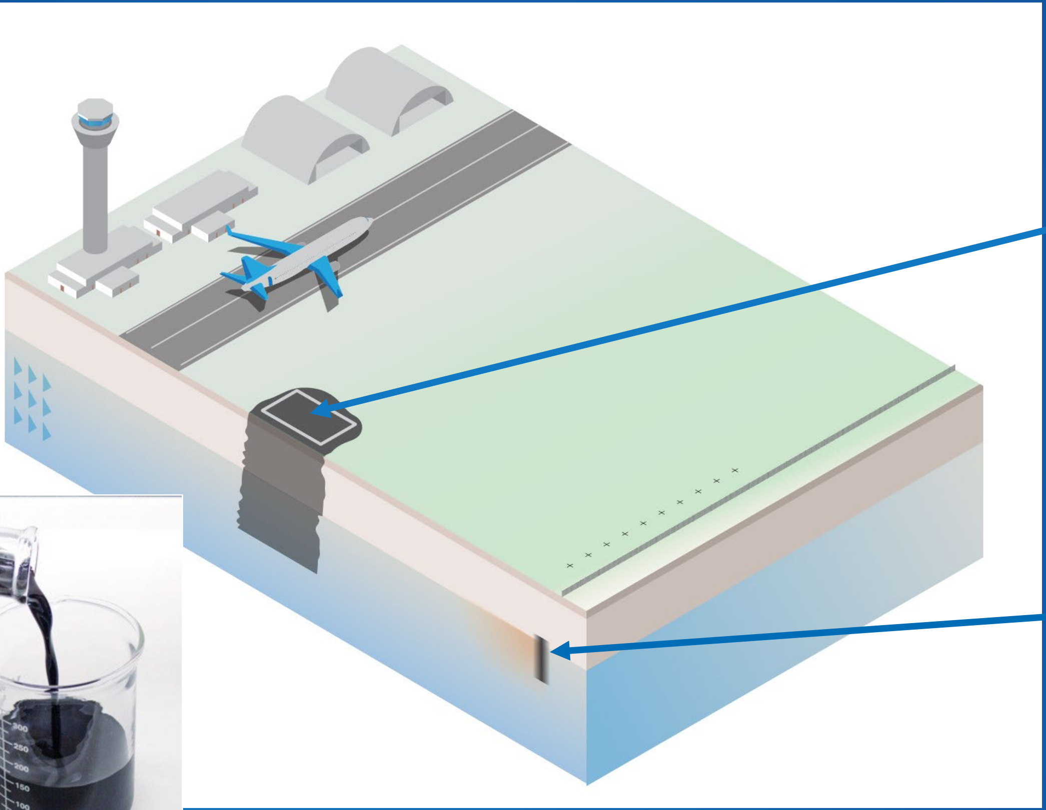
Size: 1 – 2 µm = Size of a red blood cell

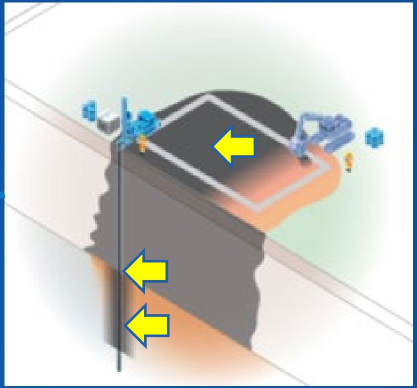
Suspended in water





PFAS Source-Plume System

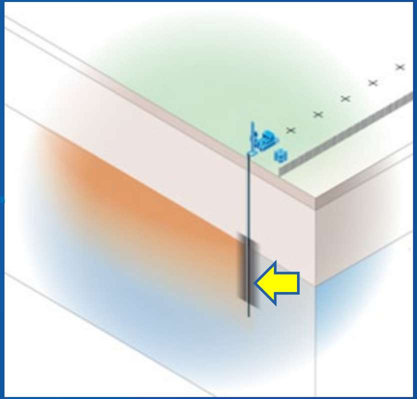




1. Soil - unsaturated

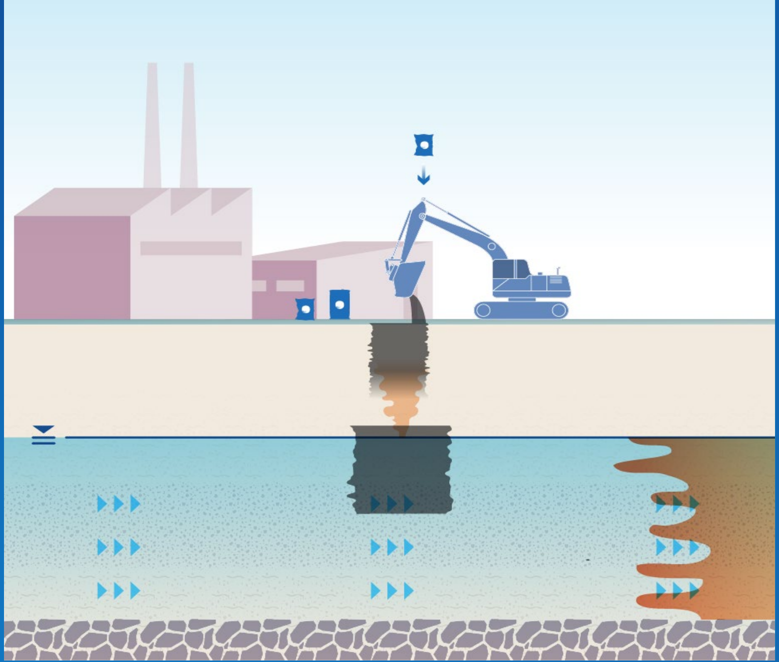
2. Soil – Capillary fringe

3. **Groundwater -** Source



4. **Groundwater - Plume**

Result



- Stabilization of PFAS source
- Stop leaching (‘bleeding’) of source
- Elimination of risks inside treatment area and for downgradient receptors
- (Enhanced) attenuation!

DOI: 10.1002/rem.21731

RESEARCH NOTE

WILEY

Enhanced attenuation (EA) to manage PFAS plumes in groundwater

Charles J. Newell[1] | Hassan Javed[1] | Yue Li[1] | Nicholas W. Johnson[2] | Stephen D. Richardson[3] | John A. Connor[1] | David T. Adamson[1]

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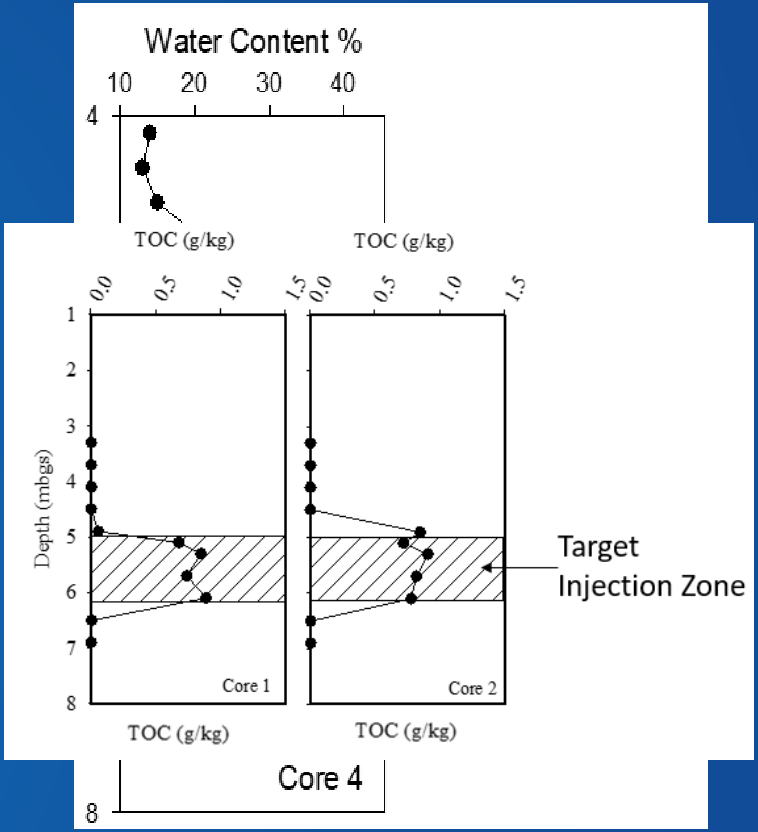
described in a companion paper (Newell et al., 2021). The three-tiered approach applies direct measurements and indirect measurements, calculations, and more complex field and modeling methods to assess PFAS retention in the subsurface. Data requirements to assess the LOEs for quantifying retention in both the vadose and saturated zones are identified, as are 10 key PFAS MNA questions and 10 tools that can be applied to address them. Finally, a list of potential methods to enhance PFAS MNA is provided for

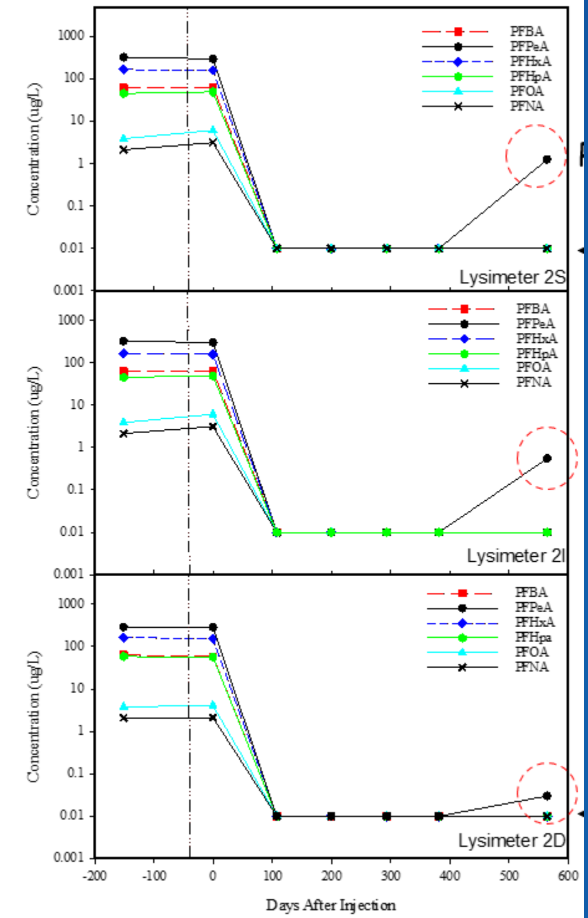
Example site: treatment capillary fringe (InSitu Remediation Services, Canada)

- Geology: silty sand
- Extensive investigation incl. porewater samples collected from lysimeters
- Importance of capillary fringe!
  - Groundwater: max. 66 µg/l (sum ind. compounds)
  - Porewater: max. 709 µg/l (sum ind. compounds)
- Treatment targets air-water interface only
- Injection of PlumeStop
- Placement validation through TOC analyses



Treatment capillary fringe – Results lysimeters

Lysimeter 2



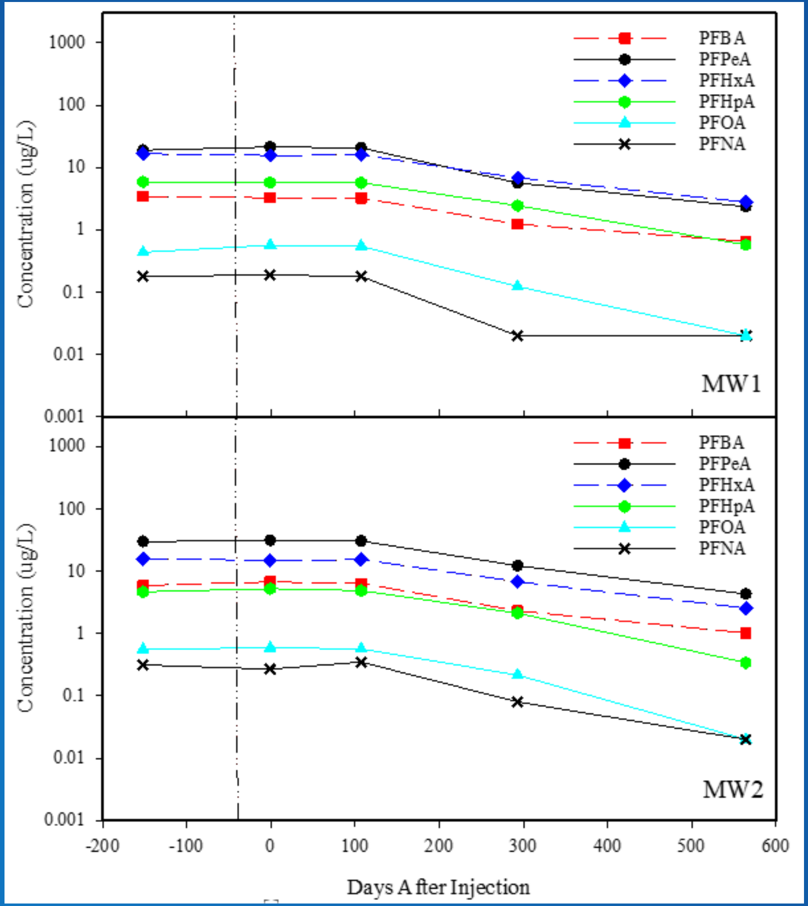
PFPeA – short C chain PFAS (5)

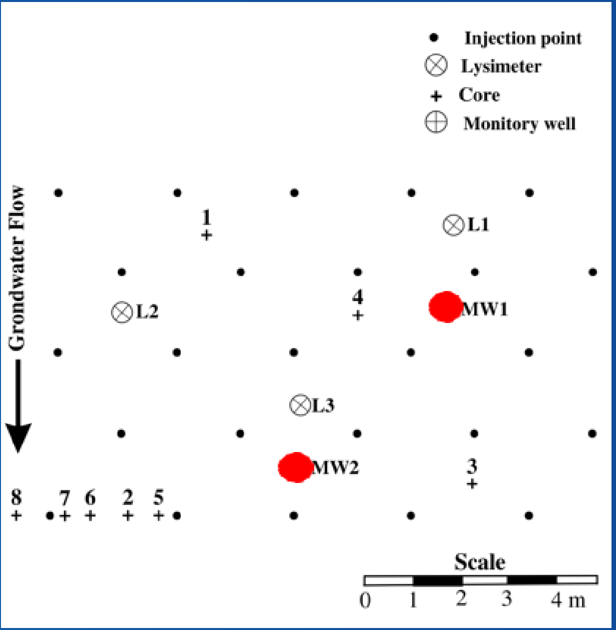
Detection Limit

Detection Limit

Detection Limit

Treatment capillary fringe – Results groundwater





Plume Treatment

REGENESIS

PlumeStop barriers – proven technology

REGENESIS

REGENESIS

REMI

Grid View List View

Award-Winning PFAS Remediation At A Private Airfield

In situ PlumeStop barrier treatment unlocks site divestment and redevelopment in England, UK A sustainable solution - REGENESIS and Mott...

PlumeStop Eliminates PFAS For 7 Years

Download Case Study10m 46s reading time This case study reviews the first known full-scale in situ PFAS treatment worldwide completed in...

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RESEARCH ARTICLE

WILEY

Longevity of colloidal activated carbon for in situ PFAS remediation at AFFF-contaminated airport sites

Grant R. Carey[1] | Seyfollah G. Hakimabadi[2] | Mantake Singh[3] | Rick McGregor[4] | Claire Woodfield[3] | Paul J. Van Geel[3] | Anh Le-Tuan Pham[2]

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Funding information

Porewater Solutions, Ontario Centers for Excellence, and Natural Sciences and Engineering Research Council

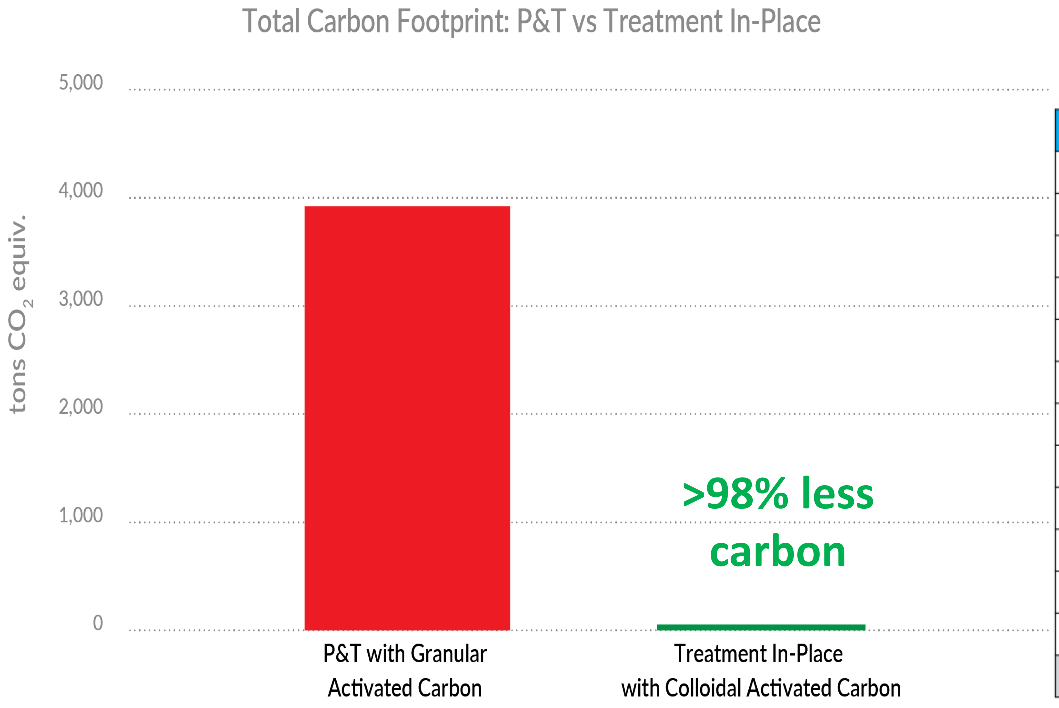
Abstract

A review of state per- and polyfluoroalkyl substances (PFAS) guidelines indicates that four long-chain PFAS (perfluorooctanesulfonic acid [PFOS] and perfluorooctanoic acid [PFOA] followed by perfluorohexanesulfonic acid [PFHxS] and perfluorononanoic acid [PFNA]) are the most frequently regulated PFAS compounds. Analysis of 17 field-scale studies of colloidal activated carbon (CAC) injection at PFAS sites indicates that in situ CAC injection has been generally successful for both short- and long-chain PFAS in the short-term (0.3–6 years), even in the presence of low levels of organic co-contaminants. Freundlich isotherms were determined under competitive sorption conditions using a groundwater sample from an aqueous film-forming foam (AFFF)-impacted site. The median concentrations for these PFAS of interest at 96 AFFF-impacted sites were used to estimate influent concentrations for a CAC longevity model sensitivity analysis. CAC longevity estimates were shown to be insensitive to a wide range of potential cleanup criteria based on modeled conditions. PFOS had the greatest longevity even though PFOS is present at higher concentrations than the other species because the CAC sorption affinity for PFOS is considerably higher than PFOA and PFHxS. Longevity estimates were directly proportional to the CAC fraction in soil and the Freundlich K_f, and were inversely proportional to the influent concentration and average groundwater velocity.

Sustainability study

REGENESIS

Carbon Footprint



	PlumeStop	P&T w/ GAC
Remediation equipment		15,2
Civil works		
Fixed installations	0,05	0,9
Machinery	1,0	1,3
Remediation and operations		
PlumeStop / GAC	50,5	2 860
Electricity		281
Maintenance		3,6
Monitoring	4,0	4,0
Waste management		
Hazardous waste		112
Wastewater treatment		644
Total carbon footprint	**56**	**3 922**

carbon footprint = 70 x

REGENESIS

Thank you

Kris Maerten MSc Eng
Technical Manager Europe
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ENSOr

The Evolution of Two Remediation Technologies: Combined In Situ Stabilization (ISS) and In Situ Chemical Oxidation (ISCO)

Brant Smith, Evonik Active Oxygens LLC, Director of Technology Soil & Groundwater Remediation

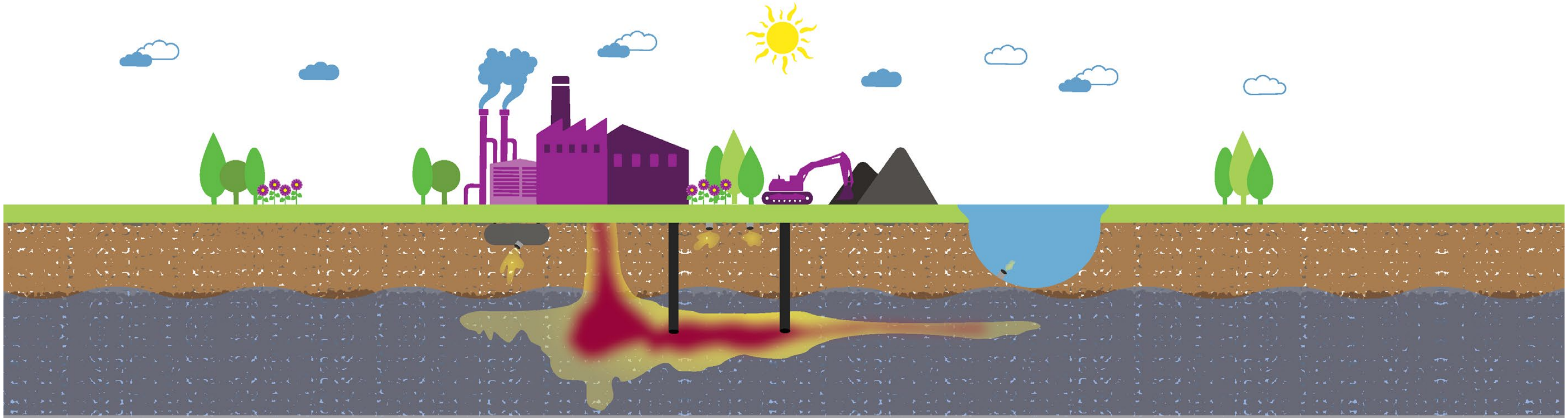
The Evolution of Two Remediation Technologies: Combined In Situ Stabilization (ISS) and In Situ Chemical Oxidation (ISCO)

Brant Smith, Director of Technology, Evonik

Evonik
Leading Beyond Chemistry

Evonik Soil & Groundwater Remediation

Field-Proven Portfolio of Remediation Technologies



Chemical Oxidation

- Klozur® Persulfate Portfolio
    - Klozur® SP
    - Klozur® KP
    - Klozur® One
    - Klozur® CR
- Hydrogen Peroxide

Aerobic Bioremediation

- Terramend® Reagent
- PermeOx® Ultra
- PermeOx® Ultra Granular

Enhanced Reductive Dechlorination

- ELS® Microemulsion
- ELS® Liquid Concentrate

Chemical Reduction

- EHC® ISCR Portfolio
    - EHC® Reagent
    - EHC® Liquid
    - EHC ® Plus
- Daramend® Reagent

Metals Remediation

- MetaFix® Reagents

BioGeoChemical

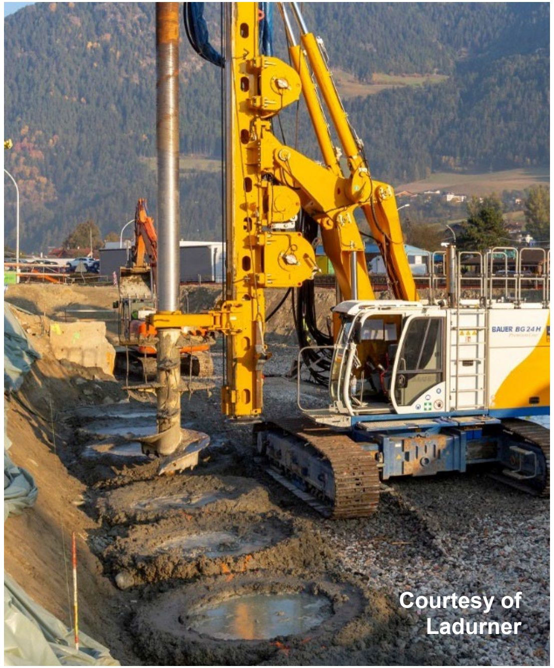
- GeoForm® Reagents

NAPL Stabilization

- ISGS® Technology

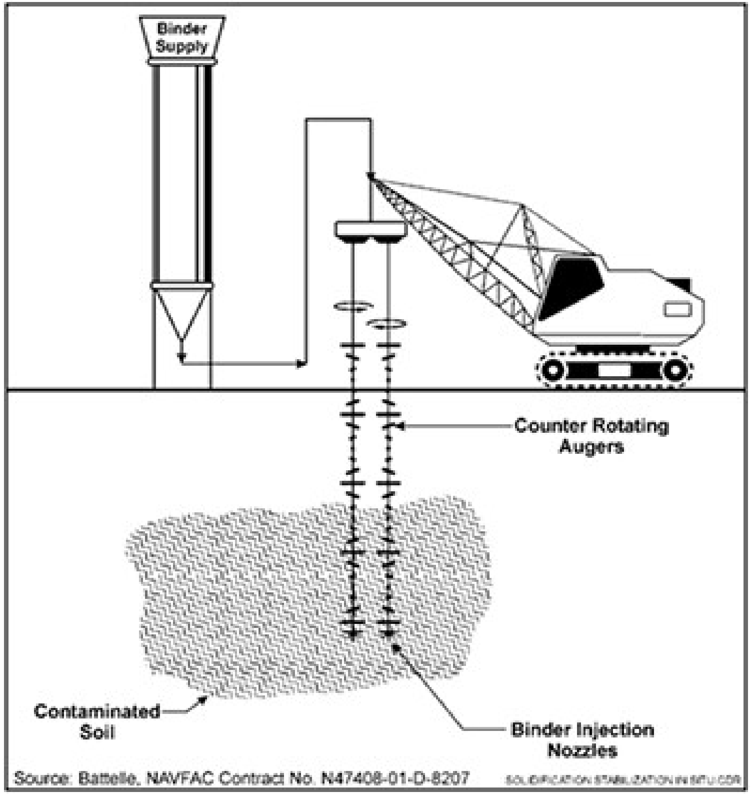
Presentation Outline

- Technology Overview
  - ISS
  - ISCO
  - Combined ISCO / ISS
- Why Combine?
  - Synergies
- Case Studies



In Situ Solidification and Stabilization

- Use of soil mixing to blend binding agent(s) with contaminated soils:
  - Portland Cement
  - Blast Furnace Slag
- Methods:
  - Stabilization:
    - Chemical processes that reduce leachability
  - Solidification:
    - Decreasing of surface area, hydraulic conductivity, effective porosity
    - Increasing compressive strength



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Common Objectives of ISS

1. Reduced hydraulic conductivity
   - 2-3 orders of magnitude below native soils
   - 1 x 10^{-6} cm/sec
2. Unconfined Compressive Strength (UCS)
   - "Workable" ~20-60 psi
   - Hardened
     - ISS often targets 50 psi
3. Lower contaminant flux and leachate concentrations

General Relationship between Soil Consistency and Unconfined Compressive Strength

Consistency	Unconfined Compressive Strength (UCS) Ranges			
	psi		kPa (KN/m^2)	
	Low	High	Low	High
Very soft	0	3	0	24
Soft	3	7	24	48
Medium	7	14	48	96
Stiff	14	28	96	192
Very Stiff	28	56	192	383
Hard	>56		>383	

Typical target range for "workable" soils ~20-60 psi

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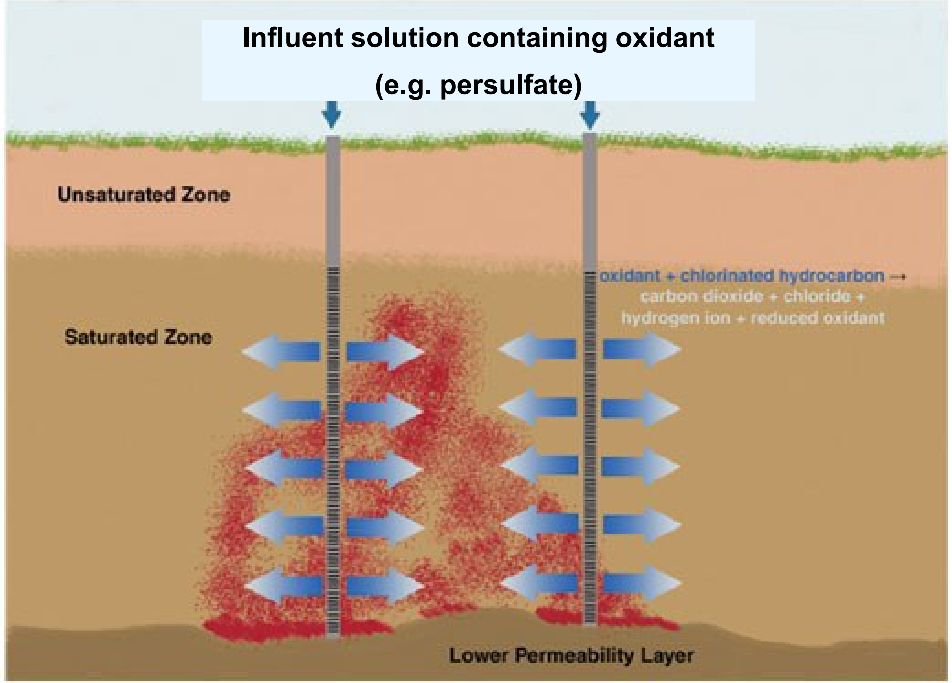
In Situ Chemical Oxidation

- What it is:
  - Oxidants are reagents that accept/take electrons from, or oxidize, contaminants of concern → CO_2
  - Typically applied via injection or soil mixing
- Objectives:
  - Contaminant destruction / mass reduction
  - Reduced concentrations in soil, groundwater, leachate and vapors



Examples (persulfate reactions):

Benzene: $15\ S_2O_8^{-2} + C_6H_6 + 12\ H_2O \rightarrow 6\ CO_2 + 30\ HSO_4^{-1}$

PCE: $2\ S_2O_8^{-2} + C_2Cl_4 + 4\ H_2O \rightarrow 2\ CO_2 + 4\ Cl^{-} + 4\ H^{+} + 4\ HSO_4^{-1}$

Combined Remedy: Benefits

- Benefits:
  - Two remedies from single application
  - Ready for redevelopment/access shortly after application
  - Soil mixing
    - Homogenizes heterogenious contaminant
    - Ensures better contact with contamination
    - Can add more oxidant per application (if needed)

Courtesy of Stockholm Stadt

Courtesy of Bill Lang

Courtesy of Jacobs

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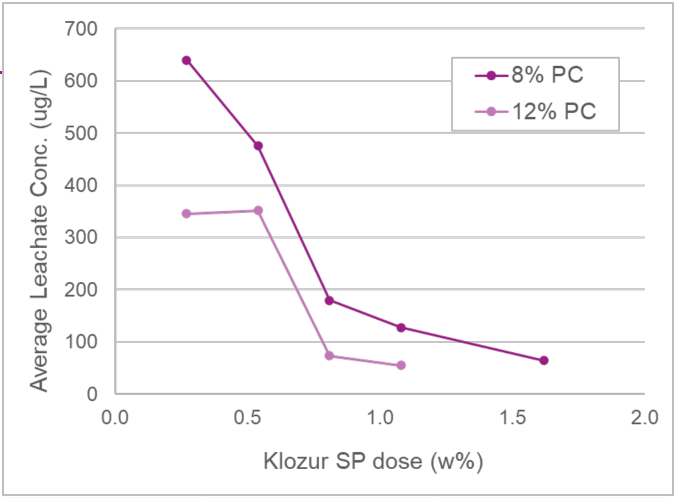
Combined Remedy: Synergies

- Synergies
  - Alkalinity from ISS creates alkaline activated persulfate
    - ~2 parts PC to 1 part SP
  - Compounding effect:
    - Both technologies reduce leachate and soil vapors
  - Oxidizing organic results in stronger solidification
    - Lower hydraulic conductivity
    - Can result in less bulking/swell
      - Decrease handling/disposal costs



Klozur SP (% w/w soil)	8% PC		8% PC/BFS	
	Day 90 UCS (psi)	% of ISS only	Day 90 UCS (psi)	% of ISS only
0	90	100%	110	100%
1	105	117%	160	145%
2	110	122%	175	159%
4	75	83%	140	127%

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ISCO-ISS Successfully Remediates PCE DNAPL at Former Dry Cleaner in Residential Neighborhood

Location: Former Kent Cleaners, Lansing, Michigan

Lead Consultant: Hamp Mathews & Associates

Contractor: Lang Tool

Regulator: EGLE

Contaminants: PCE (up to >1,000 mg/kg)

Goal: Reduce vapor intrusion risk

Treatment volume: 12,354 cy soil,

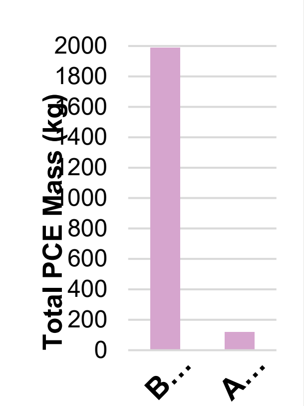
Reagent Dose (w/w soil):

- Klozur SP: 1-2% (440K lbs)
- Portland Cement: 4% (1.6M lbs)

Results

- 94% reduction in PCE mass
- UCS of 25-50 psi (Day 60)
- Underlying GW conc. reduced by 90 to 99%

Saved client >$2.5 Million compared to excavation estimate



ISCO-ISS Successfully Remediates Petroleum Contaminated Soils for Site Redevelopment

Location: Bolzano, Italy

Lead Consultant: Ladurner Bonifiche S.r.l.

Contaminants: Petroleum Hydrocarbons

Goals: Combination of contaminant reduction, soil stability targets, limit soil bulking

Treatment volume: 3,500 m^3, from 3-8 m bgs

Dose (w/w soil):

- Klozur SP: 0.7-1%
- Portland Cement: 4-8%

Installation: 556 columns w. large diameter auger

ISCO Results & Goals:

- Benzene: 100% samples < 2 mg/Kg
- TPH (C4-C12): 100% samples <250 mg/Kg
- TPH (C13-C40): Over 50% samples <750 mg/Kg

ISS / Geotechnical Goals Achieved:

- UCS: 30 to 70 psi
- Permeability: 2.8×10^{-6} to 7.3×10^{-7} cm/sec

Less than 15% soil bulking

Summary

- ISCO-ISS is combined remedy of two established technologies
  - Single application
    - Treat/degrade significant portions of contaminant mass
    - Residual is solidified in a monolith
  - Several synergistic benefits:
    - Higher UCS, lower leachate, lower hydraulic conductivity
      - Target UCS range, soils can be reworked, if needed
    - Less soil bulking can decrease project costs
    - Site ready for redevelopment/access shortly after application

Thank you!

Questions?

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Thank you!

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Managing soil contamination in green areas using nature-based solutions

Dorien Gorteman, Arcadis, Projectleider,
Karen Van Geert, Arcadis, Projectmanager

SAMEN MAKEN WE MORGEN MOOIER
OVAM

ARCADIS

Nature-based solutions for managing soil contamination in green areas

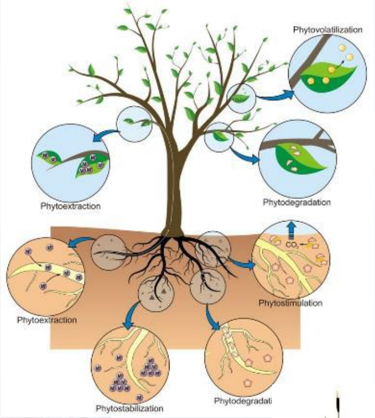
14/3/2024

Introduction

Can we design municipal parks in a way that soil contamination from point sources of diffuse sources and their impact can be reduced? E.g. by using wel chosen materials, plants, water supply systems, water management etc?

What are the possibilities of using nature-based solutions in the management of soil contamination in green areas?

Nature-based solutions



Nature-based solutions

Soil management

Green areas

Diffuse/ point source

Advantages of nature-based solutions for soils

Reducing the impact of existing (diffuse or residual) pollution

- Reducing direct contact with soil
- Reducing dust spread by wind
- Partial removal of contamination

win-win situation

Possibilities for development of brownfields and unused urban land

Queen Elizabeth Olympic park before and after redevelopment

Advantages of nature-based solutions for soils

Social

- Space for recreation
- Esthetical
- Health benefits:
  - Air quality
  - Noise pollution
  - Heat island effect

Economical

- Land reclamation
- Local reuse of soil
- Less removal and transportation of soil

environment

- ecological habitats
- Mitigation climate impact
- Water management

The right intervention in the right spot

Soil pollution in (future) green areas

Soil contamination may be present in (potential) green areas

- Road verges along (busy) roads/railways
- Parks in the vicinity of industry
- Green areas where a lot of pesticides were used in the past (parks, cemeteries,..)
- Green areas developed on former industrial sites/old municipal landfills
- ditches/sites that catch run-off from roads
- Residual pollution underneath the pavement

How can nature-based solutions be used to manage contamination in these soils?

Examples Nature Based Solutions

Replanting

Flow direction

Reduced exposure to pollutants

- Less spreading by wind
- Less leaching
- Less evaporation

Stabilisation

Stabilisers

- *Biochar*
- *Biosolids*
- *Green mulch*)
- Compost
- Woodchips

Application

- Soil

Mechanism

- Adsorption
- Complexation
- Precipitation
- Reduction/oxidation

+	-
simple	Type of pollutant important: increase in organ carbon effects solubility/mobility
cheap	
Reduces bio-availability	

Phytoremediation

Amsterdam Noord, de ceuvel

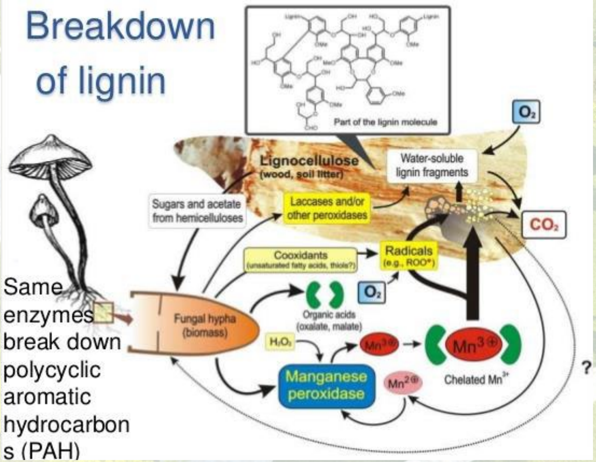
- Former shipyard – levelled with dredged material
- Planting of grasses, short rotation trees and mature trees
- Uptake and break down of contamination

Bioremediation (micro-, myco-, vermi-)

Application
- Soil

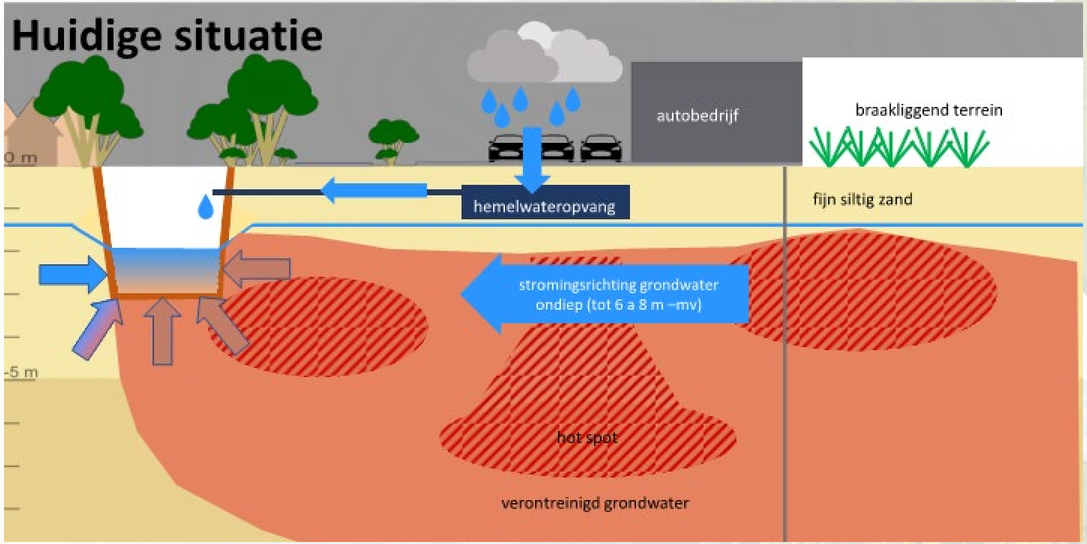
Polluenten
- Chlorinated solvents
- PAHs
- PCBs
- Pesticides
- Heavy metals
- Oil

+	-
Improvement of the soil structure, reduced soil erosion + due to strong humus-rich soils, (volatile) components are better adsorbed and/or fixed on the soil	Applicability depending on concentrations in soil (in case of "remediation")
Relatively simple and easy to learn technique	
Positive impact on plants and thus reduction of exposure/direct contact to diffusely contaminated soil	
No impact on the aesthetic aspect of the topsoil	

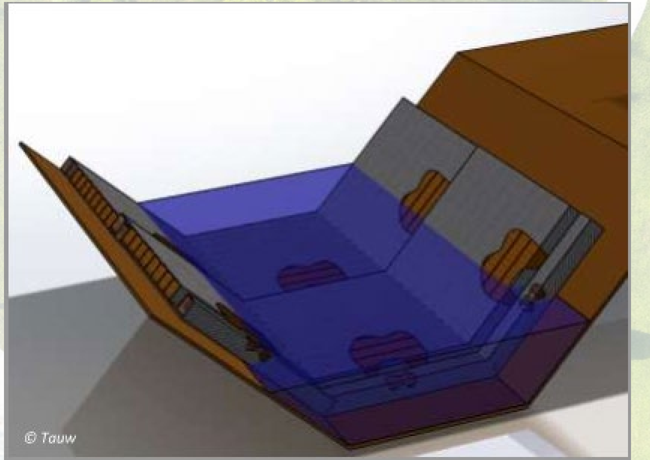


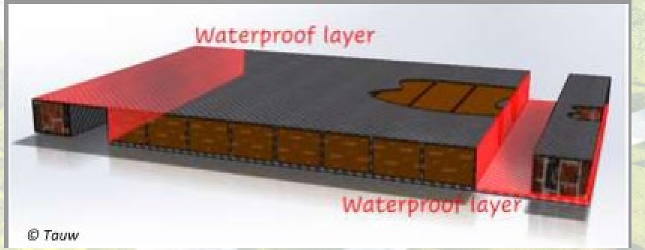
Reactive (organoclay)mats

example: De Lieve in Ghent (RESANAT-project)



Organoclay RCM

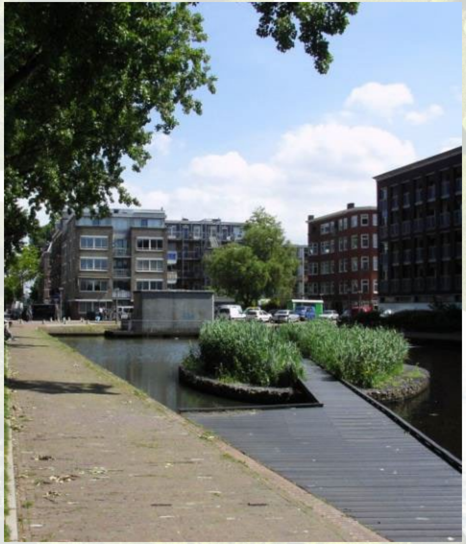
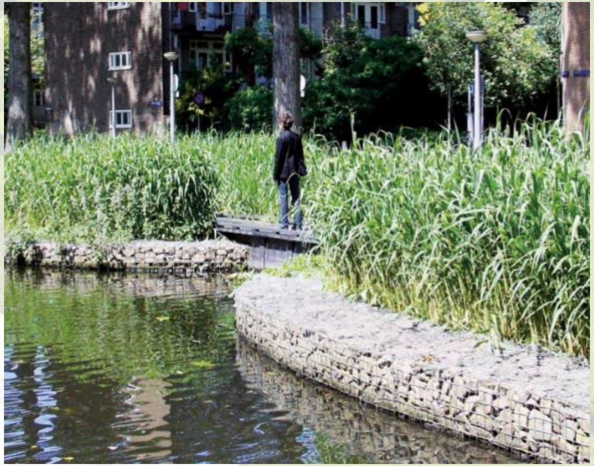




Constructed wetlands

Ex. Amsterdam, erasmusgracht

- Treatment of polluted rainwater before discharge into canal

Foto's: ateliergroenblauw.nl

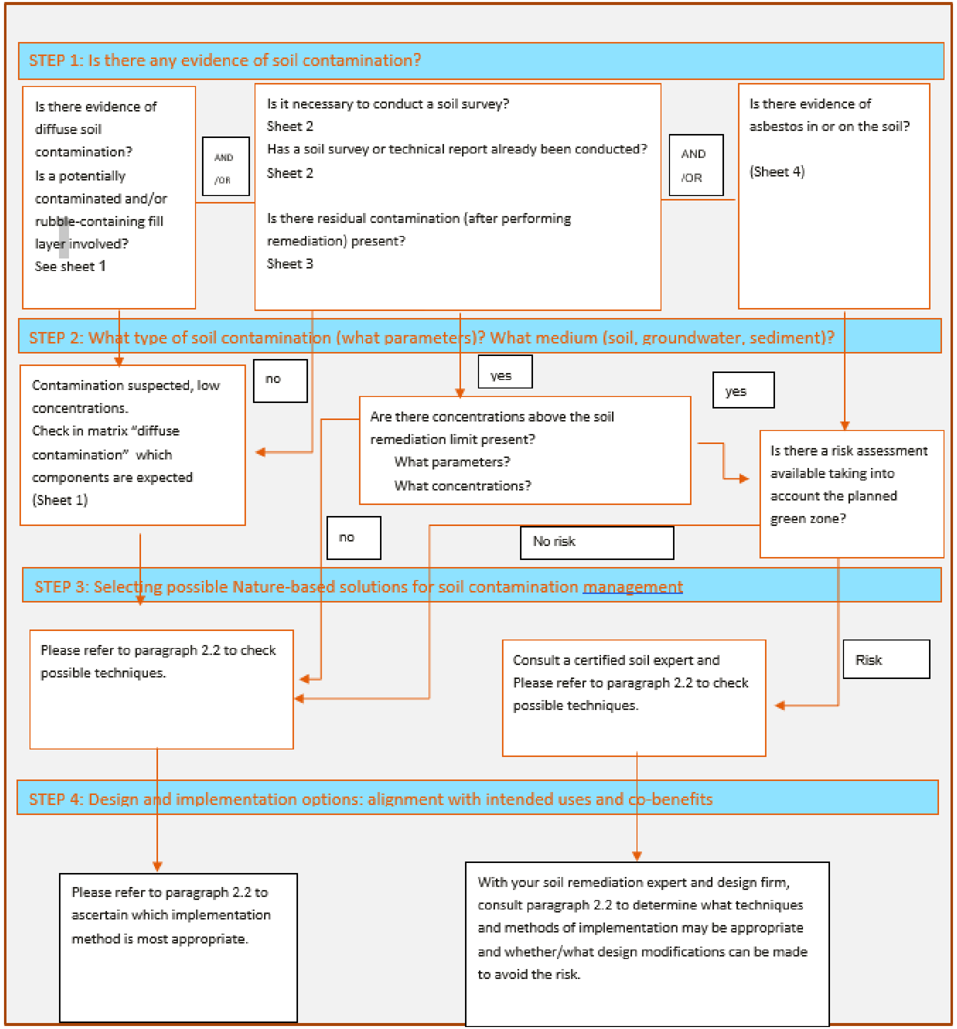
Co-benefits

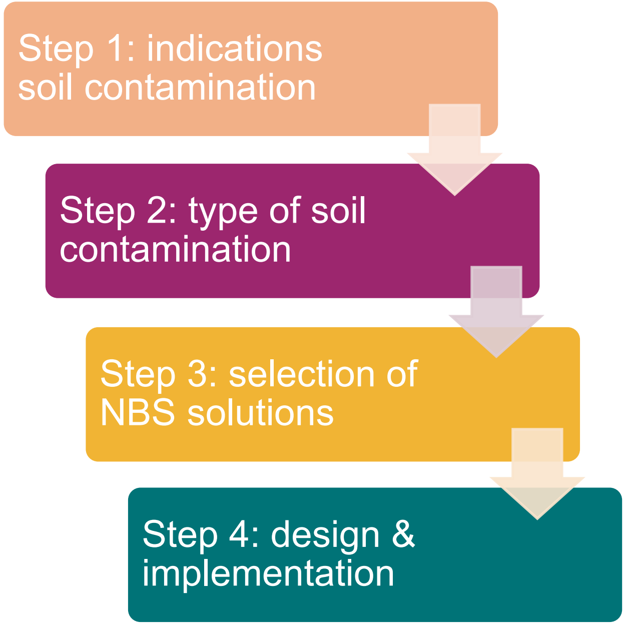
- **Many nature-based techniques also have benefits in areas other than soil.**
- **Ex. Constructed wetlands:**
  - Absorbing CO_2
  - Support biodiversity and create habitats for animals
  - Reduce the impact of storm water on the environment
  - Provide a buffer against erosion
  - Provide increased water storage and resilience to changing weather patterns
  - Help replenish aquifers

Practical Guide

For green areas

Foto: catalogue of nature-based solutions


STEP 1: Is there any evidence of soil contamination?
Is there evidence of diffuse soil contamination?
Is a potentially contaminated and/or rubble-containing fill layer involved?
See sheet 1
AND /OR
Is it necessary to conduct a soil survey?
Sheet 2
Has a soil survey or technical report already been conducted?
Sheet 2
Is there residual contamination (after performing remediation) present?
Sheet 3
AND /OR
Is there evidence of asbestos in or on the soil?
(Sheet 4)
STEP 2: What type of soil contamination (what parameters)? What medium (soil, groundwater, sediment)?
Contamination suspected, low concentrations.
Check in matrix "diffuse contamination" which components are expected
(Sheet 1)
no
yes
Are there concentrations above the soil remediation limit present?
What parameters?
What concentrations?
yes
Is there a risk assessment available taking into account the planned green zone?
no
No risk
STEP 3: Selecting possible Nature-based solutions for soil contamination management
Please refer to paragraph 2.2 to check possible techniques.
Consult a certified soil expert and Please refer to paragraph 2.2 to check possible techniques.
Risk
STEP 4: Design and implementation options: alignment with intended uses and co-benefits
Please refer to paragraph 2.2 to ascertain which implementation method is most appropriate.
With your soil remediation expert and design firm, consult paragraph 2.2 to determine what techniques and methods of implementation may be appropriate and whether/what design modifications can be made to avoid the risk.


Step 1: indications soil contamination
Step 2: type of soil contamination
Step 3: selection of NBS solutions
Step 4: design & implementation

Selection matrix nature-based solutions

Aspects to be considered

- What is the goal/type of green area? a playground, a park, a roadside, etc.?
- Other obligations? E.g. water buffering, infiltration? Protected elements?
- What was the natural stat of the site? Wetland? Moor? Meadow?
- Type of soil?
- What are the most important co benefits for you? Functionality? Aesthetics? Maximisation of biodiversity?
- How much space is available?
- What is the ambition level? This can be adjusted over time

Technique	medium	Chemical compound	effect	Co- beneftis	implementation options	Focus points	More information/ dimensioning	Link to chapter with more infomation end examples

Techniek	matrix	parameters	effect	cobaten	Uitvoeringsmogelijkheden	aandachtspunten	meer informatie/ dimensionering	Link naar hoofdstuk met meer informatie en voorbeelden
beplanten	grond	brede range organische en anorganische parameters, afhankelijk van tolerantie plant: zie ook bijlage 4 van de code van goede praktijk fyotremediatie ter inspiratie	verminderde opwaaiing, uitloging en uitdamping	minder verdichting esthetische verbetering creatie van een ecosysteem	Bloemperken, weg- en spoorwegbermen, groenstroken in parkings, eventeel in combinatie met slim grondverzet..	keuze plan van belang: inheemse soorten, die passen bij de lokale fauna. Meer info kan bvb gevonden worden op online plantenzoekers zoals https://beweegt.velt.be/plantenzoeker of ook bijlage 4 van de code van goede praktijk fyotremediatie	https://www.ecopedia.be/pagina/landschapsbeheer https://www.ecopedia.be/pagina/groenbeheer https://www.ovam.be/sites/default/files/atoms/files/2019_Code%20van%20goede%20praktijk_Fytoremediatie.pdf: bijlage 4: plantenlijst onlne database met verzameling van alle fytoremediatieprojecten: https://clu-in.org/products/phyto/search/phyto_search.cfm	**Fout! Verwijzingsbron niet gevonden.**
Stabilisatie	Grond	Zware metalen en organische polluenten	Adsorptie, complexatie, precipitatie, redoxreacties	Esthetische verbetering Beter overstromingsbeheer Verhoging vruchtbaarheid bodem, reduceert run off, minder stof	Bloemperken, weg- en spoorwegbermen, groenstroken in parkings,.. eventeel in combinatie met slim grondverzet..	Opletten met het type polluent: organisch koolstofgehalte doen verhogen heeft effect op de oplosbaarheid/mobiliteit		**Fout! Verwijzingsbron niet gevonden.**
fytoremediatie	grond en grondwater	brede range organische en anorganische parameters, afhankelijk van tolerantie plant: zie ook bijlage 4 code van goede praktijk fyotremediatie ter inspiratie	vermindert direct contact breekt af vermindert uitloging vermindert opwaai	Esthetische verbetering, Gezondheidsvoordelen Verbeterd overstromingsbeheer, productie van biomassa voor energieopwekking, creatie van een ecosysteem, verbetering luchtkwaliteit	Bloemperken, weg- en spoorwegbermen, groenstroken in parkings, bomenrijen in straten,.. Ook geschikt voor grotere terreinen zoals parken, herbebossingsproject etc. eventeel in combinatie met slim grondverzet..	Toepasbaarheid afhankelijk van concentraties in de bodem en diepte verontreiniging. Afhankelijk van component en bodemtype: zie code van goede praktijk	code van goede praktijk fytoremediatie: https://www.ovam.be/sites/default/files/atoms/files/2019_Code%20van%20goede%20praktijk_Fytoremediatie.pdf	**Fout! Verwijzingsbron niet gevonden.**
helofytenfilters	grondwater/ afvalwater/ oppervlakte water	VOCl, ZM, BTEX, NH3, NO3, PO4, fenolen, chloorbenzenen, MTBE	afbraak verontreiniging	esthetische verbetering, creëert ontmoetingsplaats, beter bestand tegen overstromingen, ontlasten van rioleringsstelsel, creatie van een ecosysteem, absorbeert CO_2	Grotere groenzones, zoals parken, brede wegbermen. Combineren met een WADI, infiltratiegracht,..	mogelijke geurhinder, Nodig om regelmatig nutriënten bij te voegen, te monitoren Afhankelijk van component en bodemtype: zie code van goede praktijk fytoremediatie	verschillende bedrijven zijn gespecialiseerd in het aanleggen van rietvelden. Contacteer hen voor meer informatie Zie ook CvgP fytoremediatie plantkeuze: p118	**Fout! Verwijzingsbron niet gevonden.**
bioremediatie	Grond/grond water	Gechloreerde solventen, PAK's, PCB's, Pesticiden, Zware metalen, Olie	Afbraak of stabilisatie van verontreiniging	Relatief snelle verwijdering van contaminanten	Toepasbaar op vele types van terreinen eventeel in combinatie met slim grondverzet..	Toepasbaarheid afhankelijk van concentraties in de bodem, afbraakproducten, omstandigheden in de bodem. Onderscheid tussen micro-, vermi- en mycoremediatie Situatie afhankelijk, labo-testen nodig bij twijfel	Contacteer een EBSD of gespecialiseerde bedrijven rond vermi- of mycoremediatie	**Fout! Verwijzingsbron niet gevonden.**
reactieve (organoklei)matten	Grondwater, sediment, oppervlakte water, grond (als afdekking)	PAK's, PCB's, methylkwik, zware metalen, olie	Adsorptie en afbraak van de verontreiniging	/	In waterlopen Als afdekking: Bloemperken, weg- en spoorwegbermen, groenstroken in parkings,..	/	Contacteer een EBSD	**Fout! Verwijzingsbron niet gevonden.**

Practical Guide

Available on the OVAM-website

- https://ovam.vlaanderen.be/documents/177281/0/WEB_Natuurgebaseerde+oplossingen+voor+beheer+van+bodemverontreiniging+in+groene+zones.pdf/dff4d00e-336d-3081-8362-ed0095d0533e?t=1652253227638&download=true

ENSOr

Nature-based approaches for metal contaminated alluvial plains

Froukje Kuijk, OVAM, Project Coordinator LIFE Narmena

NAture-based Remediation of MEtal pollutants in Nature Areas to increase water storage capacity

narmena

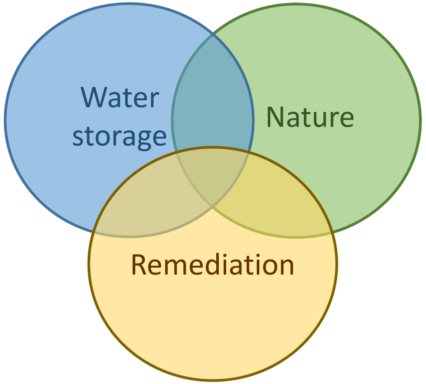
Ruimte voor schone waterlopen

Problem setting

- Historical backlog of contaminated sites
- Flanders is a densely populated land
  - Pressure on land, water resources and in particular blue-green infrastructure is high
  - In Flanders over 500 land and water sites are contaminated with metals
- Drawbacks of conventional remediation
  - high cost (energy, materials, carbon emission, financial) for transport and treatment
  - considerable residual waste or by-products
  - change in edaphic conditions or soil erosion, drastic impact on nature
- Dynamic character of sediments
  - Contaminated sediments spread easily via currents and flooding
- Increasing flood risk and growing need for space to store water

LIFE Narmena

NAture-based Remediation of MEtal pollutants in Nature Areas to increase water storage capacity



Nature-based: using natural processes, in-situ remediation

Remediation of Metal pollutants: (historical) metal contamination & nutrients in sediments, bank zones and floodplains of watercourses

- ➢Reduction of bioavailable concentrations

Nature areas: demo sites are watercourses that flow through nature reserves (Natura2000)

To create water storage capacity: creation of natural flood control areas

NBR techniques benefits

- Less drastic impacts on nature (+ ecosystem services)
- Cost-efficient (also for energy & materials)
- Low CO2-emission
- Co-benefits (water storage, nature goals)

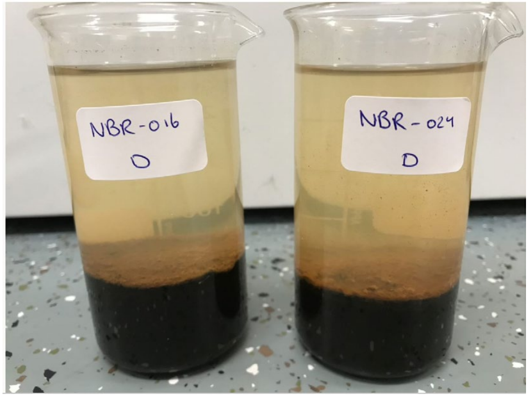
Monitoring

- Intensive baseline and post-remediation monitoring
- Several methods to quantify bioavailable concentrations (e.g. passive sampling, metal extractions, bio-assays, AVS-SEM)

Ecomodelling

- Ecomodelling allows to extrapolate toxicity effects in the lab to populations in the field
    - More realistic
    - Extrapolation to non-tested scenarios

- Ecomodelling requires ecotoxicity data
    - As, Cd and Cr are most important contaminants
    - Literature study for available ecotoxicity data
    - Aquatic and soil: literature data available
    - Sediment: data gap
    - ➢ toxicity testing for certain metals on key biotic indicators



Project information

01/07/19 - 31/08/25 **+ 3 years After-LIFE**

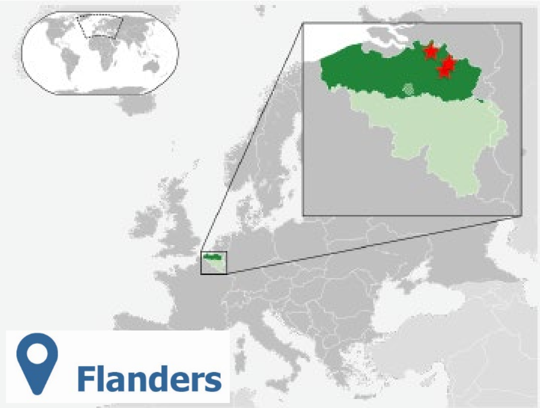
Total: € 4.520.488

55 % EC Co-funding

PROJECT PARTNERS

Coordination: OVAM (WE MAKE TOMORROW BEAUTIFUL)

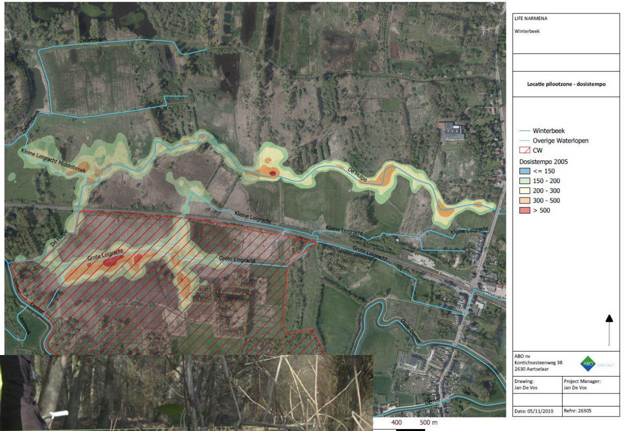
Associated partners: ABO Consultancy, Arche Consulting, Natuurpunt, Vlaamse Milieumaatschappij, Vlaanderen is natuur, bio2clean (growing clean soils)

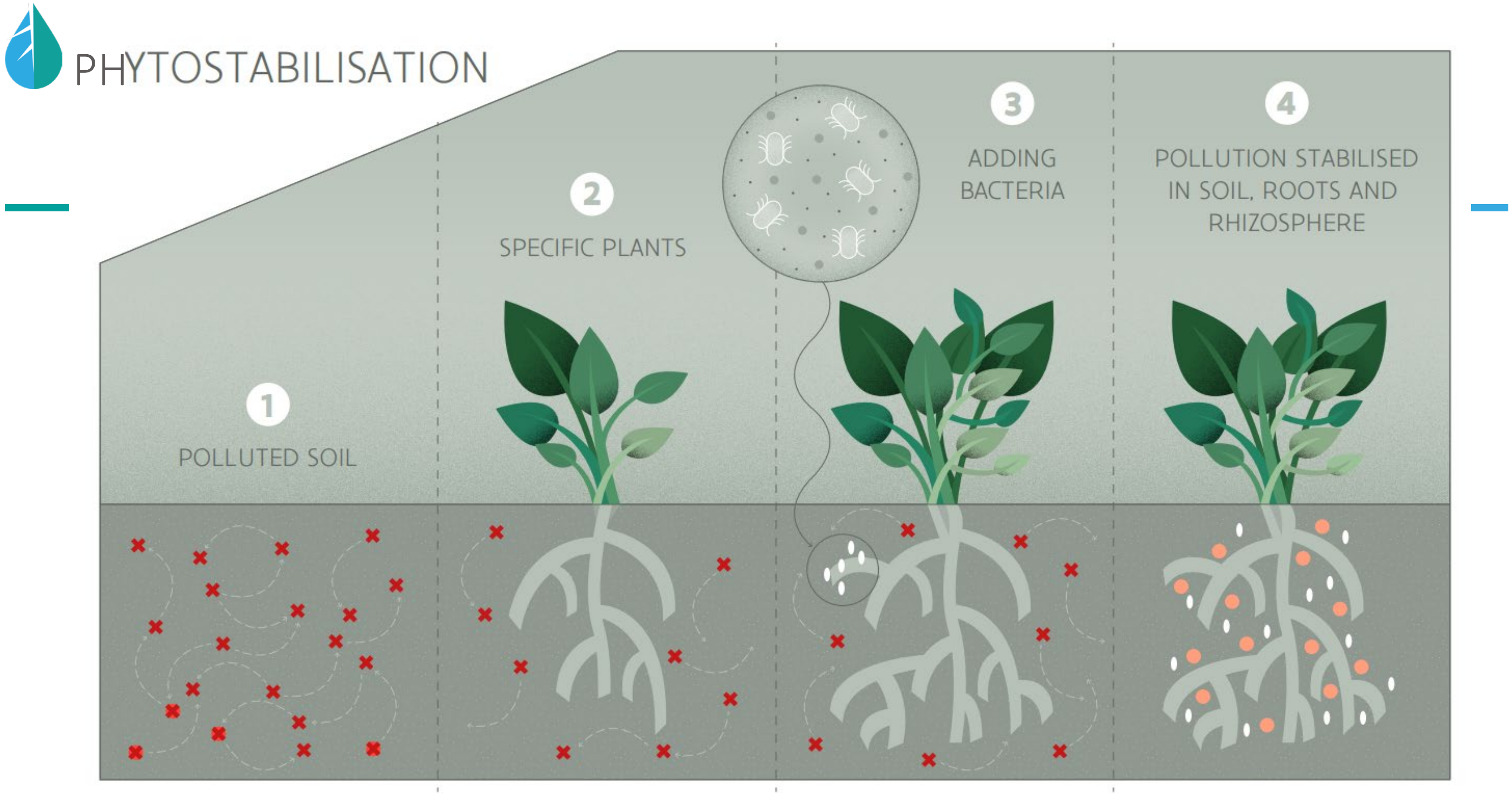


Grote Calie (Turnhout)
Winterbeek (Scherpenheuvel-Zichem)
Grote Laak (Geel-Laakdal)

Pilot projects of Narmena

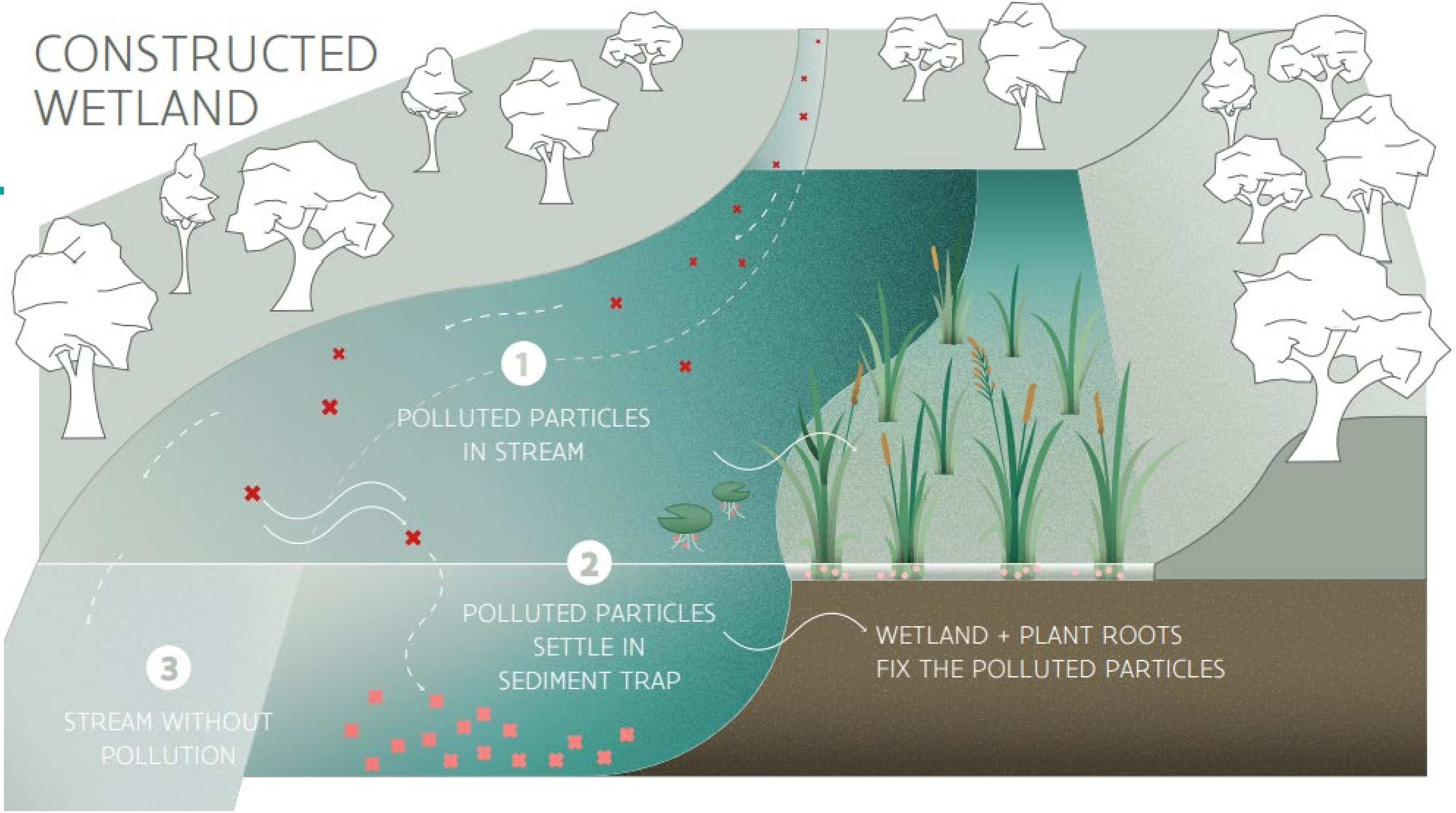
- Grote Calie (Turnhout)
  - 2 BAP (bacterie-assisted phytostabilisation) fields: nature and agricultural terrain
  - 1 constructed wetland
- Winterbeek (Scherpenheuvel-Zichem)
  - 1 constructed wetland (confluence area)
- Grote Laak (Laakdal - Geel)
  - 1 constructed wetland (confluence area)



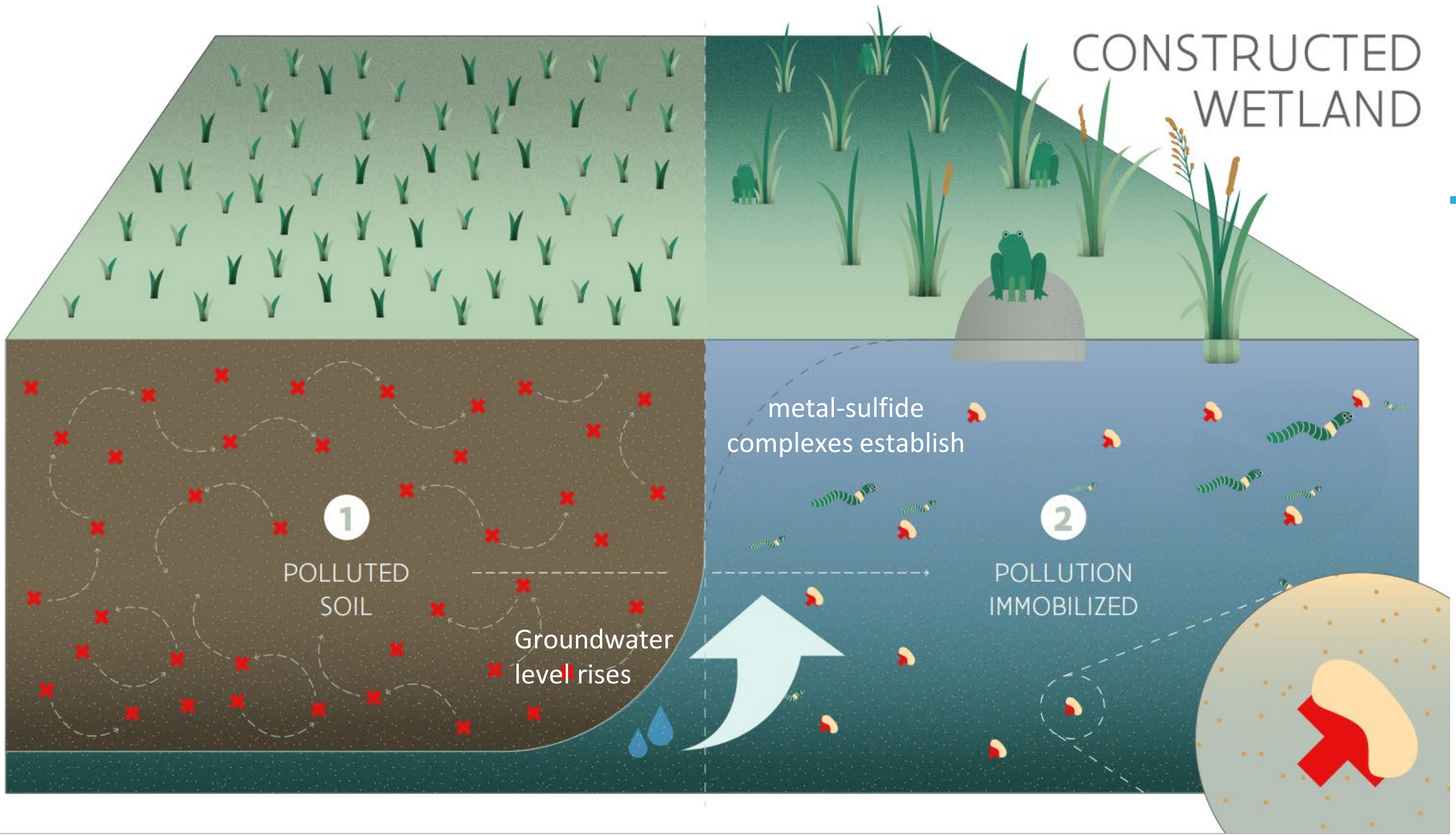


Using phytostabilisation, the metals are fixed in the rhizosphere of the plants. Bacteria can be inoculated to help the plant stabilizing the metals and support surviving in environment with high metal concentrations.

CONSTRUCTED WETLAND

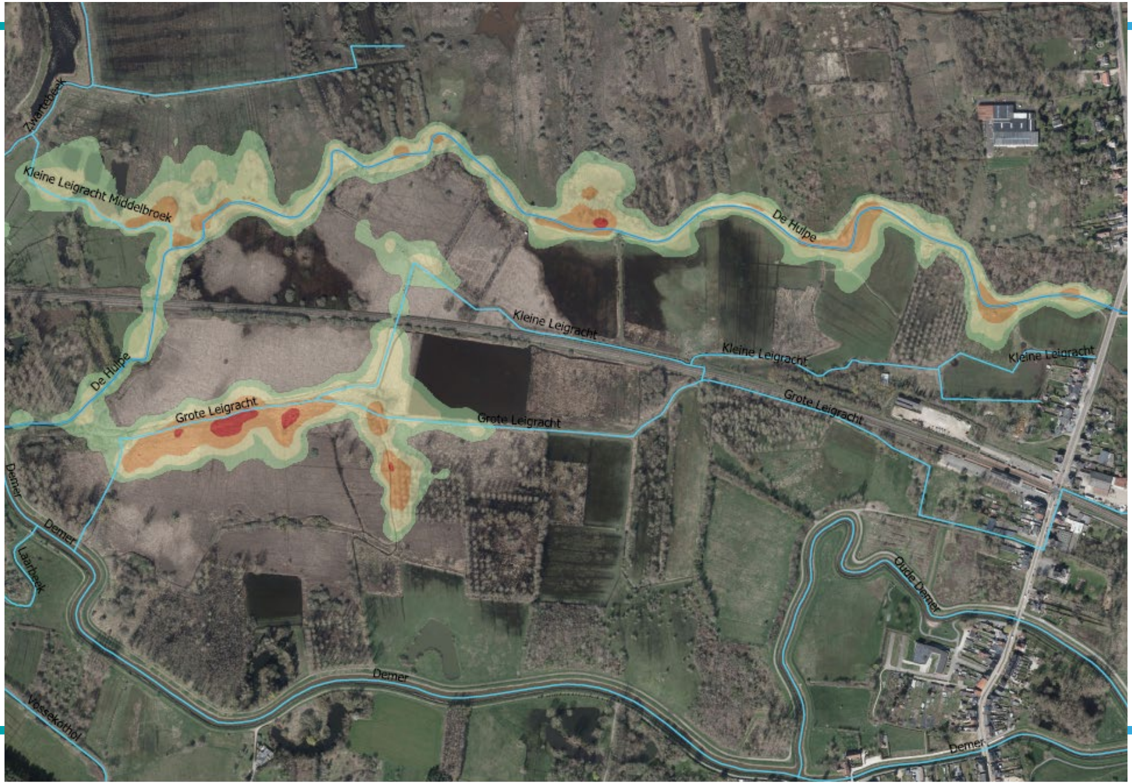


In this type of constructed wetland we tackle the spreading of contaminated sediment (chromium) downstream and lower the bioavailability of the chromium in the constructed wetland



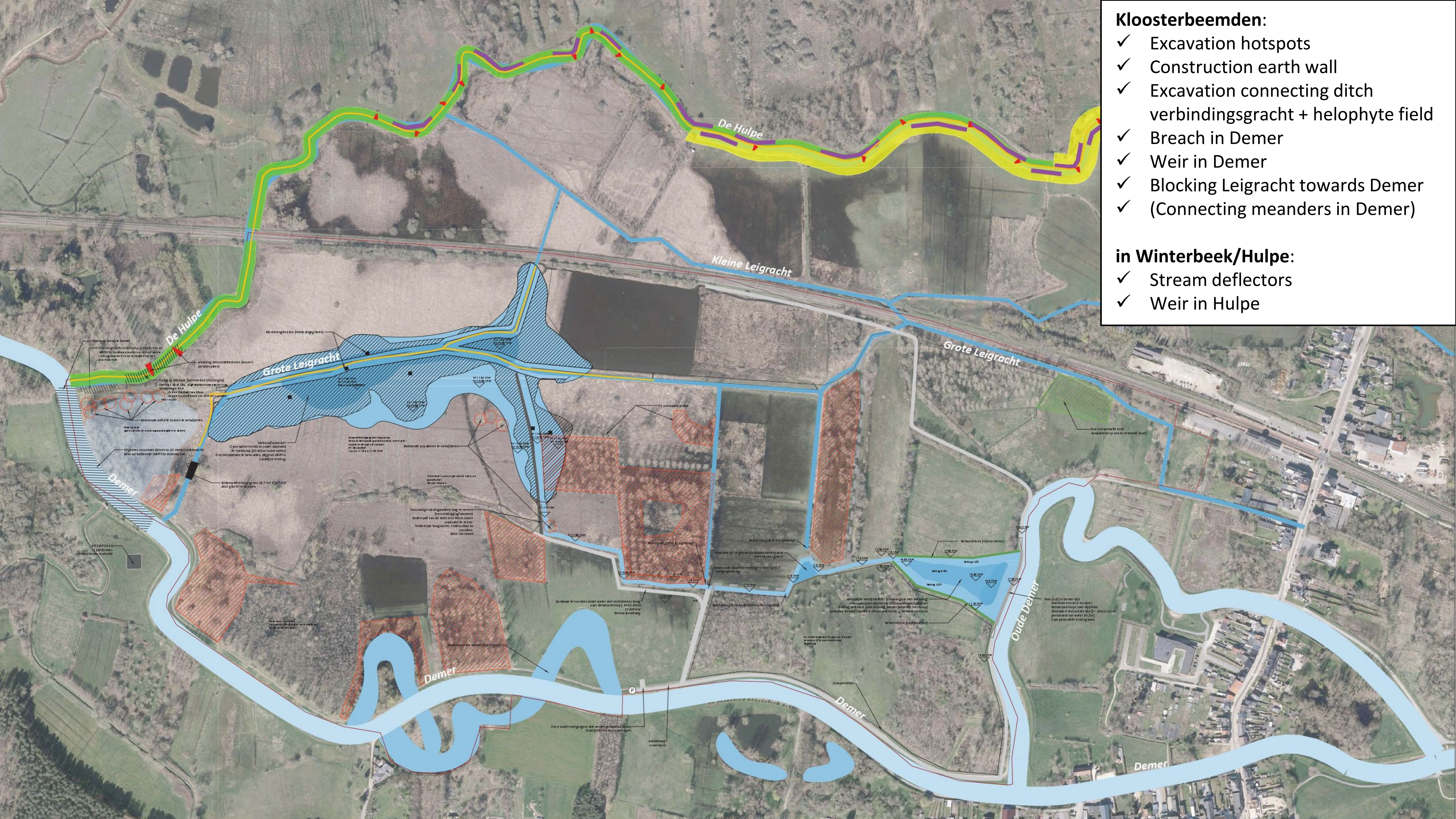
In this type of constructed wetland we immobilize the metal contamination (Cd and As) by complexation of metals with sulfides once anaerobic conditions are established. Metal-sulfide complexes cannot be taken up by organisms or plants.

Winterbeek: contamination



Dosistempo

- <= 150
- 150 - 200
- 200 - 300
- 300 - 500
- > 500



Kloosterbeemden:
- ✓ Excavation hotspots
- ✓ Construction earth wall
- ✓ Excavation connecting ditch verbindingsgracht + helophyte field
- ✓ Breach in Demer
- ✓ Weir in Demer
- ✓ Blocking Leigracht towards Demer
- ✓ (Connecting meanders in Demer)

in Winterbeek/Hulpe:
- ✓ Stream deflectors
- ✓ Weir in Hulpe

Lessons learned

- Dissemination of the results
  - Actively reaching out to nature and water managers, authorities, etc. EU-wide
- Development of an application framework (AF) for NBR
  - AF aims to integrate the use of NBR-techniques in water retention, nature and soil policies
  - Responsible water and nature management bodies in Flanders participate in NARMENA
  - Develop a manual and improve guidelines and codes of good practice
  - AF will be transferred to observer locations for replication

Visit our website:
https://www.narmena.com

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