SHORT OVERVIEW OF PFAS REMEDIATION METHODS FOR SOIL AND WATER

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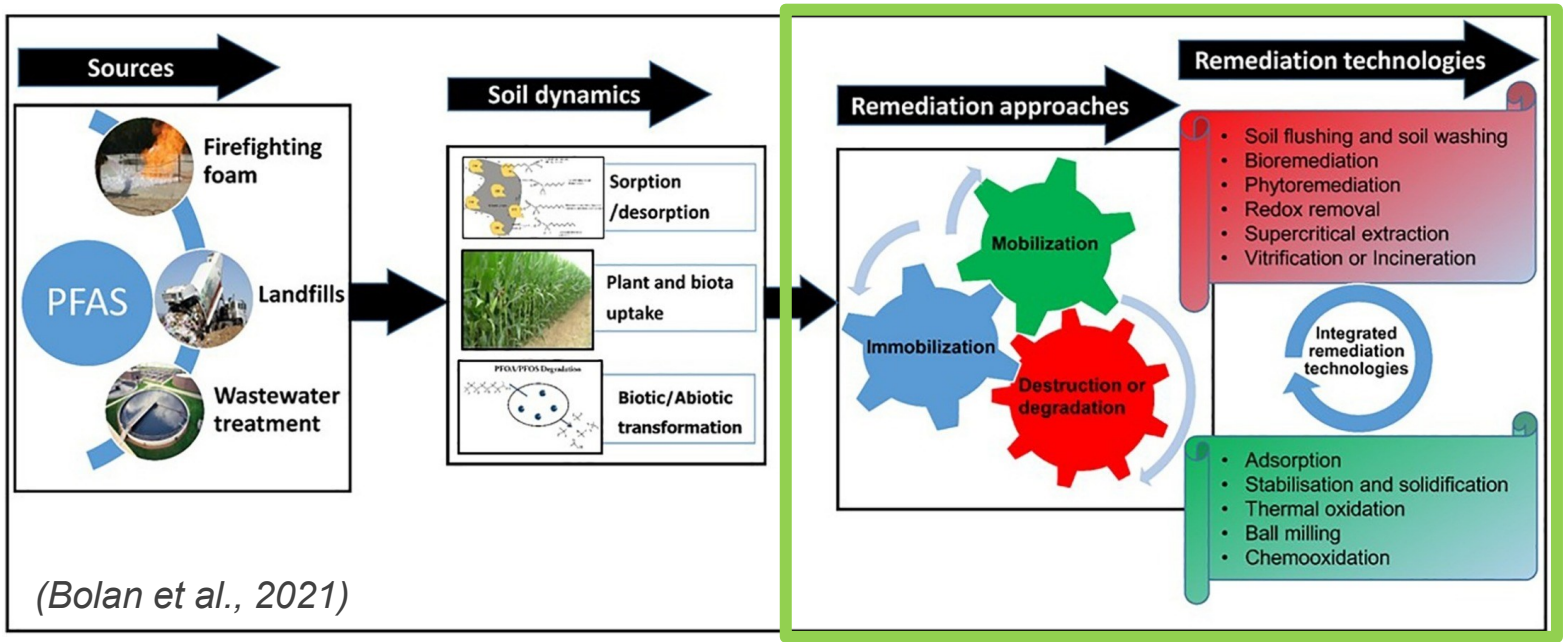
We studied **proven** remediation technologies for PFAS contaminated soil (OVAM, 2021 - updated)

Questions addressed:

- What are the effects of **soil composition** (clay + OM content, co-contaminants,…)
- What **PFAS concentrations** can be treated and which **end concentrations** can be reached after treatment
- What is the currently available **capacity** per technology (off-site soil treatment)
- Which technologies are available for **(proces)water treatment**

Method

- **Limited study of available (scientific) literature**
- **Direct contacts** with selected **marked players** and **specialists** in Flanders and surrounding regions: land management organisations, soil treatment centres and specialists in FL, NL, D



(Bolan et al., 2021)

Literature study

- **Booming recent (scientific) research and papers** on the **treatment of** PFAS in soil and water
- **Proven (ex-situ) soil treatment technologies**: **physico chemical (= soil washing) and thermal treatment**

Alternatives for soil cleaning:

- **Stabilisation/immobilisation** of PFAS by adding **sorbents** (activated carbon, biochars, aluminium hydroxide, kaolinite, zeolites,….): proven but not (yet) applied in Flanders
- **Phytoremediation** (PFAS bio-accumulate in plant parts)
- **Isolation** (on-site or off-site)

Treatment of PFAS in water phase:

- **Commonly** used
  - Flocculation/precipitation
  - Sorption by activated carbon and/or ion-exchange resins
- **Promising** technologies:
  - Alternative sorbents: all-silica zeolite beta, activated biochars, modified clays
  - Foam and ozone fractioning
  - Non-thermal plasma
  - Reversed osmosis
  - Electrochemical, photo catalytical, sonochemical destruction

www.concawe.org - *//pfas-1.itrcweb.org*

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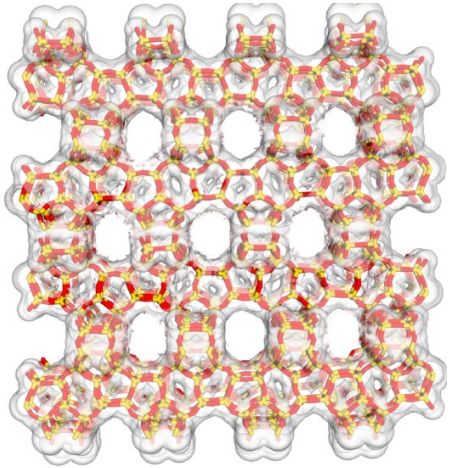
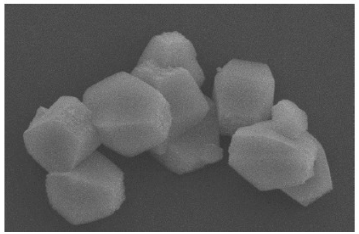
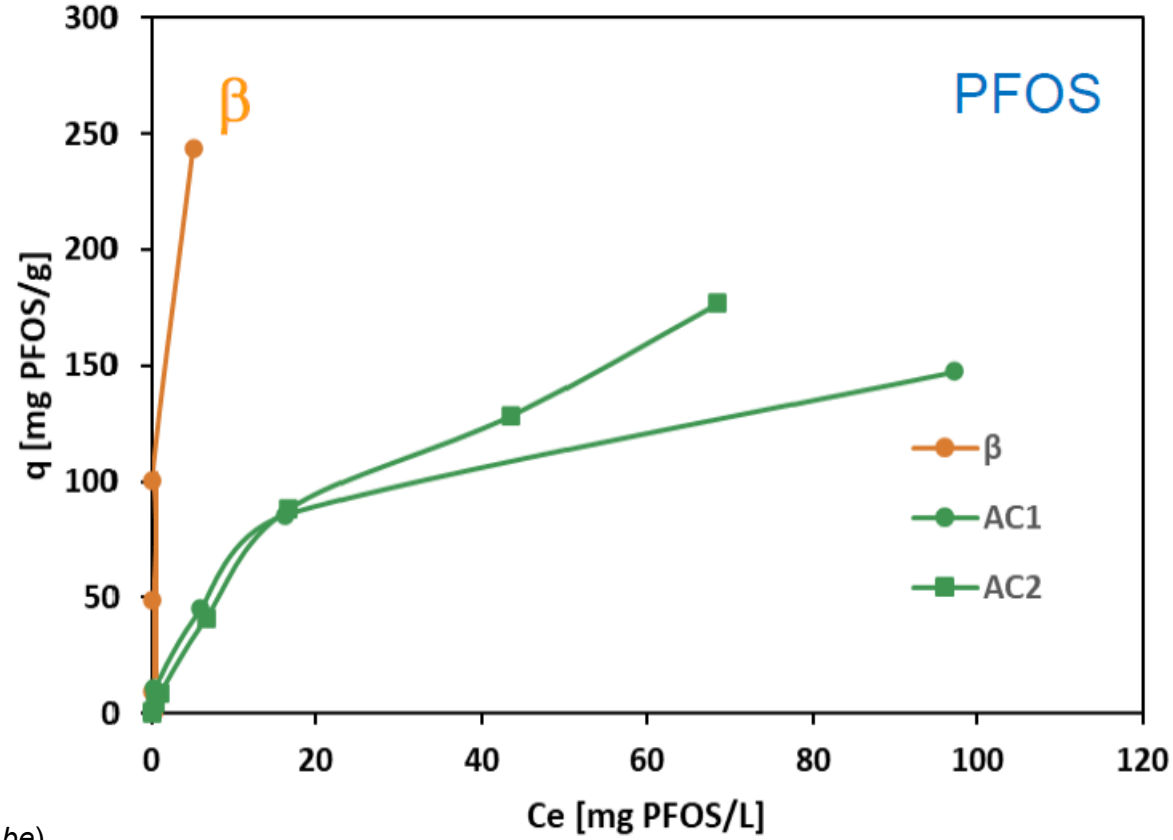
Adsorption of PFOS from water by all-silica zeolite beta







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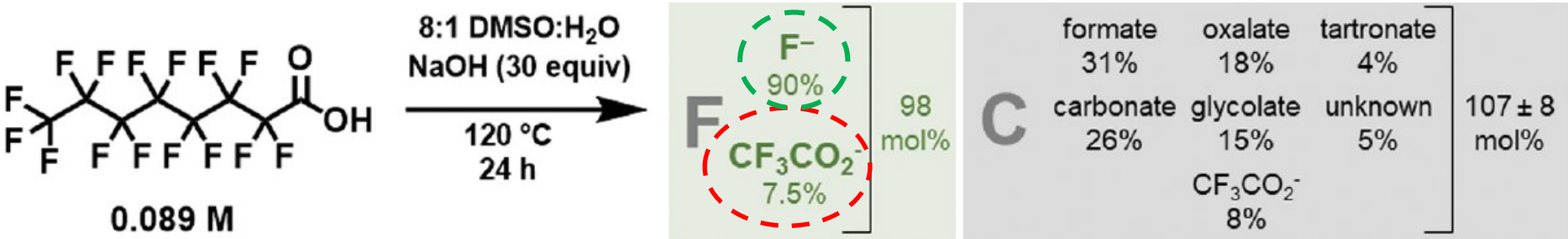
Very recent new low-temperature PFCA destruction technology

- **Mineralize PFCA's** of various chain lengths at **mild temperatures** (80 to 120°C) in a **mixture of water, NaOH and dimethyl sulfoxide (DMSO)**

- **PFOA** is completely degraded with >90% defluorination and minimal formation of fluorocarbon by-products



(Trang et al., Science 377, 839–845 (2022) 19 August 2022)

Soil treatment in Flanders

- **Large available capacity for** physico-chemical treatment (>300000 ton/yr)
- **Max. 300 µg/kg dm sum PFAS input concentration** – (**cleaning efficiency** 95 - 99 %) for 3 µg/kg dm in output
- In 2021 one centre cleaned 47000 tonnes of PFAS contaminated soil, other centres conducted only pilot scale tests. Since then more centres accept PFAS containing soil.
- The cleaning process must be extended with an **extra PFAS water purification step** (activated carbon or ion-exchange resins)
- Physico-chemical treatment **consumes water**, leading to minimal water effluent
- PFAS water discharge threshold levels: LOQ or criteria dangerous substances in water

Soil treatment in Flanders

- **Soil < 40 % fines** (<63 µm + organic material) is physico-chemically treatable
- **Soil > 40% fines**: non-treatability document from the OVB required (the soil must be landfilled, PFAS immobilised or isolated)
- At present **no alternative ex-situ treatment technologies are available** in Flanders
- **Base cost**: **40 to 60 euro/ton** (depending on volume, PFAS concentration, water treatment requirements)
- **Extra cost** when fines > 15 %: 0.8 to 1.6 euro/ton per extra %.
- The sludge fraction must be **landfilled** (! leachability of PFAS – acceptability criteria – special isolation conditions required)

Note: physico-chemical treatment **does not destroy PFAS**, they get moved and isolated

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Soil treatment in The Netherlands

- Available capacity for pfysico-chemical treatment (100000 ton/yr)
- Several treament facilities still in permit application for PFAS containing soils
- Ongoing testing for optimalisation cleaning proces or requested by authorities
- Sandy soils with PFAS up to 60 à 100 µg/kg dm are accepted for physico-chemical treatment
- Soils with higher PFAS concentrations:
  - No immidiate treatment: max 5 year of storage, or
  - Landfilling: >60 µg/kg dm PFOS and/or other PFAS (sum) or >140 µg/kg dm PFOA or fines >40%
- Cleaning of soils needs to be done up a level for free use of the soil

Thermal soil treatment in The Netherlands?

- **ATM** in Moerdijk **withdrew their permit request** to treat PFAS-polluted soils
- **Theo Pouw** in Utrecht did not request a permit for PFAS

- Thermal treatment (thermal desorption and incineration of desorbed PFAS in gas phase) can potentially **destroy the PFAS**
  - But PFAS require higher (> 1400 °C) than standard incineration temperatures (~ 1000°C)!
  - **Risk** of (short-chain) **PFAS emissions!**
  - Thermal treatment requires **huge amounts of energy**
  - **Greenhouse gas emissions** are very high;
  - Also the **native soil organic carbon** is largely emitted as CO_2 to the atmosphere

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Soil treatment in Germany

- **Physico-chemical soil treatment**: not investigated (sufficient capacity in FL)
- **Several thermal installations** have a permit for **thermal desorption/incineration**
- Max. input **concentration**: 50 mg/kg dm PFAS (sum)
- **Costs ~** 300 - 400 €/ton
- ? Emissions of PFAS to the atmosphere during the process ?

Discussion – points of attention

- **DIG & DUMP – boundary conditions / legal aspects?**
  - “Eternal” percolate treatment required?
  - Complete isolation (“salt-cell conditions”)?
  - Limited capacity in Flanders?
  - How to handle PFAS-saturated sorbing materials? (GAC, resins, zeolite, activated biochars, modified clays,…)
  - Acceptation criteria max. PFAS concentrations and/or leachability?

- **In-situ soil remediation? Prevent migration - human exposure?**
  - PlumeStop, SourceStop (Regenesis)? Costs? Long-term solution? Other adsorption substances?
  - Fytoremediation? Short-chain PFAS vs long-chain? Treatment of PFAS-containing plant materials? Applicability in contaminated agricultural areas?
  - In-situ soil flushing? Groundwater recirculation? Groundwater treatment BAT?

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- **Off-site treatment:**
  - What are acceptable PFAS concentrations for free **soil re-use**? → Flanders: < 2, 3, 8 µg/kg dm (PFOA, PFOS, sum PFAS)
  - Re-use as building material? Other re-use?
- **Is thermal treatment applicable for complete destruction of PFAS?**
  - **Over-all environmental benefit?** (energy consumption, GHG emissions, destruction of native OM)
  - Risk of **PFAS emissions** (partial destruction) – **incineration temperature?**
  - Is integration with **cement industry** possible ?

Most remediation technologies **do not destroy PFAS but temporarily remove them from the environment** or **immobilise** them.

➡ **"Eternal" monitoring** required (as with nuclear waste).

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