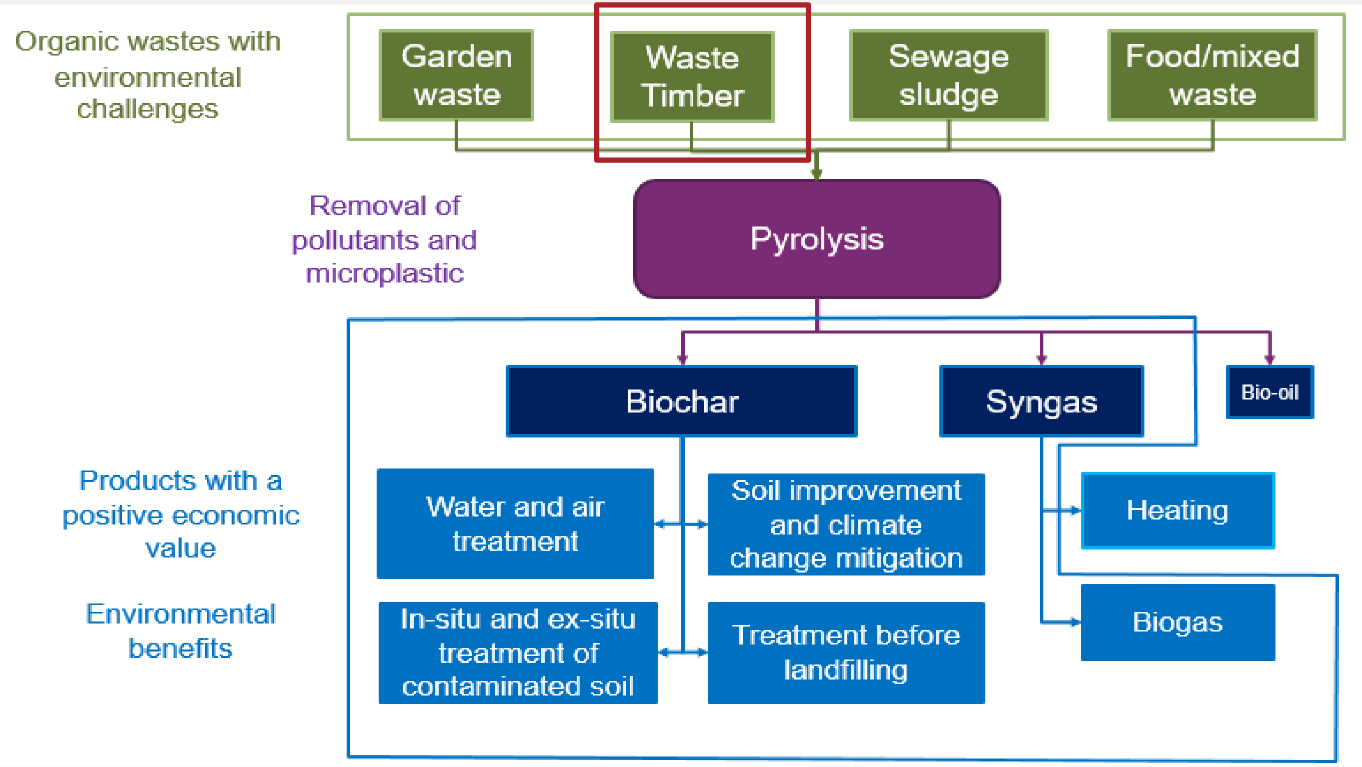
VOW – Valorization of Organic Waste as Biochar for the Cleanup of Water, Soil and Air

Valorization of Organic Waste, WASTE2ROAD Webinar, March 10th 2022

Erlend Sørmo and Gerard Cornelissen, NGI

VOW: Valorization of Organic Waste into Sustainable Products for Clean-up of Contaminated Water, Soil, and Air



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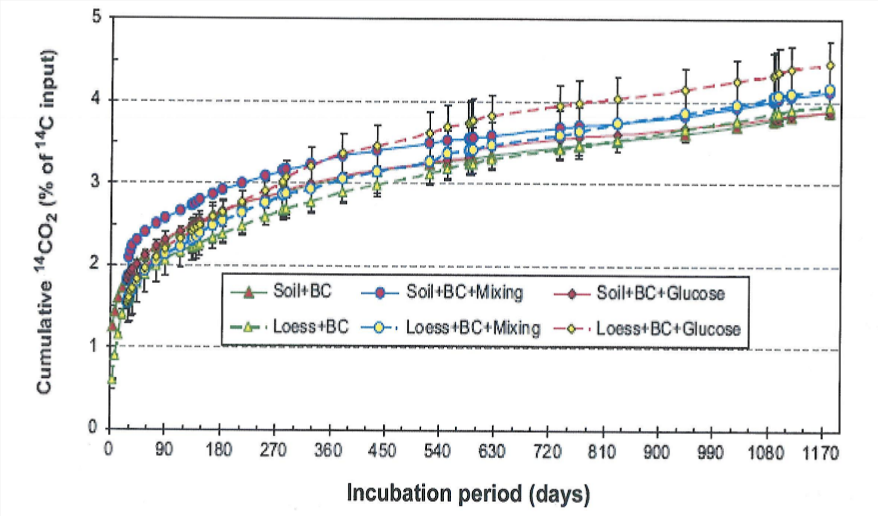
Pyrolysis – the basics

- Heating of organic matter residues in an O_2-free environment produces a carbon-rich charcoal material → **biochar**[1]
- When biochar is added to soil, it remains stable for a long time = carbon storage[1]
  - → Half life of 1400 years[2]
  - → MRT 2000 years[2]



Kuzyakov et al (2009) Soil Biol. and Biochem.

1) Lehman & Joseph (2015) Biochar for Environmental Management
2) Kuzyakov et al (2009) Soil Biol. and Biochem.

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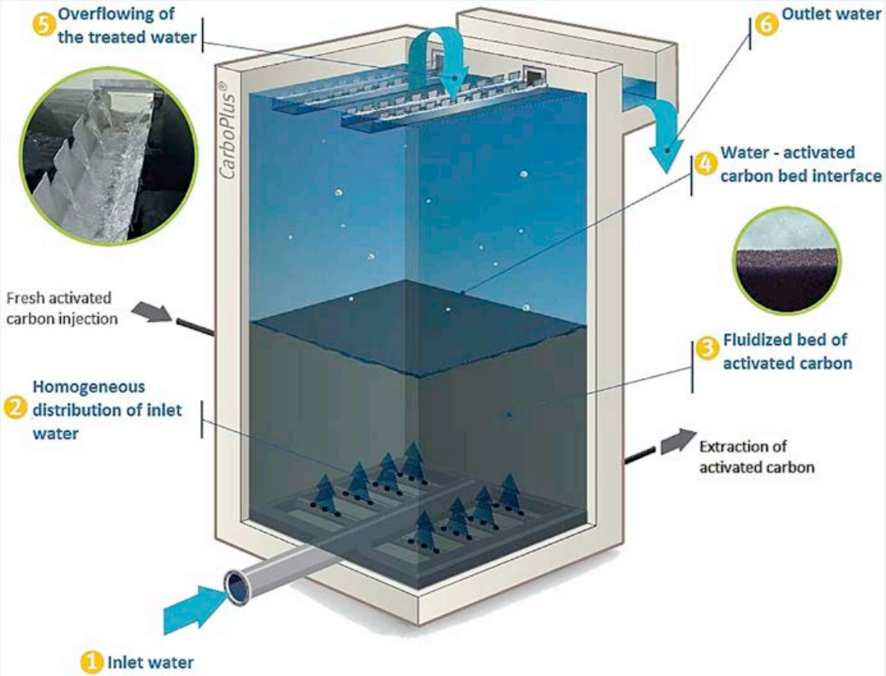
What is a sorbent?

- A material that absorbes/adsorbes a contaminant strongly
  - Ion exchange resins
  - Metal oxides
  - PP-fibers/Cellulose fibers
  - Activated carbon (AC)
  - **Biochar**

- Some current uses:
  - Waste water treatment plants
  - Landfills
  - Water purification
  - Oil spill clean-up
  - Industrial air filters
  - Gas masks
  - *Remediation of soil and sediment*



Mailler et al., 2015, Water Research

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Waste timber (WT)[1]

- Discarded wood and wood products
  - Wooden beams, panelling and flooring
  - Pallets, furniture and other wooden objects
  - Hard- and softboard
  - 750 000 t/y
- Lightly contaminated
  - Paint residues
  - Binders
  - Metals (remains of nails, hinges etc.)
  - No impregnated wood!

Photos: NGI

1) Sørmo et al 2020, STOTEN, 718, 137335

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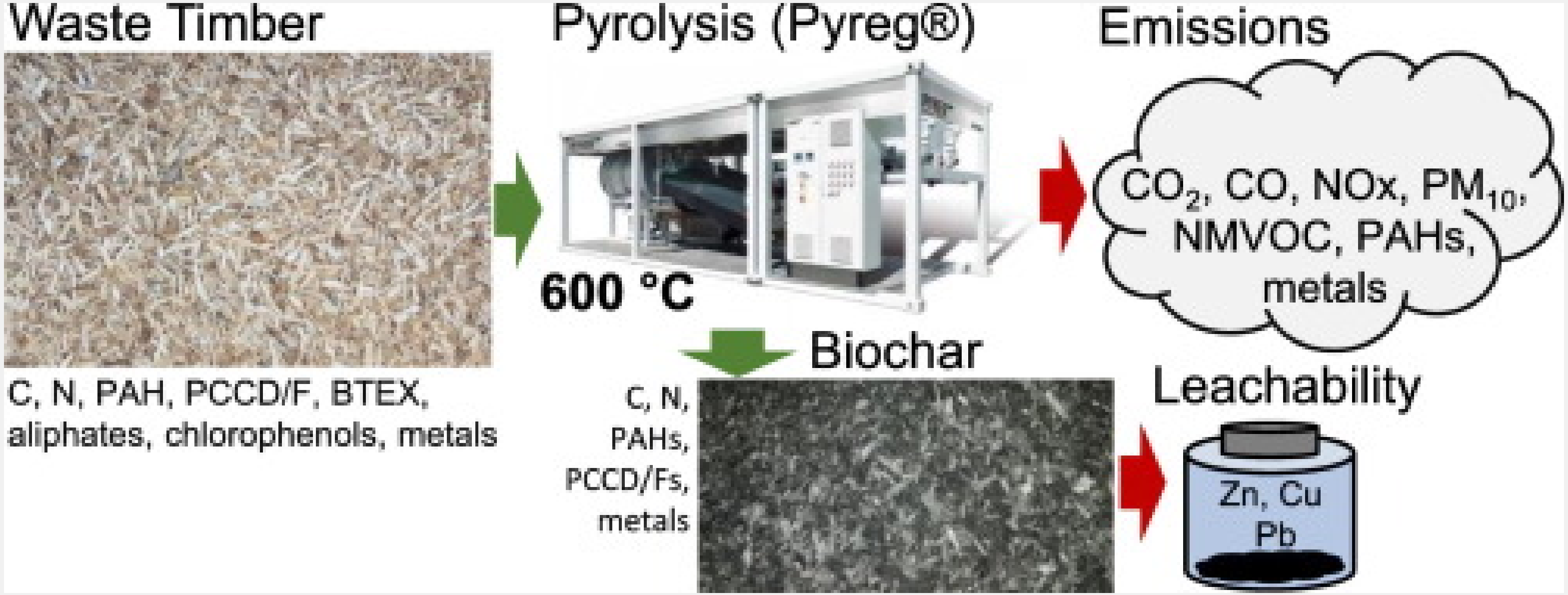
Emission budget for the pyrolysis of waste timber biochar



Sørmo et al 2020, STOTEN, 718, 137335

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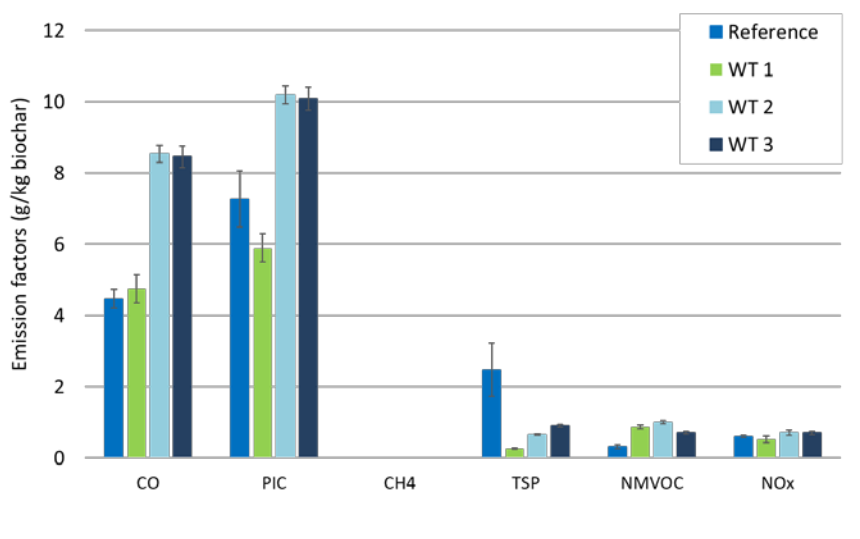
Main findings[1]

- Organic contaminants present are destroyed during pyrolysis
- Some heavy metals accumulate in the biochar (Cu, Pb, **Zn**), but do not leach to water at ambient pH
- Pyrolysis emission data show promising results for setup with combustion of pyrolysis gasses
- Optimization needed



CO = carbon monoxide, PIC = products of incomplete combustion, CH4 = methane, TSP = total suspended solids, NMVOC = non-methane volatile organic carbon, NOx = nitric oxides

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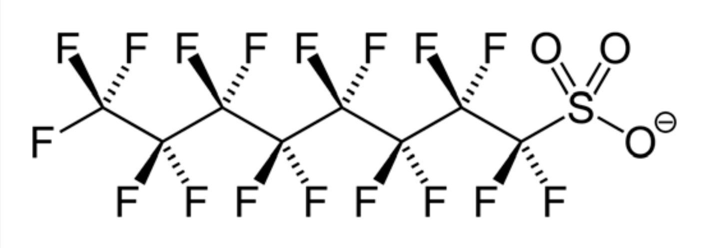
1) Sørmo et al 2020, STOTEN, 718, 137335

Where is our waste timber biochar best applied as a sorbent and will it work?

Per- and polyfluoroalkyl substances (PFAS) – a threat to our food and drinking water

- PFAS belong to the PMT-class of chemicals
  - Persistent, mobile and toxic (PMT)
- Where do they come from?
  - Fire fighting foam, GoreTex® clothing, Teflon® cookware, paper products (non-stick surfaces), industrial applications
- How do they end up in our drinking water and food?
  - **Point source release**, atmospheric transport, bioaccumulation
  - Fire fighting training sites, sewage sludge fertilizer, industry

Perfluorooctanesulfonic acid (PFOS)

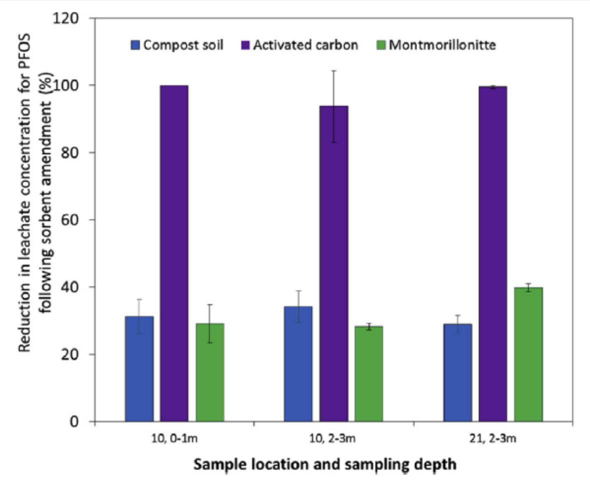


Source: Wikipedia

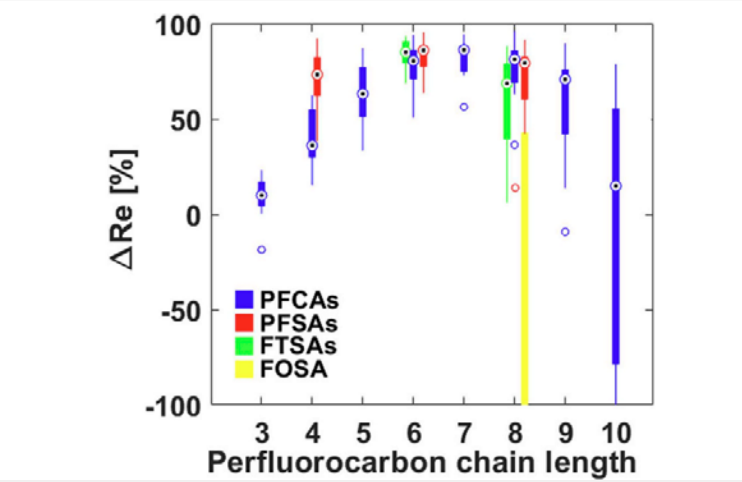
Photo: NGI

AC has been used to remove PFAS from soil solutions

- AC suited for PFOS sorption
- Hydrophobic interactions the dominant mechanism
- Varied effects for other PFAS congeners



Hale et al., 2017, Chemosphere



Sorengard et al., 2019, Jrn. Env. Man.

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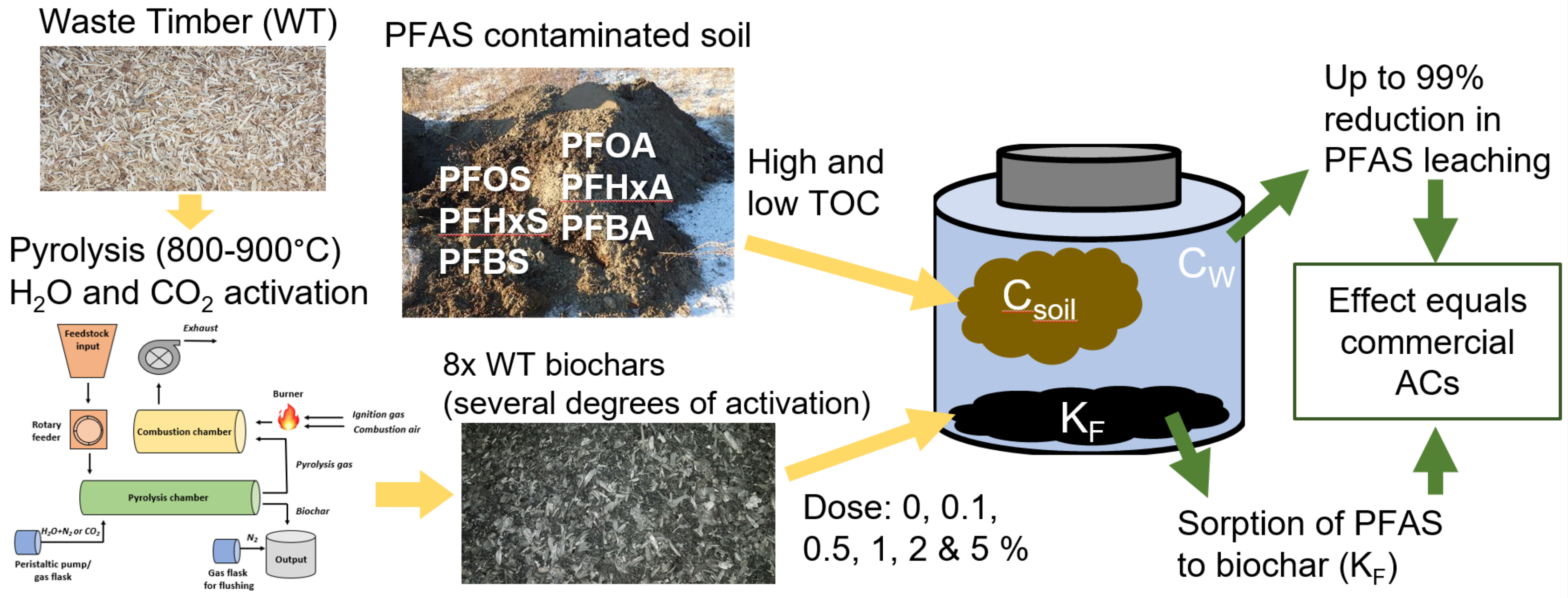
Stabilizing PFAS-contaminated soil with **activated waste timber biochar**



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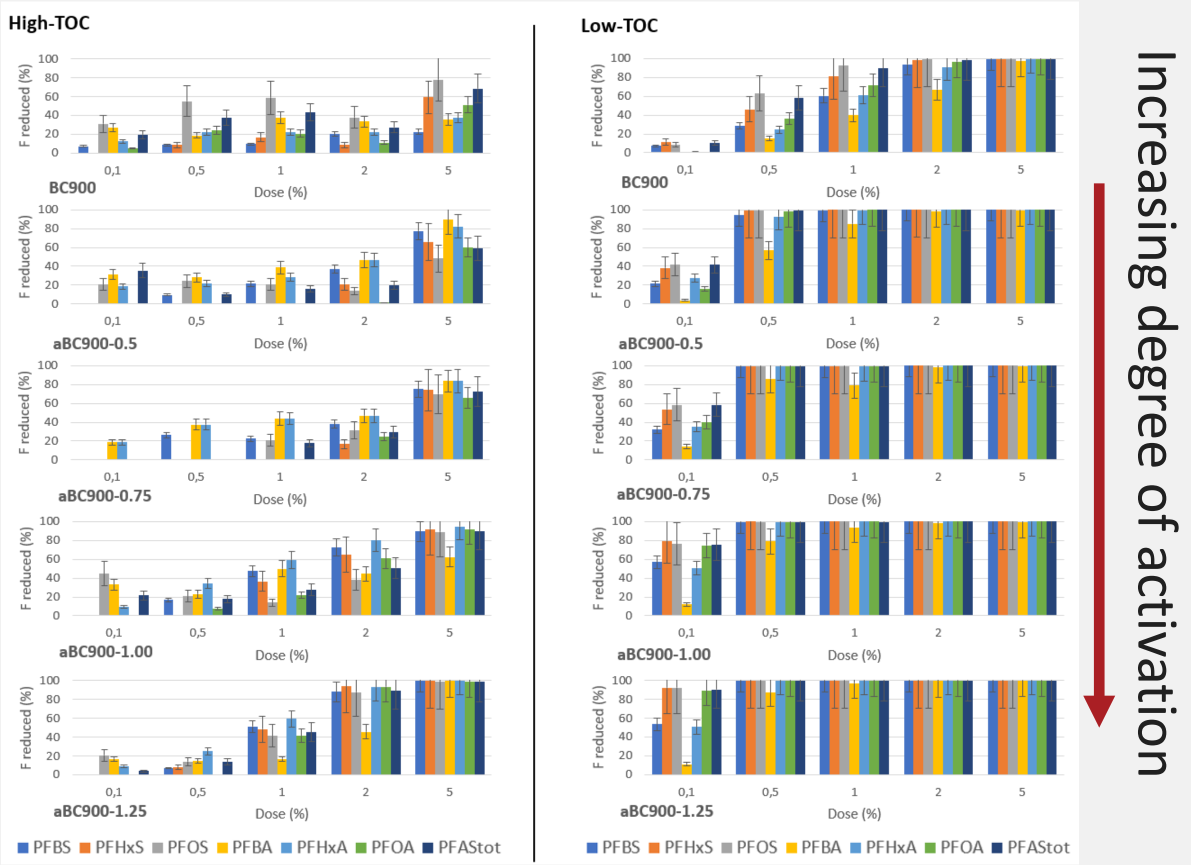
Sørmo et al (2021) STOTEN, 763, 144034

Main findings[1]

- Effect depends on PFAS congener and soil type
  - High TOC soils more difficult to treat
  - Short chain PFAS more difficult to retain



1) Sørmo et al (2021) STOTEN, 763, 144034

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Great, this might actually work!
Now what about other organic waste streams?

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Organic waste in Norway[1]

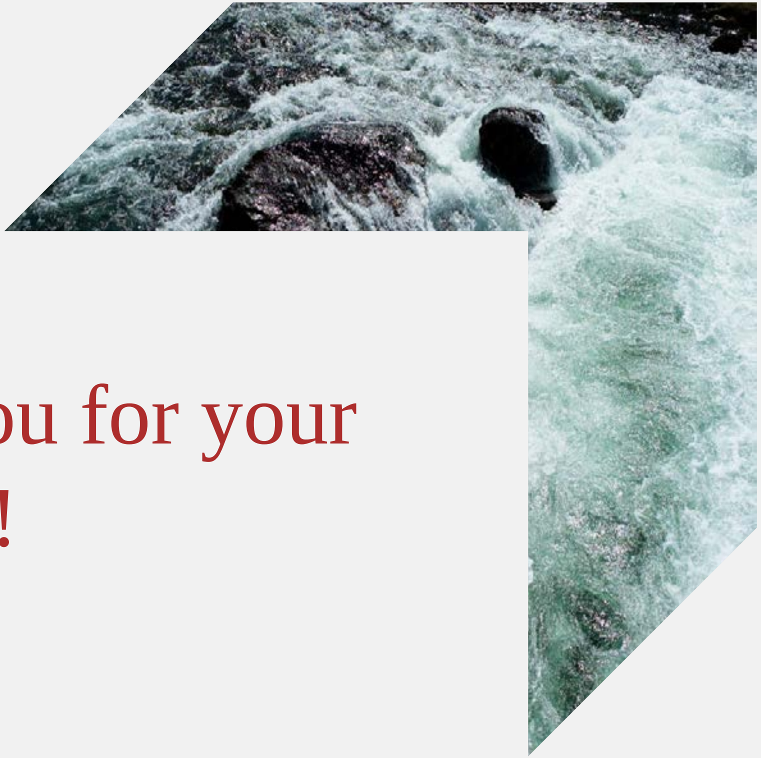
- Waste timber – 750 000 t/y
  - Heavy metals, traces of organic contaminants from binders, paint etc.
- Garden waste – 195 000 t/y
  - Heavy metals, plastics (plasticisers), pesticides
- Food/biological waste – 470 000 t/y
  - Plastics (plasticisers), PFAS
- Sewage sludge – 260 000 t/y
  - Heavy metals, plastics (plasticisers), PAH, PCB, PFAS, phenols

1) www.ssb.no, Avfallsregnskap 2012-2018

Unanswered questions being tackled in 2022-2023

- Making biochar from waste feedstocks
  - Will the biochar be clean enough?
  - What feedstocks will result in proper sorbents?
  - What pyrolysis conditions/modifications are needed?
- Residual contaminants
  - Some metals are enriched in the biochar and PAHs created during pyrolysis
  - Will use as sorbent add contaminants to the soil that are available for leaching or uptake in plants?
- Does this all make sense in a life cycle perspective?

To be continued…….



Thank you for your attention!

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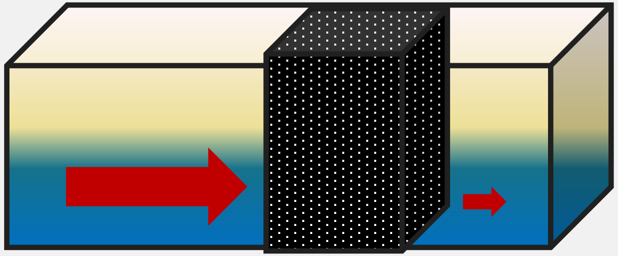
How can we use sorbents for contaminated soil?

- In landfills
  - Ex situ stabilisation
  - Limits leaching
  - Reduces need for landfill leachate treatment
- Active barriers
  - Across groundwater flow path
  - Limit transport
- Mixed into top-soil
  - Limit uptake in plants
  - Reduce effect on soil microorganisms
  - Limits downward transport to groundwater



Photos: NGI

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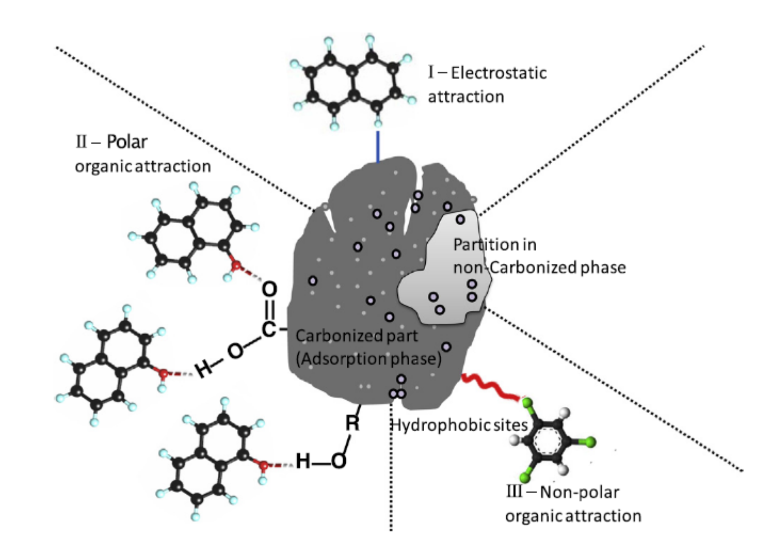
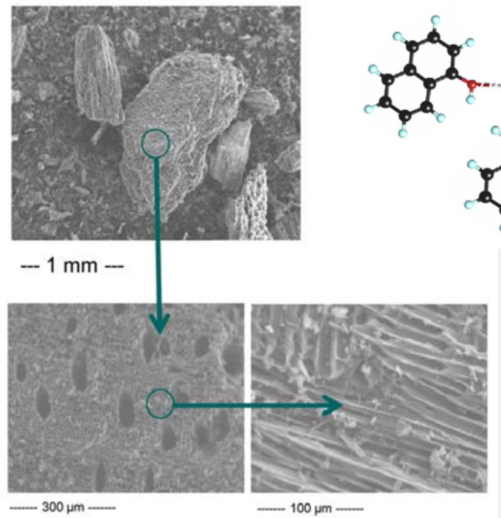
Can we use biochar as a sorbent for PFAS?

- Yes!
  - It has been done
  - Sorption mechanisms similar to AC
- Pros:
  - Sustainable version of AC
  - *Biochar properties more variable than AC*
- Cons:
  - Less efficient than AC
  - *Biochar properties more variable than AC*

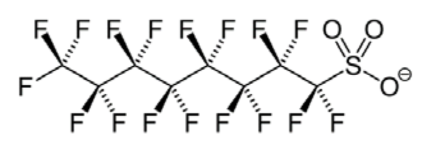
- What is needed?
  - Large internal surface area (>100 m^2/g)
  - High degree of aromaticity
  - Modifications (?!)



Ahmad et al., 2014, Chemosphere



Beesley et al., 2011, Env. Poll.



Properties of steam activated WT biochar

Sorbent	Molar ratio of oxidant to BC carbon (-)	Temp. (°C)	Biochar Yield (%)	N_2 adsorption – pores >1.5 nm		CO_2 adsorption – pores 0.3-1.5 nm		Elemental content	
				Surface area (m^2/g)	Pore volume (cc/g)	Surface area (m^2/g)	Pore volume (cc/g)	Total C (%)	Total O (%)
BC900	0	900	19.0	411	28 %	840	24 %	89	6.8
aBC900-0.50	0.50	900	12.2	550	45 %	744	22 %	91	5.9
aBC900-0.75	0.75	900	12.1	605	52 %	746	23 %	89	5.6
aBC900-1.00	1.00	900	8.9	713	83 %	750	24 %	88	8.0
aBC900-1.25	1.25	900	8.0	623	51 %	846	28 %	87	5.7

Sørmo et al (2021) STOTEN, 763, 144034