

Assessing PFAS Contamination in Dutch Groundwater

Insights from an age-dated depth profile

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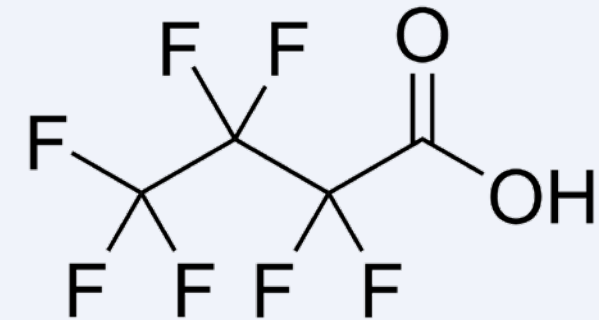
Everywhere



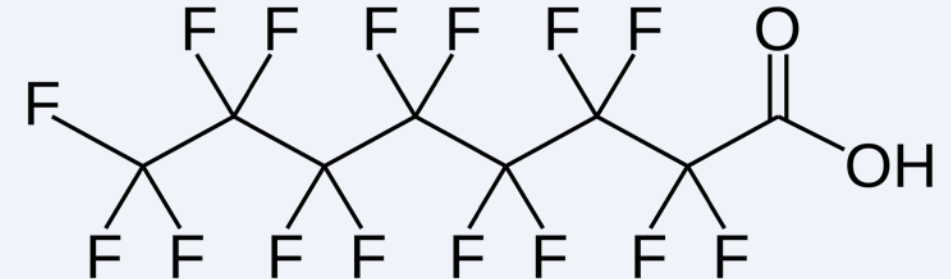
PFAS

- PFAS: Per- and polyfluoroalkyl substances
- Carbon-fluorine bonds: one of the strongest bonds in organic chemistry
- “Forever chemicals”
 - Persistent in the environment
 - Bioaccumulate
- Related to health risks, eg:
 - Liver damage
 - Thyroid disease
 - Obesity
 - Fertility issues
 - Cancer
- Chain length of PFAS determines mobility

PFBA (Perfluorobutanoic acid)

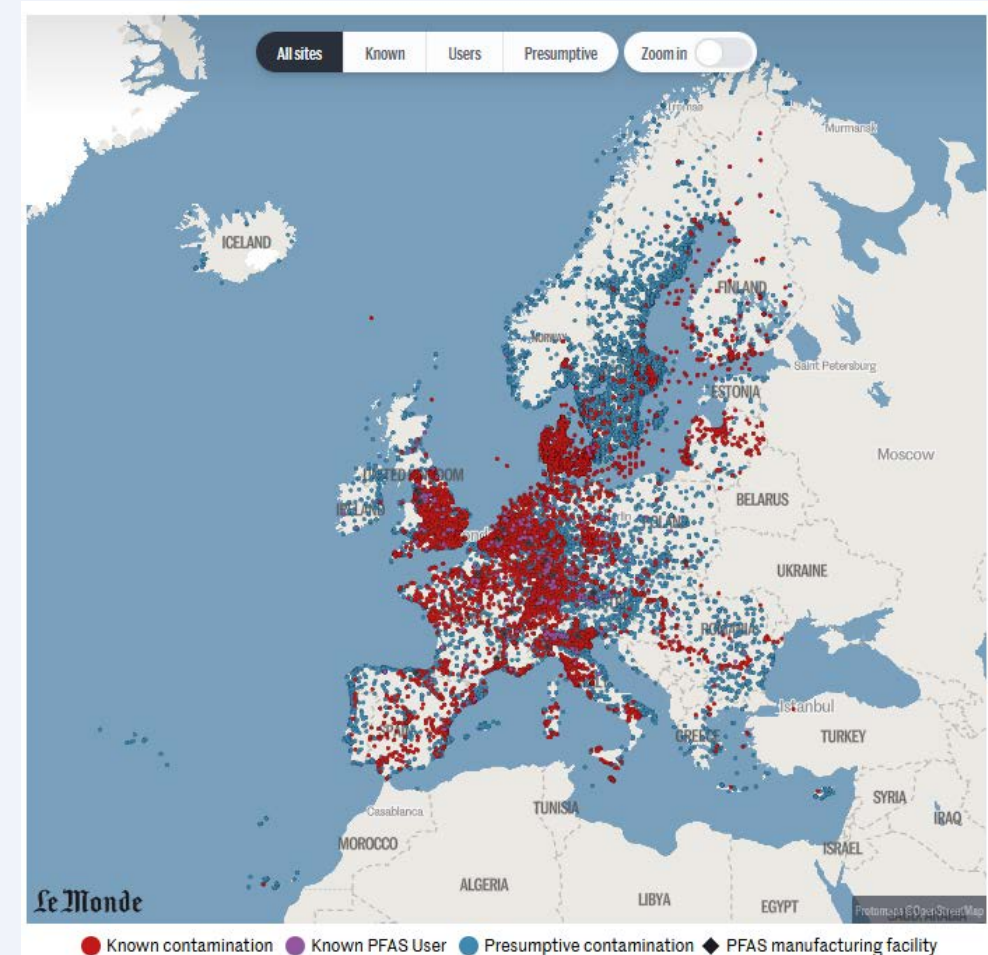


PFOA (Perfluorooctanoic acid)



Questions

- A lot of attention for PFAS
- Difficult to know contamination history
 - No clear sales data like pesticides/antibiotics
- Since when have PFAS been infiltrating in the regional groundwater?
 - Relating PFAS concentrations to groundwater ages & infiltration years
 - Determined by tritium/helium dating
- How does sorption influence the transport of PFAS
- Important to understand PFAS transport in relation to deeper groundwater



Source: Forever Pollution Project

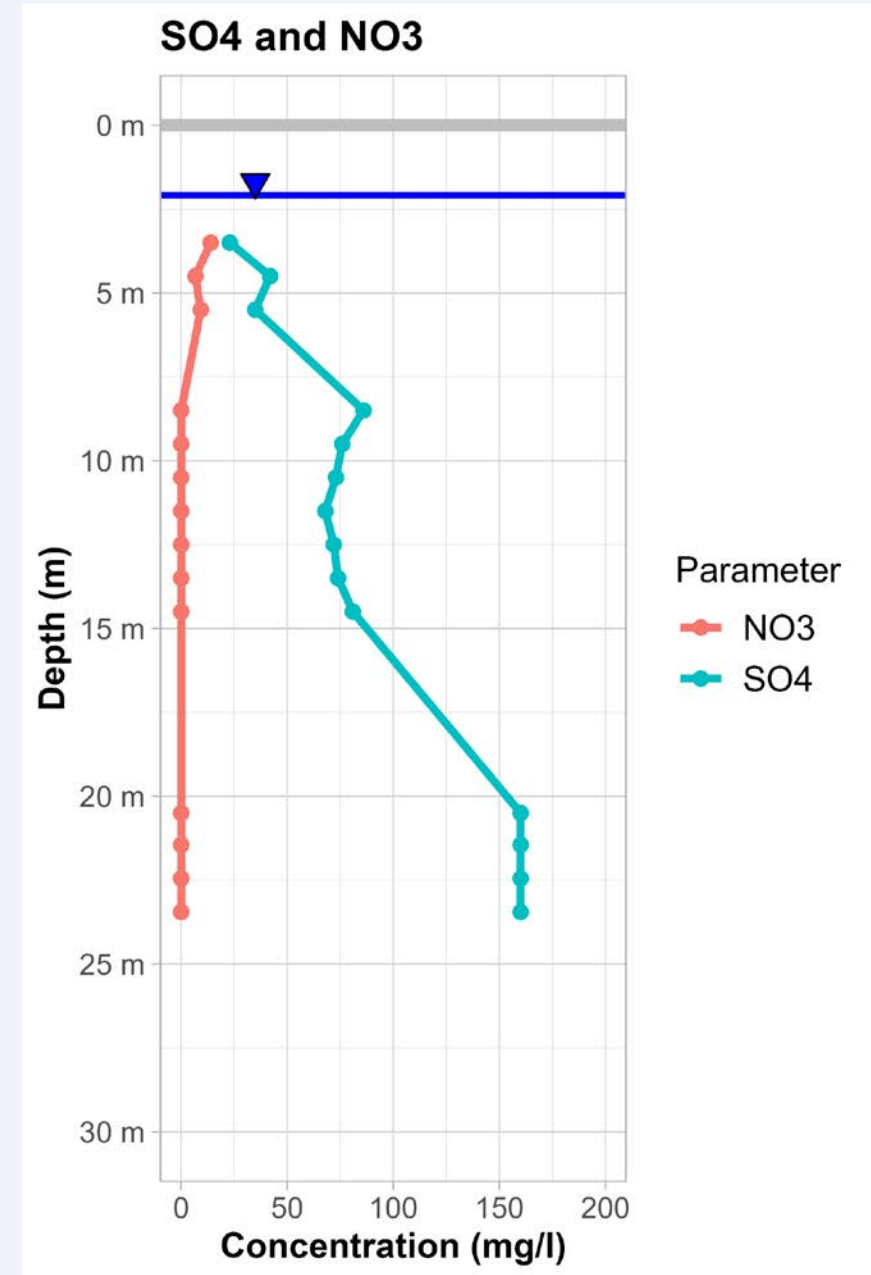
PFAS drinking water standards

- Water quality standards:
 - EU Drinking Water Directive (from 12-01-2026):
 - 500 ng/l: total PFAS
 - 100 ng/l: sum of 20 PFAS
 - NL
 - Target value of 4.4 ng/l of “PFOA-equivalents”
 - US-EPA:
 - 4 ng/l for PFOA & PFOS
 - 10 ng/l for PFNA, PFHxS, HFPO-DA (GenX)
 - Denmark:
 - 2 ng/l for sum of PFOA, PFOS, PFNA & PPHHxS



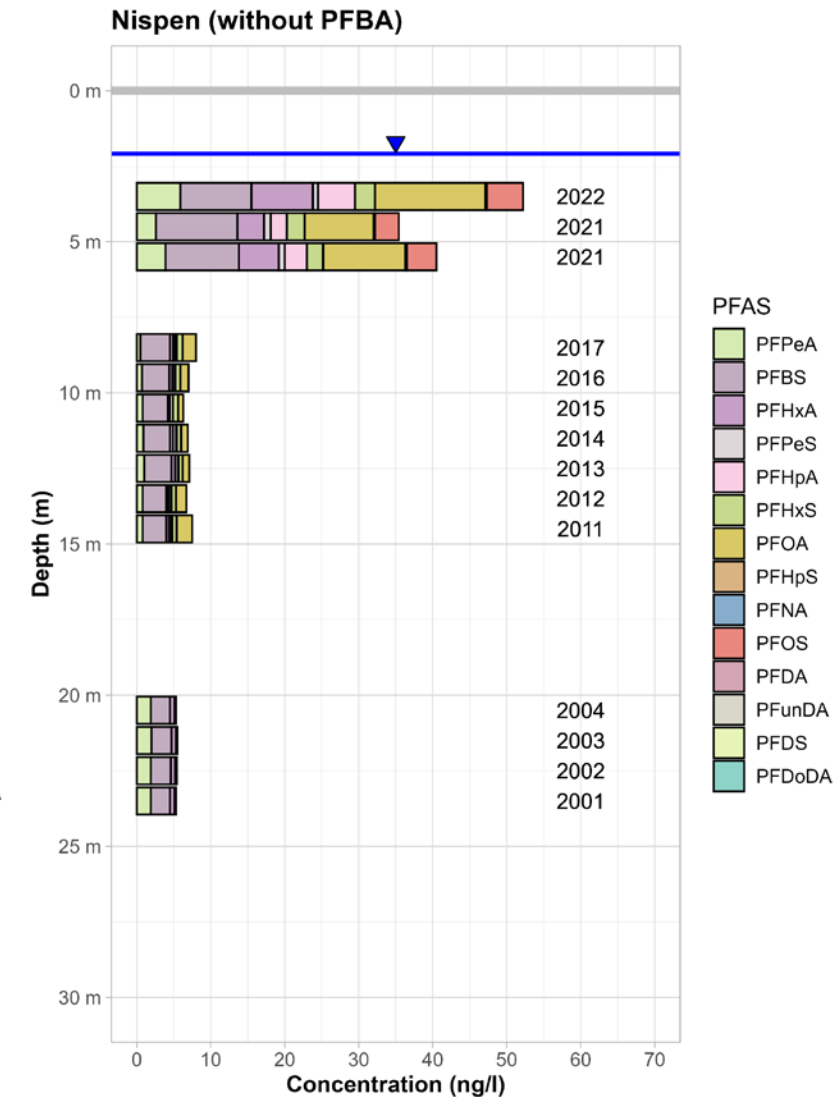
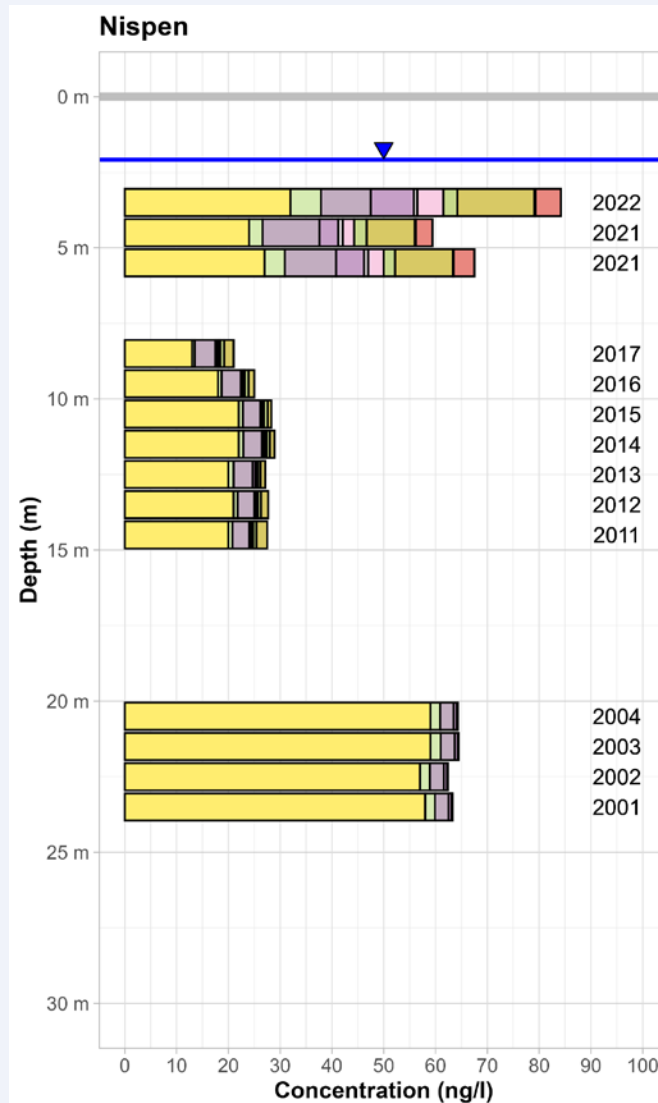
Nispen minifilter well

- Groundwater well with age-dated filters at 5, 14 and 23 m below surface
- Also includes 14 small filters at intermediary depth
- Enables high-resolution depth profiles to be made
- Agricultural area, elevated NO_3 & SO_4 concentrations



PFAS depth profile

- PFAS depth profile
 - Bars indicate filter depths
 - Years indicate infiltration years
 - PFAS ordered on molar volume
- “Chromatography”
 - Short-chained PFAS (PFBA/PFPeA/PFBS) travel deeper than long chained PFAS (PFOA/PFOS)
 - Difference in mobility
 - Difference in emission history



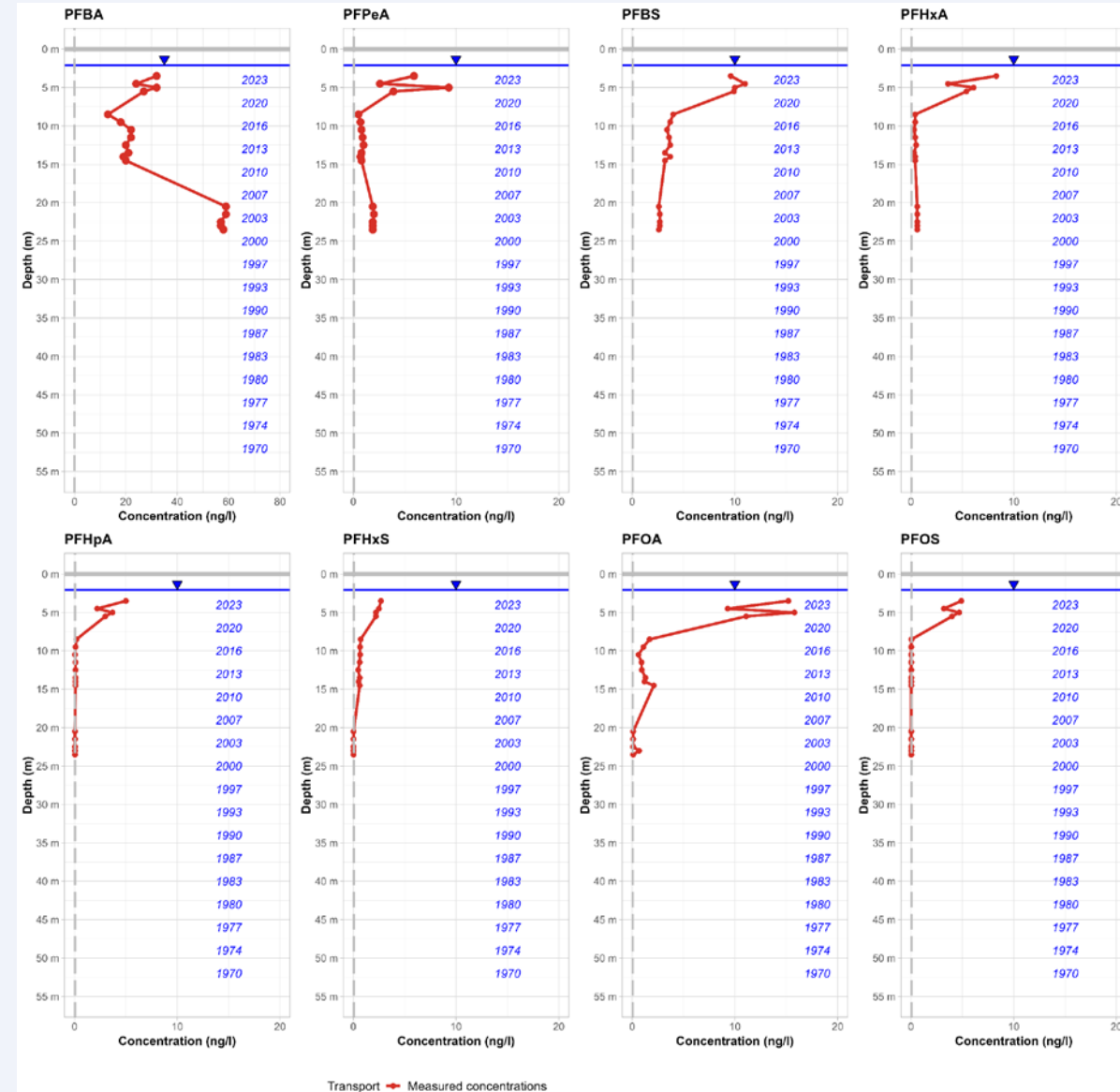
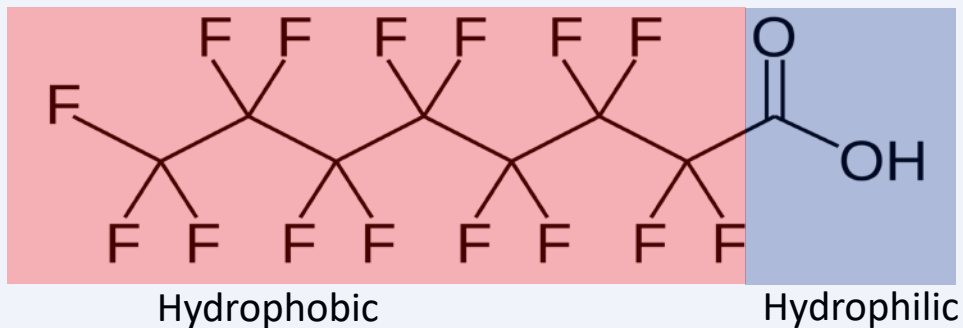
Linking PFAS to recharge year

- PFAS is not conservative
- Concentrations in groundwater cannot be directly related to recharge year
- Retardation due to sorption processes
- Two types of retardation:
 - Retardation by sorption to organic matter

$$R = \frac{\rho_{bulk}}{\theta} K_{oc} f_{oc} + 1$$

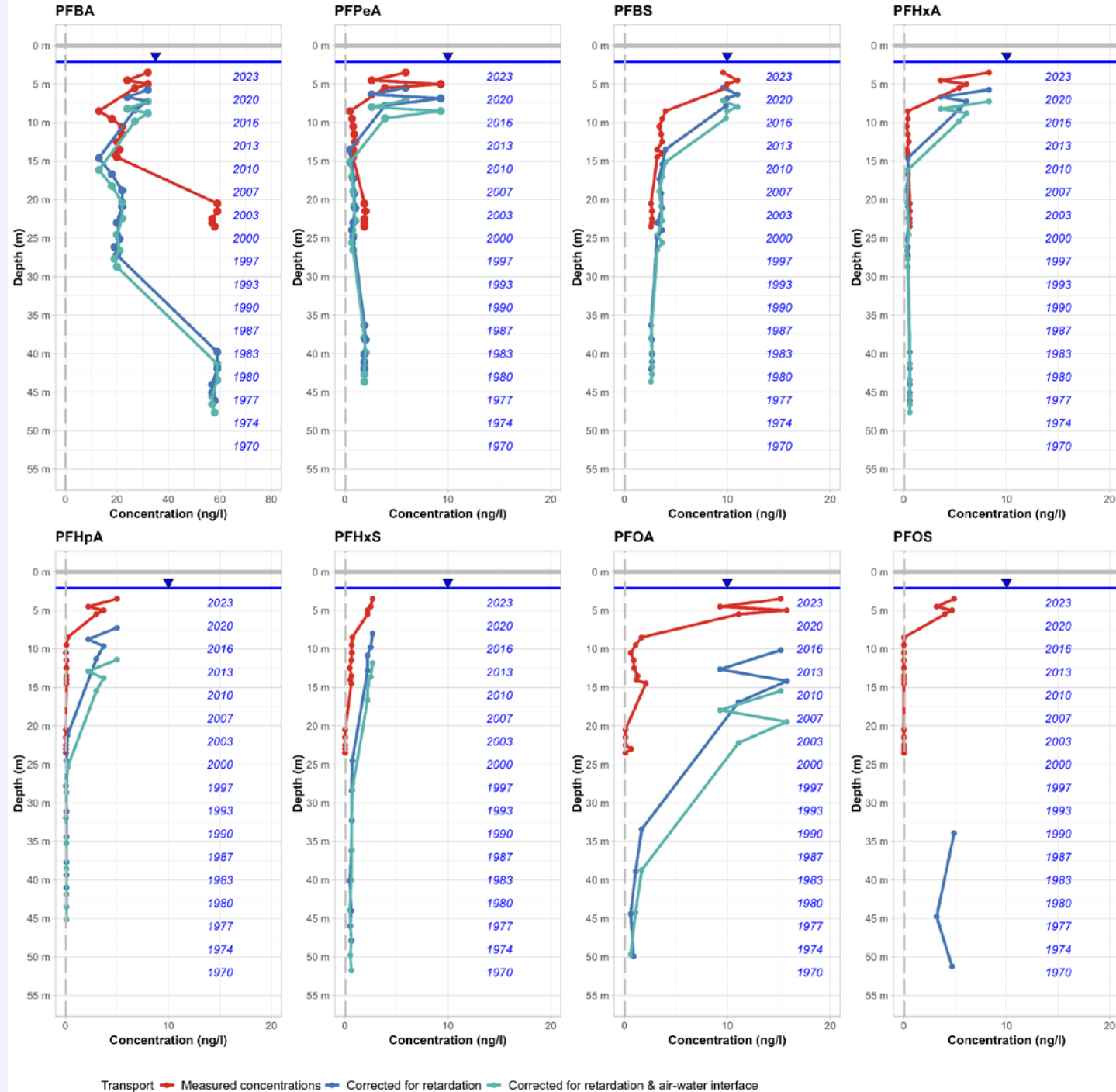
- Retardation by sorption to the air-water interface

PFOA (Perfluorooctanoic acid)



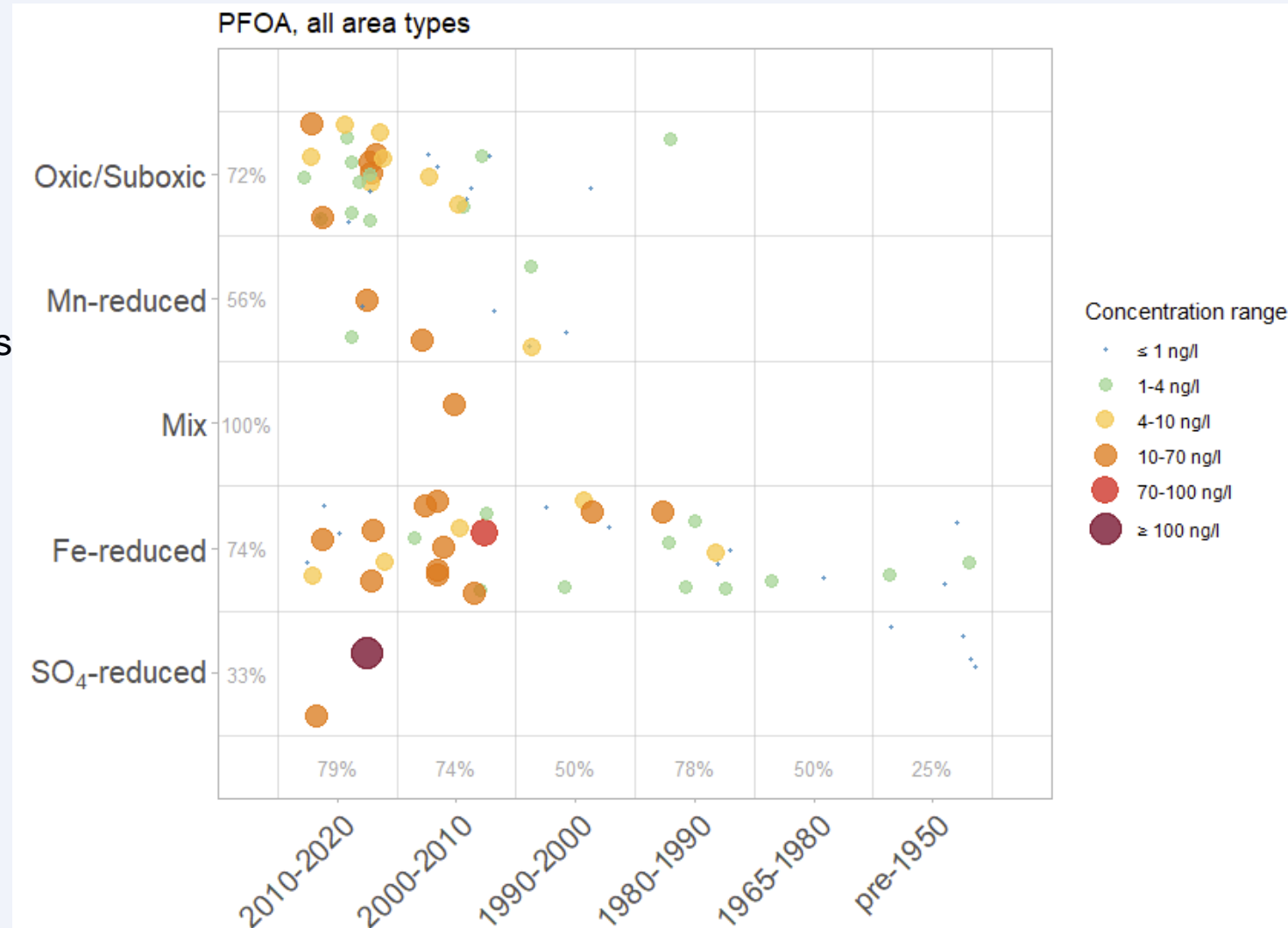
Linking PFAS to recharge year

- Short-chained PFAS:
 - Leaching since 1970s/1980s
 - Linked with production of PFOA
 - More recently as replacement
- Long-chained PFAS (PFOA/PFOS)
 - Large retardation
 - Expected decrease in PFOA not yet visible
- Possible sources:
 - Atmospheric deposition
 - PFAS-containing pesticides
 - Sewage sludge (before 1998)



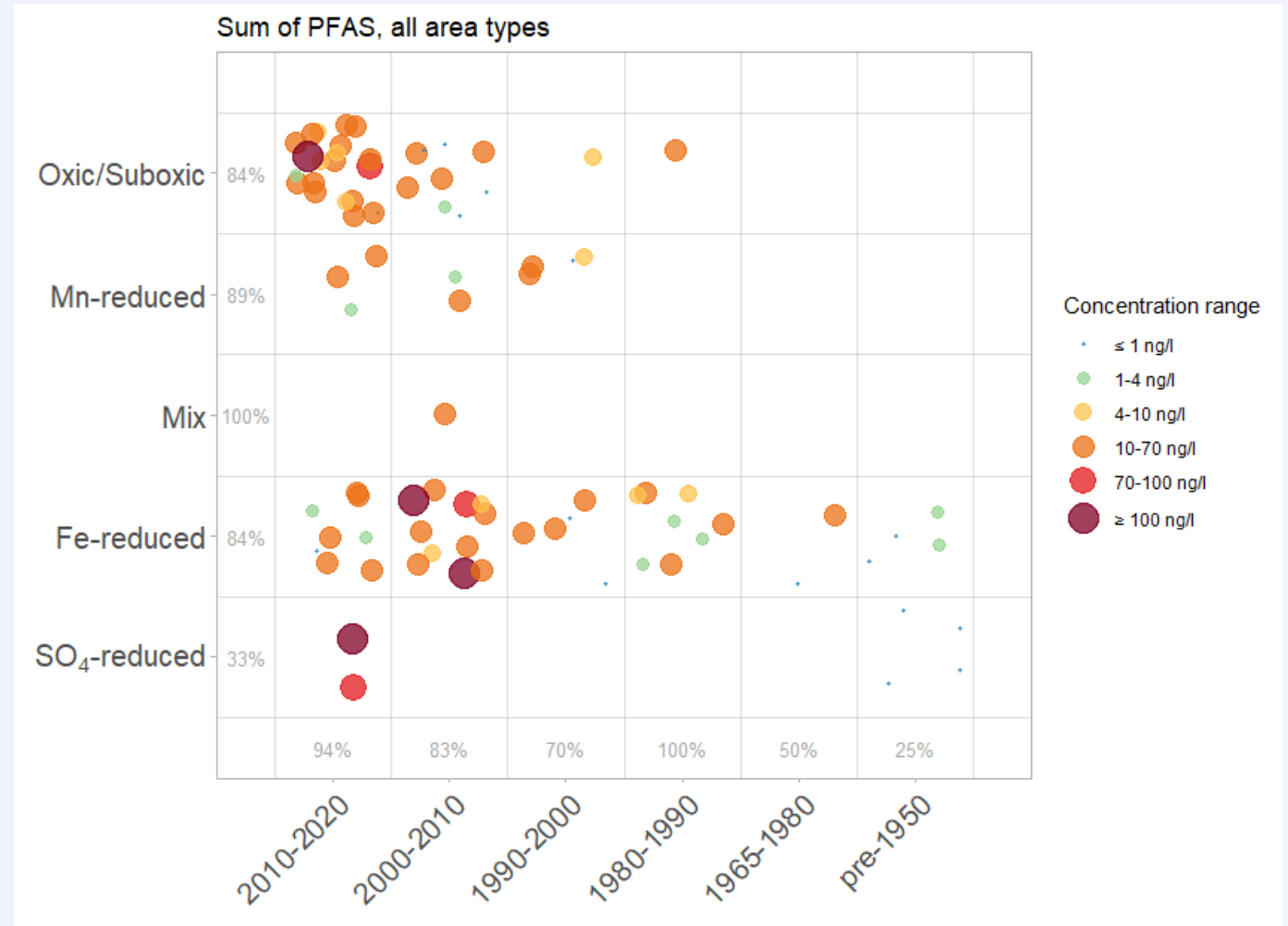
Regional patterns of PFAS contamination

- Regional results (south of NL)
 - Provincial groundwater monitoring network
 - Shallow groundwater (<30 m below surface)
- Jitter-jitter: Redox classes vs infiltration periods
 - Similar to presentations #90_Broers & #226_van Vliet
- PFOA present across all redox-classes and infiltration periods.
 - Behavior independent of redox status
 - Orange/red: above Dutch target value for drinking water (4.4 ng/l)



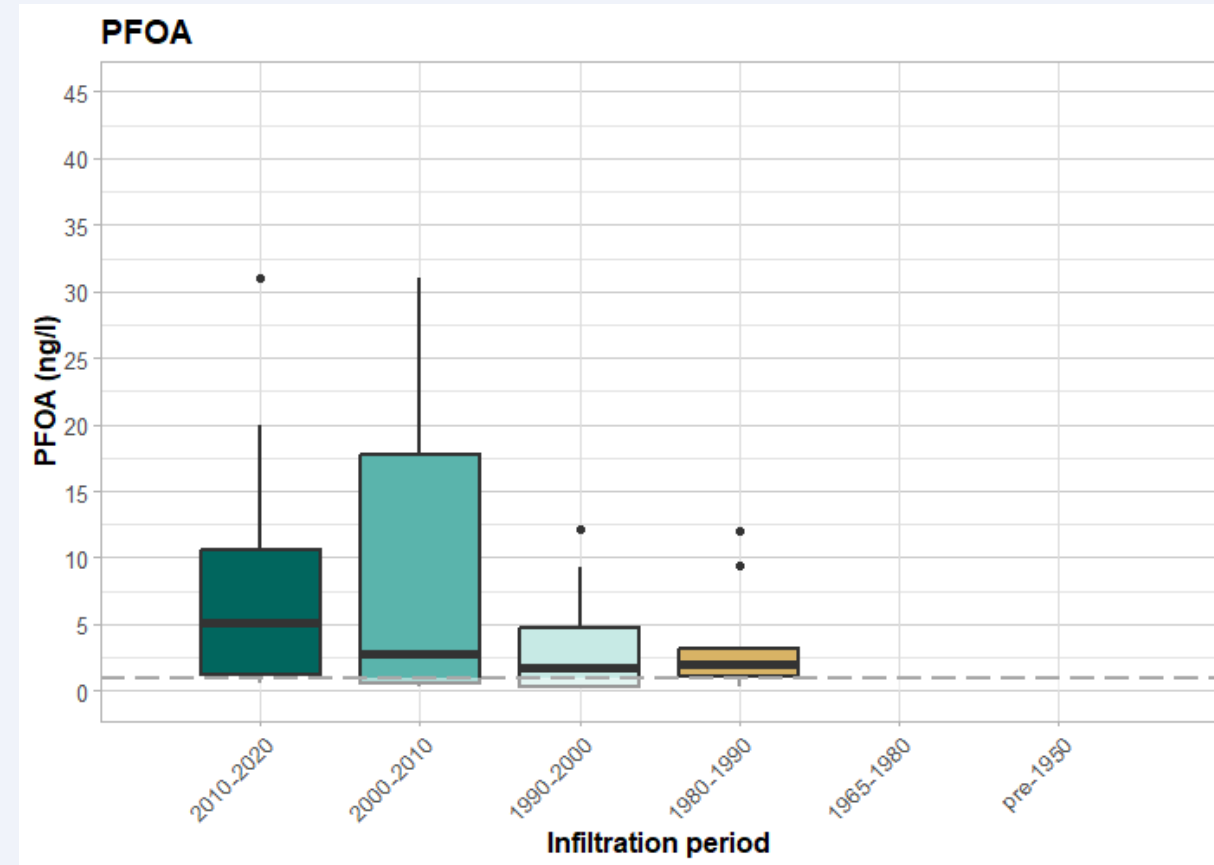
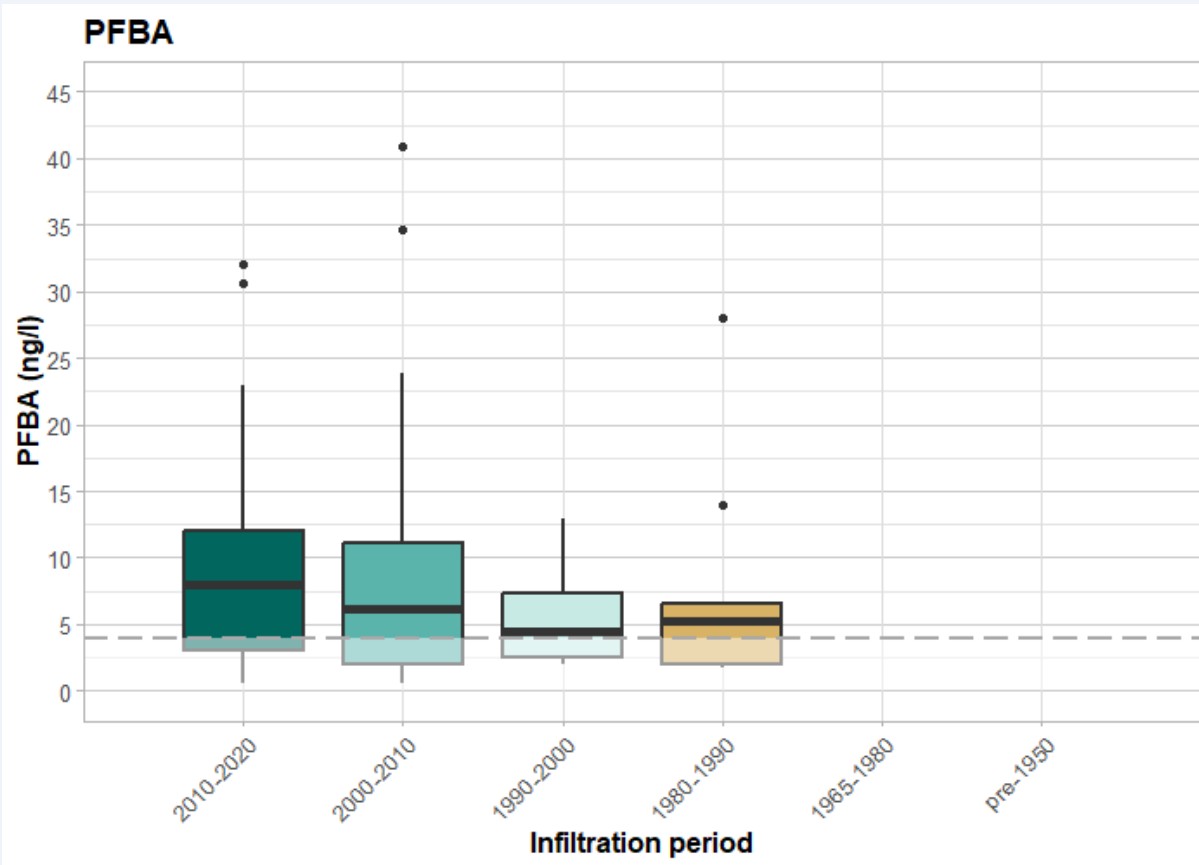
Regional patterns of PFAS contamination

- Jitter-jitter: Redox classes vs infiltration periods
- Sum of 20 PFAS
- Mostly below EU drinking water directive norm (100 ng/l)
- But still found across all redox states and infiltration periods
- At least some PFAS present in most groundwater samples



Regional patterns of PFAS contamination

- PFAS seem to behave independent of redox status
- Increasing trend in younger infiltration periods
- Both linked to retardation and emission history



Conclusions

- Unknown emission history of PFAS makes interpretation difficult
- Interpreting PFAS depth profile helps to understand emission history
 - Linking PFAS concentrations to infiltration periods by correcting for retardation
- PFOA/PFBA have been leaching since 1970s/1980s
- No clear decline of PFOA since production decrease in recent years
- Mobile short-chained PFAS do not undergo significant retardation
 - Leaching to deeper groundwater systems possible
- PFAS present in regional groundwater system across all redox classes & infiltration periods
 - Increasing trend in younger infiltration periods

Thanks for your attention!

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