Occurrence and Distribution of PFAS in the River and Groundwater at Two Danube Sites

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Background

Per- and Polyfluoroalkyl Substances (PFAS) are chemicals used for many domestic and industrial purposes related to their physicochemical properties. However, those same properties make them mobile and persistent in the environment, and on top of that, they are toxic and can affect human health in the short and long term, as they are bio-accumulative. Many processes govern the transport of PFAS in the surface waters and groundwater, e.g. sorption, biodegradation, co-transport, and transformation. Monitoring PFAS at different locations can help understand these processes and provide datasets to calibrate and validate reactive transport models simulating PFAS fate and transport. This study compares PFAS presence and distribution in river water and groundwater at four Danube river sites.

The site in Vienna has a clogging layer on top of the river bed and steady water levels while in Budapest, water levels are dynamic with no clogging.

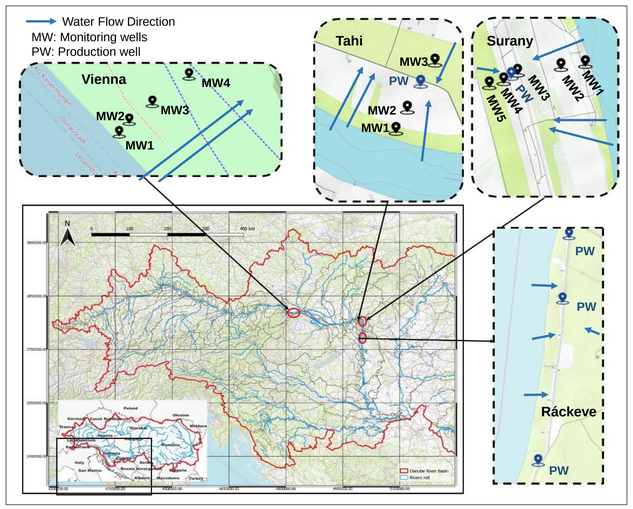

Figure 1: Study sites map

Methods

- Samples from the river and groundwater were collected bimonthly over one year in Vienna and Budapest (Surany, Tahi and Ráckeve). In Ráckeve composite sample from 3 production wells (PW) were taken.
- The analysis targeted 32 PFAS compounds and LCMS was used for PFAS analysis and pharmaceuticals.
- Censored data (<LOQ) were processed using regression on order statistics.
- Shapiro-Wilk test for normality and Kruskal-Wallis test for differences were performed on the data set.

Results

- Monitoring wells in Vienna have the same water type as the Danube, while in Budapest, background wells have a different water type. Acc. to chemical analyses

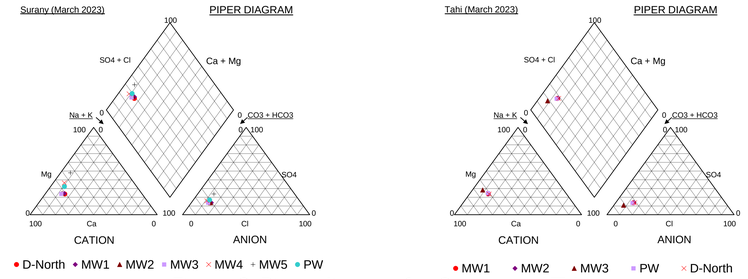

Figure 2: Piper diagram for Surany and Tahi

- ADONA had the highest concentration among all PFAS (average 10 ng/l), while many of the substances had analytical results below LOQ (Figure 3).
- Background water affects PFAS concentrations in the production wells at Budapest sites.
- Some PFAS are possibly impacted from older water or different sources (i.e. PFOS, PFOA).
- Carbamazepine is behaving similar to PFAS while Diclofenac shows sorption to some extent.

Figure 3: Boxplots of PFAS concentrations in the Danube and bank filtered groundwater (boxes: 25 – 75%, line: median, whiskers: ±1.5 IQR%).

- In Vienna, PFAS concentrations in all monitoring wells are similar as the Danube ($p>0.05$, Table 1).
- In Surany and Tahi, there is an influence from background water (Fig. 4).

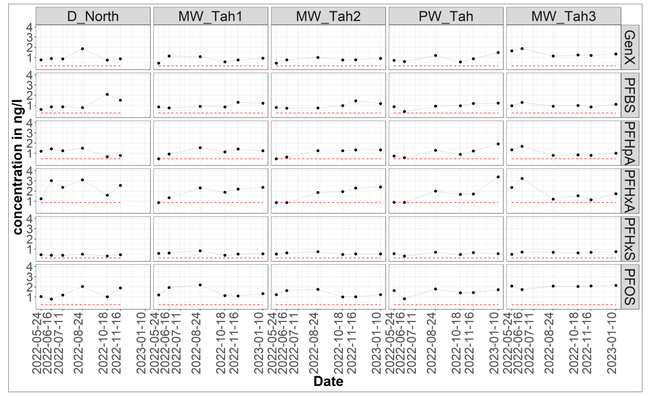

Figure 4: PFAS concentration time series in the Danube and groundwater at Tahi.

- Majority of the PFAS concentrations are not normally distributed.
- Test of differences shows that in Vienna there are no differences between all sampling locations ($p>0.05$, Table 1).
- In Budapest, PFAS concentrations in the Danube and groundwater differ ($p<0.05$).

Table 1: Kruskal-Wallis test P_values

PFAS	P_Value			
	Surany	Tahi	Rackeve	Vienna
PFBA	0.089	0.819	0.086	0.380
PFHxA	0.045	0.606	0.014	0.602
PFHpA	0.512	0.963	0.327	0.430
PFOA	0.001	0.023	0.142	0.253
GenX	0.011	0.030	0.624	0.705
PFOS	0.001	0.030	0.221	0.918
PFBS	0.296	0.918	0.462	0.930
PFHxS	0.000	0.022	0.027	0.547
NaADONA	0.013	0.797	0.086	0.161
PFPeA	0.053	0.984	0.027	0.382

Conclusion and future steps

- PFAS are generally persistent during soil passage: there was no/minimal sorption or degradation for many of the compounds.
- PFOS and PFOA seem to be from older water at the Budapest transect.
- Soil column experiments will provide more information about sorption coefficients.
- Modelling of PFAS transport using MODFLOW coupled with MT3DMS and PhreeqC.

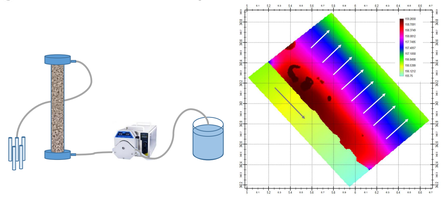

Figure 5: planned column setup (left), preliminary groundwater flow model for Vienna site (right).

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