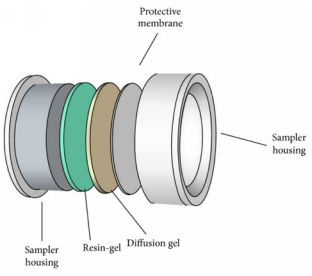
Metals and PFAS in Smålandsfarvandet South of Zealand

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ABSTRACT
The area around Great Belt and Smålandsfarvandet south of Zealand has been sampled from December 2023 to June 2025 for metals and PFAS, using both water samples and passive DGT. The data was used for hydrodynamic modelling of PFAS using inputs from WWTPs and rivers based on National databases. Results are based on a velux project, see more at projects.au.dk/newsea/

PFAS

As one of the newest "forever chemicals", PFAS joins the ranks of other halides as persistent and highly toxic compounds (chlorinated PCBs and dioxins and brominated flame-retardants) and have been forbidden in most countries for years, but still cause problems in Denmark, but already in 2008 Bossi showed it was ubiquitous in the Danish environment, leading to inclusion in the national monitoring from 2011 (Larsen, 2024).

Korsør Nor cattle grazing society

In 2021 hobby farmers eating cows grazing on the pastures around Korsør Nor got a nasty surprise as the meat was found to contain large amount of PFAS, sparking public outroar. Several warnings were given about PFAS in firefighting foams from in 2014 and 2016, but after 15 years of eating the meat, more than 180 local citizens was severely polluted by PFAS, and particularly PFOS, despite usage had been forbidden firefighting foam since 2006, and phased out in 2011.

PFAS/PFOS EQS and target values

The current Waterframework directive EQS for PFOS in water is set at 0,13 ng/l. From 2027 (EU directive 2026/805), this will change to a sum of 25 PFAS using relative Potency Factors, calculating a PFOA equivalent, with RPF of PFOS as 2. The EQS for water will be set at 4,4 ng/l as PFAS25, taken as a median of 90 samples analyzed in the Newsea project (shown in figure 1), 9.7% of the PFAS25 was attributed to PFOS (ranging from 6 to 18% as 10 to 90% percentiles, excluding the samples from the firefighting school). Using 9,7% as a precautionary PFOS concentration in the new PFAS25 EQS gives 0,43 ng/l as the updated limit. So black and cyan represent stations below the precautionary EQS for PFOS, whereas 2,2 ng/l PFOS (by definition) is the level at which the PFOA-equivalent PFAS25 EQS is exceeded (yellow or orange). Data from WWTPs and a survey of streams conducted in 2021 to 2022 is also shown in figure 1, maximum PFOS concentrations at WWTPs was 87 ng/l and in streams from all of Denmark measured in 2021 and 2022, the sum of PFOS, PFOA, PFNA and PFHxS was detected in 2551 samples with a median of 1,9 ng PFAS4/l and a 10-90% percentile of 0,59 to 9,3 ng PFAS4/l. in the Study area, one outlier value of 2300 ng PFOS/l was seen at Fedkrog.

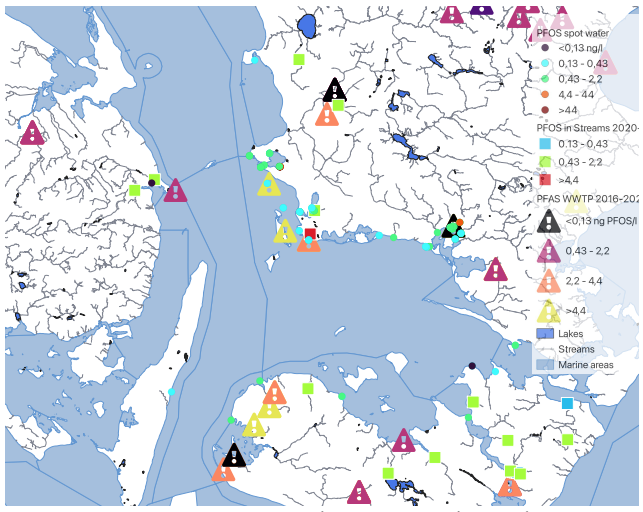


Figure 1: Overview of concentrations in WWTPs (2016-2021, triangles), Streams (2021-2022, Squares) and New Sea results (circles) with concentration levels corresponding to different hazard levels.

PFAS/PFOS Results

The boxplots of all spot samples are shown i figure 2, with an insert of the sampling rounds in Suså just outside of the Næstved WWTP (green triangles right scale) and the ditch just downstream of the firefighting school at Korsør Nor and ditch 2 to the East of the drainage area (red and orange dots, left scale). It should be noted that remediation have begun in Korsør Nor, cutting of the drains so no new PFOS polluted water from uphill is added – but there is still a seasonal effect of the legacy pollution, previous measurements in the central ditch shoved up to concentration levels of 7800 to 34000 ng PFOS/l, in June 2021, dropping to 1 to 1.7 µg/l in February and June 2022 (around the level found in 2024 by Newsea).

In Suså, the levels in the stream was higher than a spot measure taken from the WWTP channel directly in 2025, and the highest concentrations in Susa was actually found in Nolds Havn (harbour), North of the WWTP, before Suså is split into a Westerly and Easterly part, indicating a source upstream might be in play. Otherwise, maily harbours are where the highest concentrations are found, and background levels are below 0,43 ng/l but not 0,13 ng/l..

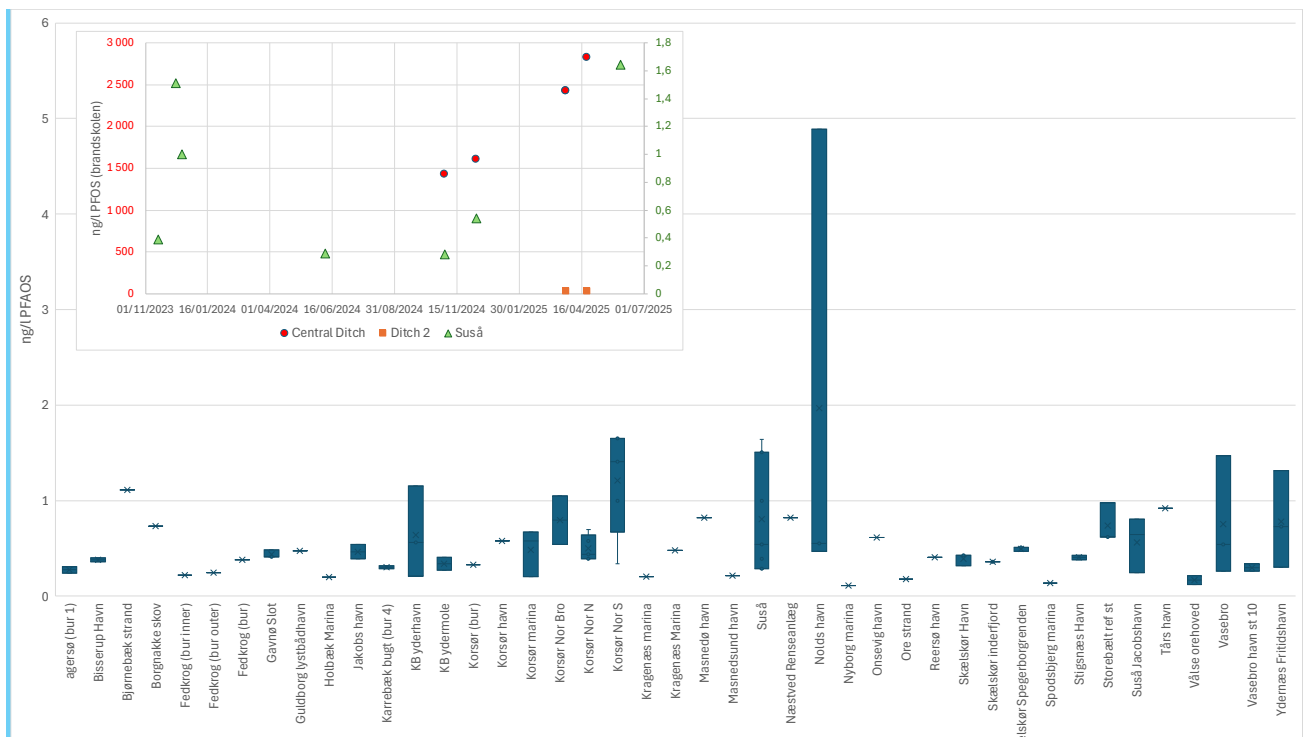


Figure 2: Overview of spot water samples analysed from 2023 to 2025 in the Newsea project from stations around the Great Belt and Smålandsfarvandet, as boxplots for 1. Insert shows individual results from the brandskole (firefighting center) central ditch, another ditch and the Suså station just outside of Næstved WWTP (Note: scale on right side -1000 times lower concentrations)

Metals

DGT results for Copper, Nickel, Lead and Cadmium in the same stations as figure 1, average of 3-4 weeks.

For Copper, most high concentrations are found in marinas or harbours, due to the use of Cu in antifouling paints. Marina's are often more closed and pleasure boats painted more often or lying in harbours longer time. Sensitive organisms are affected by Cu around 1000 ng/l.

Nickel and cadmium are not showing a clear patterns, Ni have an AA-EQS of 3100 ng/l (MAC-EQS 8200 ng/l) and Cd AA-EQSat 200 ng/l, so none show concentrations above the respective AA-EQS

Lead seems high at Ydernæs, and like both Cd and Ni at Tårs Havn and Nyborg marina. Suså and Agersø (background) also show slightly higher concentrations, but not close to the AA-EQS of 1300 ng/l.

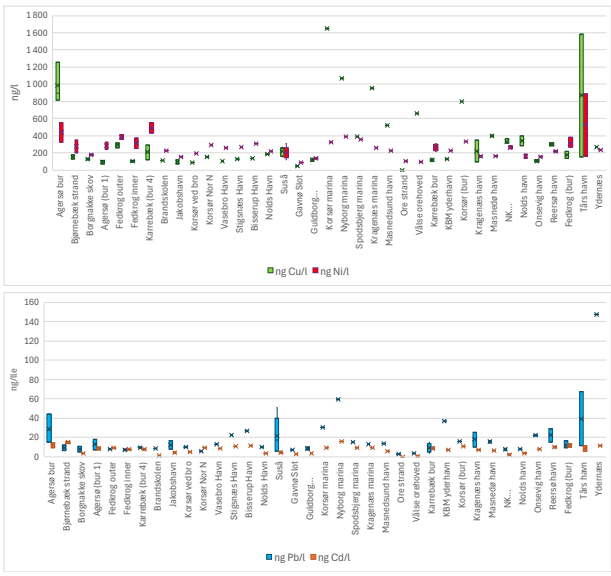


Figure 3: Metal concentrations in DGTs from same stations as PFAS (circles in figure 1).

DGT vs spot samples for PFOS

Comparison of DGT and spot samples was performed for PFOS, PFOA, PFNA AND PFHXS.

In most cases, good agreement was found between the calculated PFAS concentration from DGT deployments, and spot water samples taken at deployment and collection of the DGTs (Figure 4) For PFNA, it seemed that there was a higher discrepancy that needs some further investigation, particularly as the RPF for PFNA is 10, potentially leading to a very high difference in PFAS25 calculations from DGTs and spot water samples. DGTs nevertheless is a good candidate for monitoring PFAS in water, as an time-integrated sampler reducing the cost compared to spot samples 10-12 times a year with seasonal sampling. The DGT samplers also still need to be tested for TFA for full PFAS25 compliance.

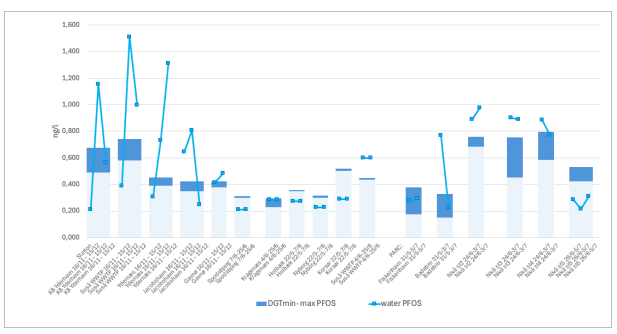


Figure 4: Comparison of DGT results (bars) from two DGTs per station and spot samples taken 2-3 times during deployment (in case of lines, mixed deployment and collection. Some large variations in spot samples seems to be caught by the DGTs.

Reference

Bossi, R., Strand, J., Sortkjær, O., & Larsen, M. M. (2008). Perfluoroalkyl compounds in Danish wastewater treatment plants and aquatic environment. *Environment International*, *34*(4), 443-450. https://doi.org/10.1016/j.envint.2007.10.002

Larsen, M, Bossi R. & Vorkamp, K (2024) PFAS overvågning i det danske marine miljø. Vand&Jord 31, 68-72