# On the sea spray as a potential dispersal pathway for persistent organic pollutants (POPs) found in fresh arctic snowfall


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## Background

**Persistent organic pollutants (POPs)** concern scientists due to their **long environmental lifetimes** and **negative impact** on the biological functions of multiple organisms (Muir and de Wit, 2010). These contaminants are typically delivered to the Arctic from lower latitudes via **long-range transport**, yet they also come from local sources in the Arctic (Hung et al., 2010; Octaviani et al., 2015; Reimann et al., 2009). More and more attention has been given recently to **secondary sources of POPs in the Arctic**, e.g. in melting glaciers (Hung et al., 2022; Pawlak et al., 2021).

**Among secondary sources**, the glacier melt has been confirmed (Ademollo et al. 2021; Pouch et al. 2021) and many other are discussed, including **revolatilisation from seawater**, once devoid of sea ice (Ma et al. 2011). It has been suggested that **sea spray** may also play a role, yet **no thorough investigation** into the matter was published from the Arctic. The environmental conditions are conductive to such a phenomenon, with the shrinking sea ice cover (NSIDC, 2022), and more frequent storms, especially in the autumn and spring (conclusions from Hornsund fjord, Svalbard; Wojtysiak et al. 2018). As **snowfall forms a path for the efficient delivery of airborne POPs** into the terrestrial environment (Lei and Wania, 2004), we have decided to study the topic with snow concentration patterns as a research tool.

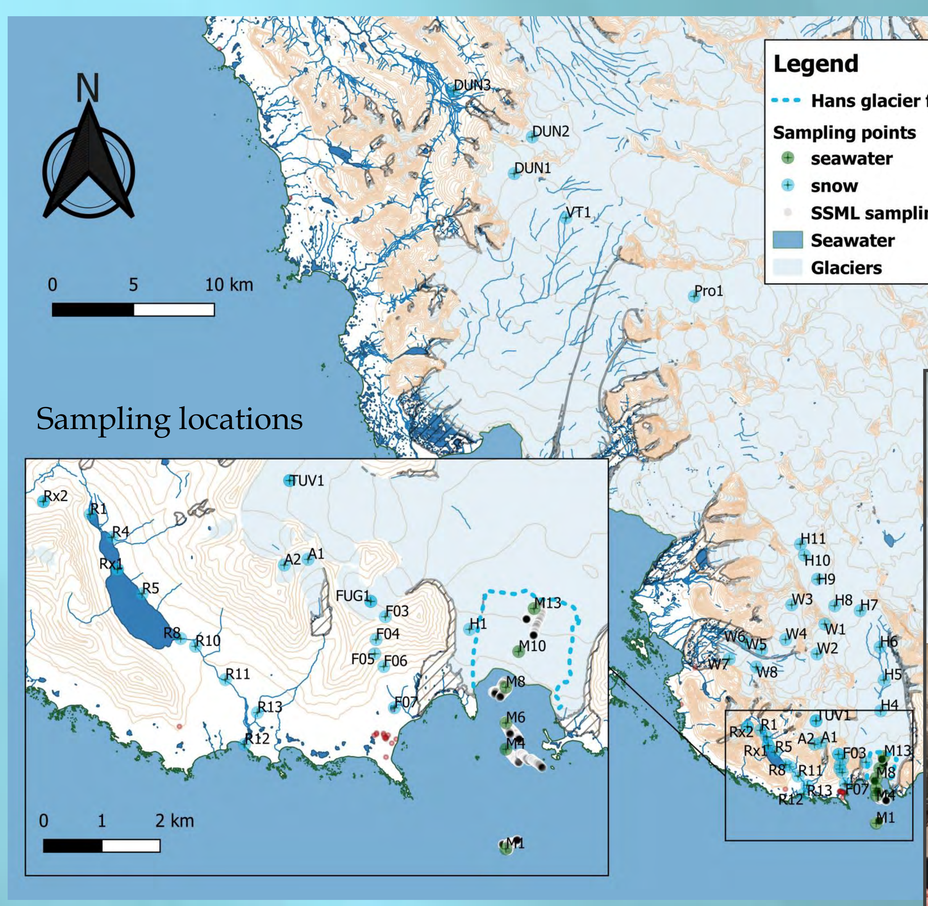
## Hypothesis:

**The sea spray is a an active means of dispersal for organochlorine persistent organic pollutants (OcPOPs), capable of transferring them, via snow precipitation, into the terrestrial ecosystem of the Arctic.**

## Objectives:

1. To study spatial distributions in the OcPOPs concentrations and fluxes in the fresh snowfall collected in Svalbard.
2. To analyse the OcPOPs sources in each precipitation event and sample group with the air-mass backward trajectory modelling, stable H and O isotope ratios, metal and metalloid concentrations, and statistical patterns in the obtained data.
3. To conclude on the possibility of sea spray transport of POPs and its efficiency in the study location.

## Sampling: fresh snow and seawater (surface and microlayer)




SSML sampling

Photo by K. & T. Jankowscy

For snow sampling, see Pawlak et al. 2022

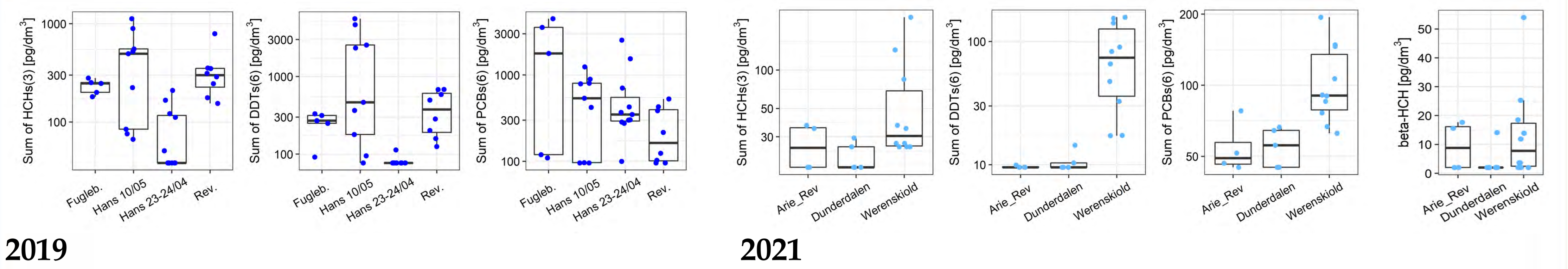
Sea conditions during SSML (microlayer) sampling

Photo by K. & T. Jankowscy

In 2021, snow sampling was improved according to Pawlak et al. 2022

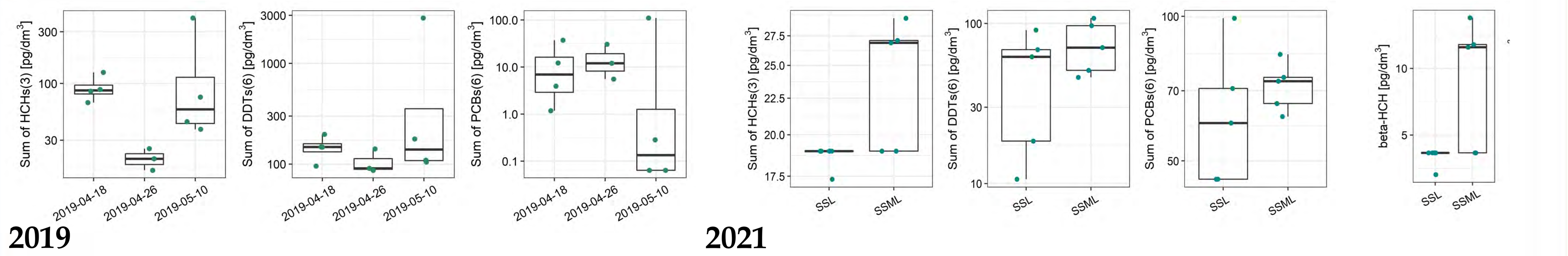
## Results

1. The concentrations of OcPOPs in snow in 2019 were by an order of magnitude higher than in 2021.




2. Air mass backward trajectories (NOAA HYSPLIT, Rolph et al. 2017, Stein et al. 2015) showed potential Europe and N Asia mainland areas as a potential source of long-range transported OcPOPs; 2021 events were all connected to Fram Strait and Greenland as air mass source areas.

3. Seawater concentrations were much lower than in snow in 2019, while the difference was not so pronounced in 2021. The sea surface microlayer sampling (SSML, as opposed to sea surface layer SSL) in 2021 showed enrichment in several OcPOPs: in β-HCH, o,p'-DDT, p,p'-DDT, and the heavier PCBs, especially in PCB 169, and in the sums of HCHs, DDX and PCBs. The same compounds were predominant in snow upon Werenskiöld on 21st April 2021.




## Discussion & Conclusions

1. In 2021, local factors could be explored in full, and in the snowfall sampled on Werenskiöld glacier on 21/04/2021 we have detected concentrations of POPs typically enriched in SSML, while the air mass passed over the Fram Strait (with open water near Spitsbergen shore).
2. Correlations of OcPOPs concentrations and fluxes with distance from the sea (which is a proxy of orographic effect in the area) follow the relationship Cincinelli et al. (2005), especially for HCHs and PCBs, which implies that closer to the sea more sodium is deposited, and further on – smaller droplets enriched in POPs (particularly many concentrations did so in the 21/04/2021 snowfall). Thus it may be explained that only rarely any POPs correlated with sodium concentrations, which is a clear sea spray indicator among elemental concentrations in snow.
3. β-HCH deposition fluxes in single snowfall upon Werenskiöld glacier on 21/04/2021 , which are interpreted here as due to sea spray dispersal alone, spanned 0.029-0.273 ng $m^{-2}$, as opposed to „negligible flux level", i.e. LOD x SWE, of 0.004 – 0.073 ng $m^{-2}$. **The OcPOPs fluxes due to sea spray dispersal are therefore possible to detect in the Arctic snowfall, despite them being approximately an order of magnitude lower than OcPOPs fluxes related to long-range transport.**

## Laboratory analytical methods:

**OcPOPs analytes:** polychlorinated biphenyls (PCBs: 28, 52, 118, 138, 153, 169, 180) and organochlorine pesticides (OCPs: α-, β-, γ-HCH; HCB; heptachlor and heptachlor epoxide; aldrin; 6 DDX: o,p'-DDD, p,p'-DDD, o,p'-DDE, p,p'-DDE, o,p'-DDT, p,p'-DDT).
**Extraction:** Supelco ENVI C-18 SPE columns; ethyl acetate and dichloromethane (DCM); with surrogate isotope-labelled standard solutions
**Determination method:** GC-MS/MS (gas chromatography coupled with mass spectrometry, triple quadrupole, Agilent), at Gdansk Univ. of Technology and Perlan Technologies, Poland.
**Metals and metalloids:** ICP-MS 2030 and ICP-OES 9820 (Shimadzu, Japan) at Adam Mickiewicz University in Poznan, Poland.
**QA/QC checked:** repeatability, recoveries, LOD, LOQ, linearity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