Mechanistic insight into the uptake and fate of persistent organic pollutants in sea ice

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The **Arctic** recieves global **chemical** emmisions waste through **atmospheric** and **oceanic** currents.

Persistent Organic Pollutants are a large class of **toxic** and **synthetic** substances.

Their uses include **pesticides**, **flame retardants**, industrial chemicals and **by-products** of combustion.

Experiments were conducted in the Roland von Glasow **Sea Ice facility** to observe chemical **uptake** and **fate** in **artificial sea ice**.

Seven chemicals that have previously been **observed** in the Arctic were **spiked** into **chilled** seawater.

Samples of seawater and ice were taken during **ice formation** and **ice melt** to track chemical fate in **young sea ice**.

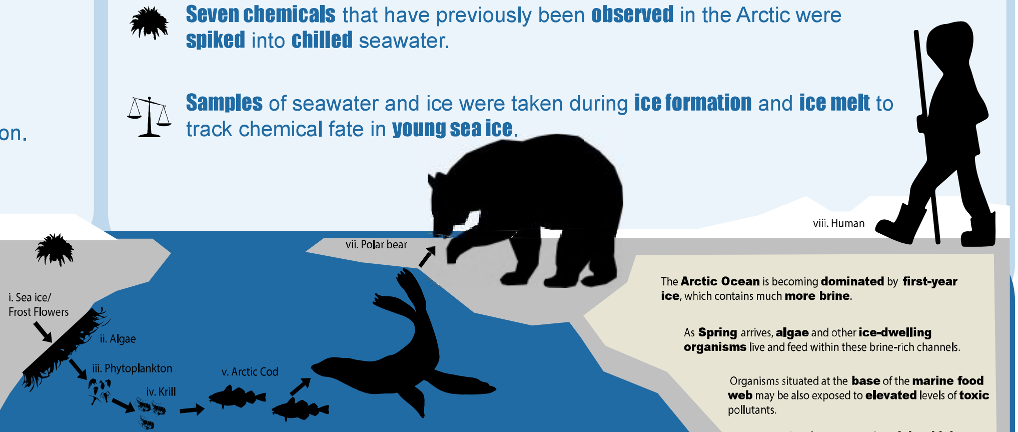
During **sea ice** formation most of the salt is **rejected** from the **bulk ice** to the ocean below.

However, some salt is entrapped within a **network** of **brine channels** and surface **frost flowers**.

As temperatures continue to fall through **winter**, the **brine** is **concentrated** (up to 10x that of ocean salinity) as more water freezes out.

Chemicals present in seawater may also be trapped and concentrated in sea ice.

To **watch** an **animation** about this research, scan **this code!**



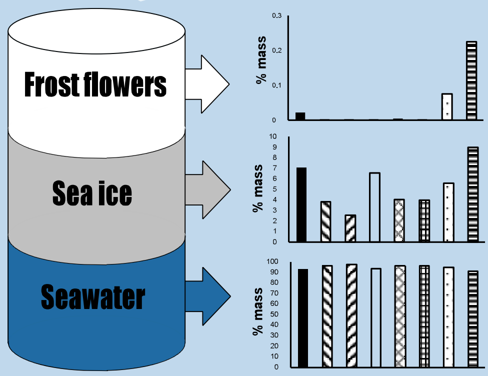
The **Arctic Ocean** is becoming **dominated** by **first-year ice**, which contains much **more brine**.

As **Spring** arrives, **algae** and other **ice-dwelling organisms** live and feed within these brine-rich channels.

Organisms situated at the **base** of the **marine food web** may be also exposed to **elevated** levels of **toxic** pollutants.

Resulting in **greater risk** to **higher** trophic-level **mammals**.

i) Mass-balance



A known amount of chemical was introduced into a glass tank containing artificial sea water and cooled to -35C.

Samples of seawater, bulk ice and frost flowers were taken at key points and analysed for their salinity and chemical concentration.

A mass-balance was conducted to determine the relative distribution of each chemical in the experimental system.

Only 2-10% of the total chemical mass was entrapped within the bulk sea ice, indicating that most of the chemical mass was rejected back into the seawater.

ii) Distribution in ice

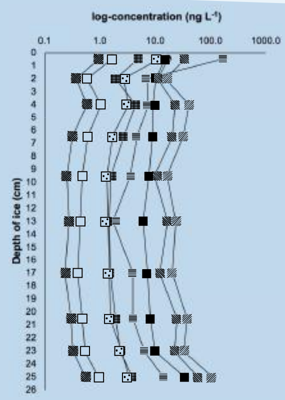
Samples of sea ice were taken and sectioned to determine the vertical distribution of chemicals throughout the ice.

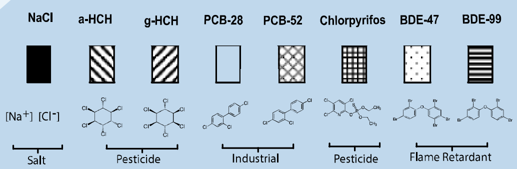
In general, the highest levels of chemical were contained at the ice-atmosphere interface and the ice-ocean interface and showed a 'c-shape' curve.

This profile is characteristic of salinity in first-year sea ice and occurs due to temperature-density differences in the brine, a process known as 'gravity drainage'.

The results indicate that the distribution of chemicals throughout the ice is primarily governed by processes that control NaCl.

The results were also accurately predicted by a 1-D sea ice brine dynamics model.



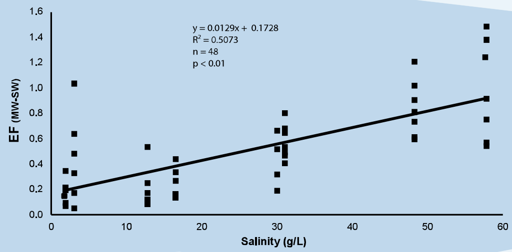


iii) Meltwater composition

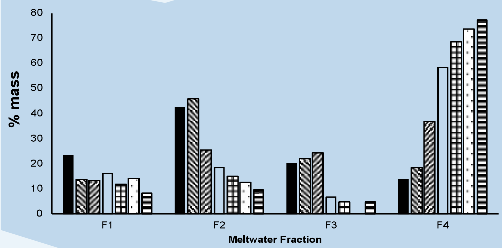
Sea ice samples were colleced, thawed (at 0C) and the meltwater fractions were sequentially collected and analysed to understand its composition during a simulated 'Spring-melt'.

The chemical concentrations were ratioed to the average seawater concentration to enable comparision of all analytes.

A positive relationship showed that, in general, saltier meltwater released at the onset of melt contain higher concentrations of chemicals.



iv) Chemical release dynamics

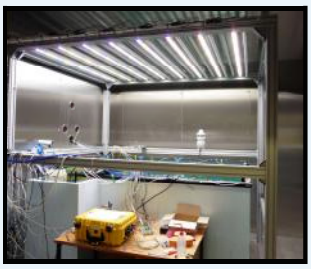


Chemical dynamics were further investigated by calculating the percentage mass of chemical in each of the meltwater fractions.

The three initial meltwater fractions (F1-F3) show that chemical mass loss from the ice is low, but highest for the more water soluble chemicals (i.e. ~75% of a-HCH and g-HCH is lost in F1 to F3, compared to only ~20% of BDE-99).

The final melt fraction (F4) contained >50% of the mass of (in increasing order) PCB-28, chlorpyrifos, BDE-47 and BDE-99, initially present in the ice prior to the onset of melt.

The results together suggest that chemicals are released at variable rates and possibly due to chemical interactions with the fresh sea ice matrix (i.e. rates of chemical release are greater for those chemicals displaying a higher aqueous solubility).



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