Potential degradation of chlorpyrifos in remote high-altitude cold sites: microcosm experiment on Forni Glacier, Italian Alps

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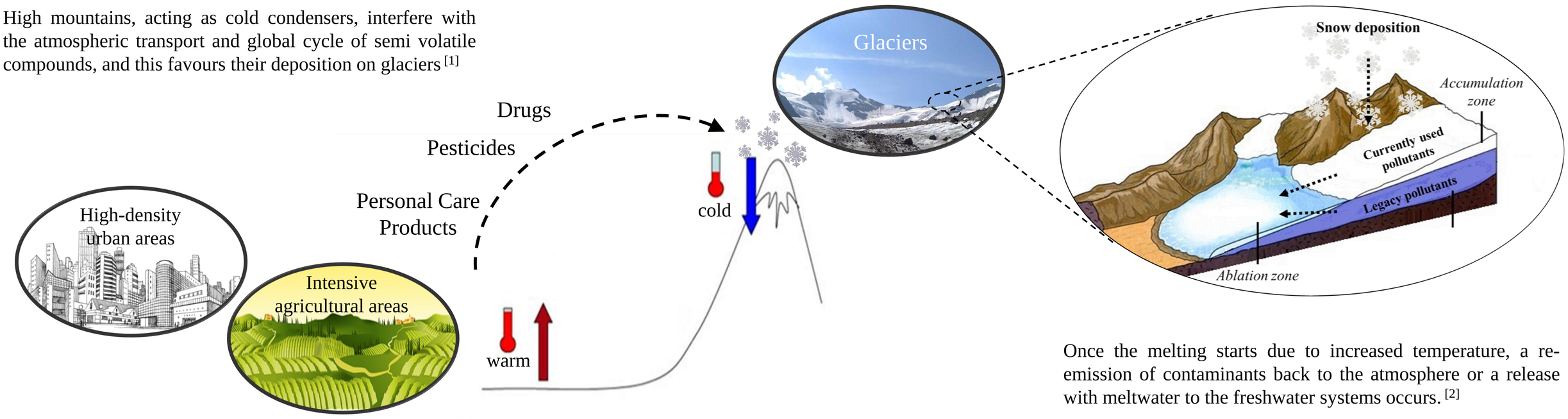
Contaminants on glaciers

High mountains, acting as cold condensers, interfere with the atmospheric transport and global cycle of semi volatile compounds, and this favours their deposition on glaciers [1]



Once the melting starts due to increased temperature, a re-emission of contaminants back to the atmosphere or a release with meltwater to the freshwater systems occurs. [2]

Aims of the project

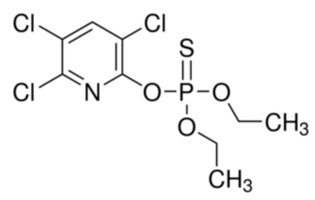
Are contaminants removed *in situ* also in remote cold sites?

Do bacterial activities contribute to *in situ* degradation of pollutants transported on glaciers?

Selected contaminant and area of study

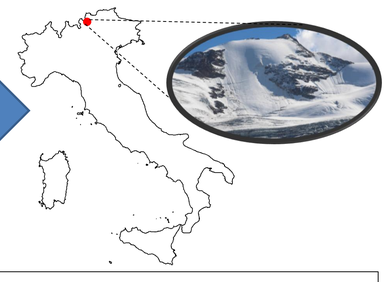
Chlorpyrifos (CPF)

- Organophosphate insecticide, acaricide, miticide acting as acetylcholinesterase inhibitor
- Major crops: cotton, corn, fruit trees



0.5-1.6 ng/L of CPF was found in Forni glacial meltwater [3]

Forni Glacier



Degradation processes

Photodegradation

Hydrolysis

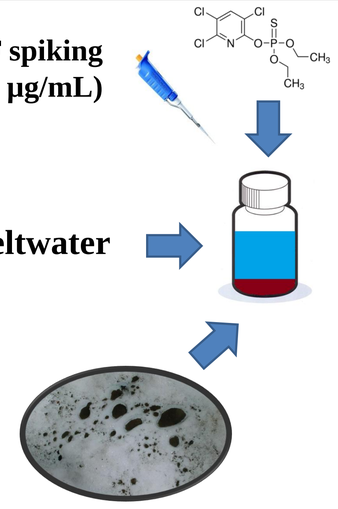
Biodegradation*

*Microbial communities living on glacier are versatile with regard to carbon and energy sources, adapted to scarcity of available nutrients (because glacier is a naturally carbon-poor ecosystem) and to cold conditions [4]

In situ microcosm experiment

CPF spiking (0.2 µg/mL)

meltwater



cryoconite
wind-blown supraglacial sediment

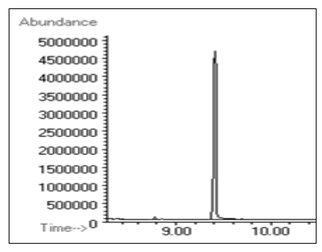
Exposure conditions

Dark - sterile | Dark - bacteria | Light - sterile | Light – bacteria

Exposure time

Bottles were located on the glacier surface and the potential degradation efficiency was observed after 10, 24, 40 days since the spike addiction.

CPF quantification



Gas chromatography mass spectrometry analyses

Results

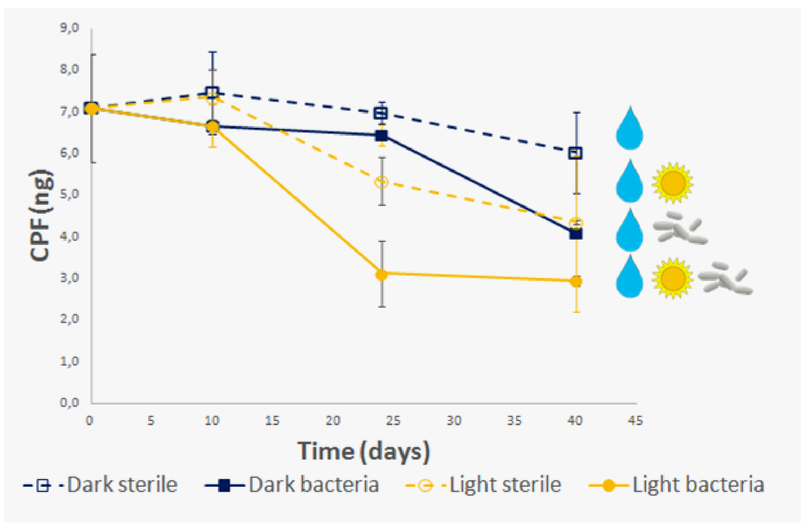


Figure 1: CPF decay rates in microcosms
(bars represent standard errors)

Statistical analyses conducted by linear models indicated that the decay rate of CPF mass differed significantly among the four experimental groups ($F_{3,26} = 9.771$, $P < 0.001$).

The lowest decay rate of CPF was observed under dark sterile condition: under this condition the amount of CPF did not decline significantly as indicated by the fact that confidence limits of decay rate included zero (95% confidence interval from -0.011 to 0.005 d^{-1}).

The largest decay rate of CPF occurred under light biotic conditions (decay rate= -0.028 ± 0.004 d^{-1}). Post-hoc comparisons of rates indicated that under this condition the decay rate of CPF was significantly larger than under other conditions ($t_{26} \geq 3.055$, $P \leq 0.026$), which, in turn, did not differ significantly to one another ($|t_{26}| \leq 2.044$, $P \geq 0.198$).

The decay rate under light biotic condition was not significantly greater than the sum of the decay rates under light sterile condition and under dark biotic condition. For this reason it is not possible to claim that the biodegradation of CPF was increased by light.

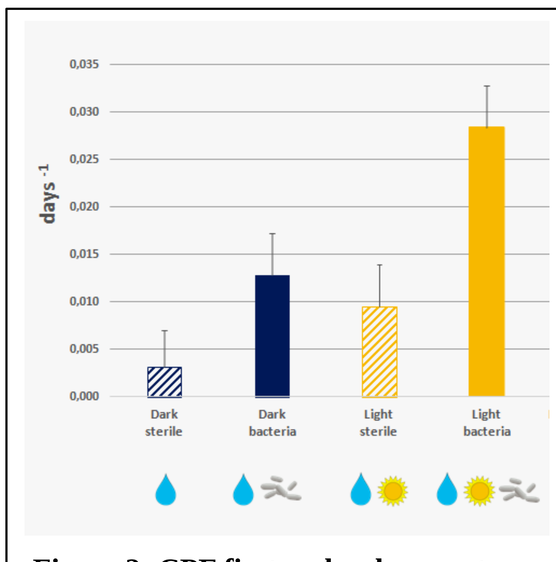


Figure 2: CPF first-order decay rates
(bars represent standard errors)

Conclusions

Based on the results, CPF can be degraded *in situ* also on glaciers. In particular this study suggests that organic contaminants can represent a source of nutrient for microbial communities living on glaciers. Therefore microbial biodegradation can contrast the accumulation of pollutants transported on glaciers and the possible re-emission of contaminants back to the atmosphere or to the freshwater systems. The presence of xenobiotic-degrading microorganisms also implies that glaciers may represent reservoirs of bacterial genes and strains with potential applications in bioremediation of cold environments.

Based on the results of the present study results, a similar experiment is currently ongoing to assess the degradation *in situ* of terbuthylazine, a widely used herbicide in northern Italy.

References

[1] Calamari D. et al., 1991. Role of plant biomass in the global environmental partitioning of chlorinated hydrocarbons. Environmental Science and Technology, 25(8), pp.1489–1495.

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[4] Cappa F. et al., 2014. Bacterial diversity in a contaminated Alpine glacier as determined by culture-based and molecular approaches. Science of the Total Environment, 497–498, pp.50–59.