

Airborne Benzothiazoles and Organophosphate Flame Retardants at a High-altitude Background Site in the Eastern Italian Alps: Occurrence, Sources and Temporal Trends

Eleonora Favaro¹, Giovanna Mazzi¹, Elena Barbaro², Andrea Gambaro¹, Matteo Feltracco¹

¹Department of Environmental Sciences, Informatics and Statistics, Ca' Foscari University of Venice, Venezia Mestre 30172, Italy

²Institute of Polar Sciences, National Research Council (CNR-ISP), Venezia Mestre 30172, Italy

E-mail contact: eleonora.favaro@unive.it

Abstract

In the last decades, rapid urbanization and industrial and economic growth have led to the acceleration of the anthropogenic impact on the planet and even remote areas are no longer pristine. The emission in the environment of Chemicals of Emerging Concern (CECs) is consistently increasing, hence their monitoring is of growing interest for the scientific community and policy makers. Among other environmental compartments, the atmosphere is one of the most affected by the growing number of CECs, as they are still poorly regulated and not extensively monitored.

Both benzothiazoles (BTHs) and organophosphate flame retardants (OPFRs) are listed as high volume production chemicals due to their extensive use in a wide range of industrial and consumer products, and their increasing release in the environment poses risks for the ecosystems and human health, as different studies have demonstrated their potential toxic effects.

This study aimed to investigate the occurrence of eight BTHs and six OPFRs in PM₁₀ samples collected at a high-altitude background site located in the Eastern Italian Alps, to observe temporal trends and to assess their sources and transport processes.

Aerosol sampling was carried out from April to October 2023 at Col Margherita Observatory (2543 m a.s.l.) using a PM₁₀ low volume sampler. Analytical determination was performed via UHPLC-MS/MS. NOAA ARL's HYSPLIT model was used to determine the origin of air masses reaching the study area. The effect of typical alpine phenomena, such as the valley breeze, on atmospheric transport of the target compounds was evaluated by calculating the daily average temperature lapse rate considering the main valleys that influence the air fluxes to the study site.

Results confirmed the presence of both BTHs and OPFRs in alpine aerosol, with concentrations ranging from pg to ng m⁻³. Both classes of contaminants exhibit a seasonal trend, with higher concentrations in spring, probably due to a combination of atmospheric processes such as thermal convection, mountain-valley breeze regimes and upward motion due to mixed-layer expansion.

The present study provides for the first time information on background concentration levels of BTHs and OPFRs in the atmosphere of an high mountain remote area, offering insights into their sources and transport mechanisms that will help for future investigations on the pathways and environmental fate of these classes of chemicals.