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The Role of Aqueous Secondary Formation in Enhancing Organophosphate Esters in Atmospheric Aerosols

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DESCRIPTION

Organophosphate esters (OPEs) are a class of chemicals widely used as flame retardants, plasticizers, and in various industrial applications, including as pesticides. These chemicals have raised growing concern due to their widespread presence in the environment, particularly in atmospheric aerosols, which can act as vectors for long-range transport and human exposure. While much attention has been given to the direct emission of OPEs into the atmosphere, recent research has highlighted the significant role of aqueous secondary formation processes in the presence of OPEs in aerosols. This process, which occurs through the interaction of gas-phase precursors with atmospheric water, is emerging as a substantial contributor to the levels of OPEs in fine particulate matter, influencing both the distribution and fate of these compounds in the environment. Secondary formation of OPEs in the atmosphere is a complex process that involves the transformation of gaseous precursors into particulate-bound forms, which can then be incorporated into aerosols. Atmospheric water, whether in the form of water vapor or as liquid droplets in clouds or fog, plays a crucial role in facilitating this transformation. Gas-phase precursors, such as volatile organic compounds (VOCs) and OPEs, can dissolve into water droplets present in the atmosphere. Once dissolved, these precursors can undergo chemical reactions, including hydrolysis or nucleophilic substitution reactions, resulting in the formation of OPEs that were not originally present in the gas phase. These new compounds can then partition onto aerosols, which are tiny solid or liquid particles suspended in the atmosphere. The aqueous phase is particularly important because it provides a reaction environment where certain chemical processes can be enhanced. In the case of OPEs, this environment allows for reactions that convert less volatile precursors into more stable forms that can more easily partition onto aerosols. Once these compounds are bound to aerosols, they can travel long distances, contributing to the global distribution of OPEs. This mechanism is important because it extends the chemical lifetime of OPEs in the atmosphere and alters their potential for human and ecological exposure. As aerosols are inhaled or deposited on land and water bodies, they become vectors for the transfer of OPEs into ecosystems and human populations. The significance of aqueous secondary formation in contributing to OPEs in aerosols has been confirmed through laboratory studies and atmospheric observations. Research shows that when gas-phase organophosphates interact with water in the atmosphere, they undergo transformations that lead to the creation of a variety of OPE compounds, some of which have been detected in aerosol samples collected from urban, industrial, and remote locations. In particular, studies have highlighted the role of ambient conditions such as temperature, humidity, and the presence of other atmospheric pollutants, which can influence the extent to which aqueous phase reactions occur. In areas with high humidity or in the presence of cloud droplets, the rate of OPE formation is notably higher, underscoring the importance of aqueous chemistry in atmospheric pollution. This process is further complicated by the fact that OPEs can be present in the environment in a wide range of chemical forms. Some OPEs may already be in aerosol form when emitted, but a substantial portion is likely to form through secondary processes like those involving aqueous interactions. This secondary formation process means that even if OPEs are not directly emitted in large quantities, atmospheric reactions can still lead to their widespread presence in fine particulate matter.

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CONFLICT OF INTEREST

The author declares there is no conflict of interest in publishing this article.

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