

Flame Retardants: A Technical Overview

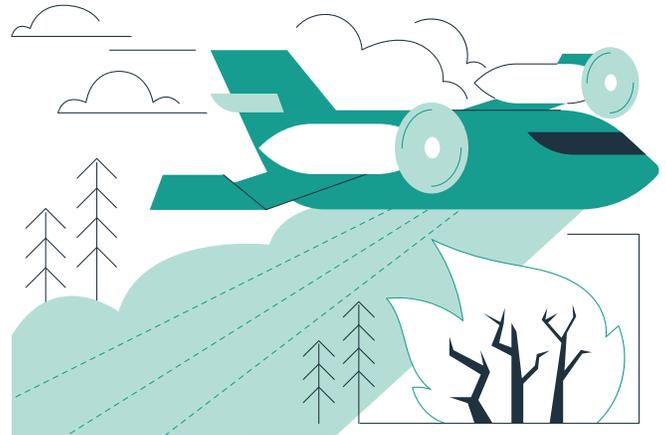
NON-FERTILIZER USES OF PHOSPHORUS – SERIES

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ENHANCING FIRE SAFETY THROUGH PHOSPHORUS-BASED COMPOUNDS

Flame retardants are crucial additives designed to significantly reduce the flammability of materials, enhancing fire safety across diverse applications. Their importance is particularly evident in the plastics industry, where a wide array of flame retardants is necessary to accommodate the vast range of plastic types and their specific properties.

Successful integration requires the flame retardant to be compatible with the target material, without compromising its mechanical strength, colour, odour, or other essential characteristics.



MECHANISMS OF ACTION

Flame retardants operate through three primary mechanisms:

1. COOLING THROUGH WATER RELEASE:

This class utilizes compounds like aluminum hydroxide ($Al(OH)_3$). Upon exposure to heat, these substances decompose, releasing water vapor. This endothermic reaction absorbs significant heat from the surrounding environment, effectively cooling the material and suppressing flame propagation.



2. INTERFERENCE WITH FLAME CHEMISTRY:

This approach employs additives that generate specific reactive molecule fragments (radicals) which interfere with the combustion process. Brominated compounds are a prime example; these interfere with the free radical chain reactions necessary for flame propagation. However, many brominated flame retardants have faced increasing scrutiny due to concerns regarding their potential health and environmental impacts.

3. CHAR FORMATION

This method involves the creation of a stable, insulating char layer on the surface of the burning material. This layer acts as a barrier, preventing further access of oxygen to the underlying flammable material and halting the spread of the fire. The most effective char-forming systems are often "intumescent," meaning they expand upon heating, creating a thicker, more effective barrier. These typically consist of multiple components that interact synergistically to promote char formation and foam expansion. Phosphorus-based compounds play a prominent role in this class of flame retardants.

MAJOR CLASSES OF PHOSPHORUS-BASED FLAME RETARDANTS:

Phosphorus-containing flame retardants are frequently used, particularly in intumescent systems. Several key classes exist, each with unique properties and applications:

- **Red Phosphorus:** This highly concentrated form of phosphorus is obtained by heating white phosphorus. However, its insolubility in most plastics and its deep red colour limit its use to materials with compatible pigmentation (red, brown, or black plastics).
- **Chloro-organophosphates:** Tris(2-chloroisopropyl) phosphate (TCPP) is a representative example. Used extensively in flexible foams (automotive interiors, furniture) and rigid foams (building insulation), TCPP also contains chlorine, raising concerns regarding its potential toxicity and environmental impact.
- **Halogen-Free Organophosphorus Compounds:** This category includes compounds like bisphenol-A bis(diphenyl phosphate) and resorcinol bis(diphenyl phosphate), commonly employed in electronic resins. The absence of halogens addresses some of the environmental concerns associated with other flame retardants.
- **Ammonium Polyphosphate:** Produced from phosphorus pentoxide, ammonium polyphosphate serves as a key component in intumescent coatings.

REFERENCES

This factsheet is based on insights from the GPI report : [Non-Fertilizer Uses of Phosphorus, an Overview](#), prepared by *Willem Schipper Consulting*.

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- **Phosphinates:** Aluminium diethyl phosphinate (DEPAL), derived from sodium hypophosphite, finds application in polyamides.
- **Tetrakis(hydroxymethyl) phosphonium salts (THPC):** This phosphine-based flame retardant, often used with urea, is effective in flameproofing textiles like cotton (e.g., Proban treatment for children's pajamas and overalls).
- **DOPO (9,10-dihydro-9-oxa-10-phosphaphenanthrene-10-oxide):** A relatively newer flame retardant derived from phosphorus trichloride, DOPO finds use in rubber, ABS plastics, and coatings.
- **Dimethyl methyl phosphonate:** This compound has minor applications as a flame retardant in foams, resins, and PVC.



The selection of an appropriate flame retardant depends critically on the specific properties of the target material and the desired level of fire protection, alongside considerations of cost, safety, and environmental impact. Ongoing research focuses on developing novel, more environmentally benign flame retardants to address the concerns associated with some existing options.



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The Global Phosphorus Institute (GPI) is a global organization dedicated to ensuring the responsible use of phosphorus through cutting-edge science and stakeholder dialogue. With a holistic vision and worldwide participation, GPI fosters sustainable practices to advance phosphorus-related technologies and applications.

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