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Recent developments in the fire retardancy of polymeric materials

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ABSTRACT

The widespread applications of polymeric materials require the use of conventional flame retardants based on halogen and phosphorous compounds to satisfy fire safety regulatory standards. However, these compounds, particularly halogen-based examples, are persistent organic pollutants of global concern and generate corrosive/toxic combustion products. To account for eco-friendliness, ultimate mechanical/physical properties and processing difficulties, the window of options has become too narrow. Although the incorporation of non-toxic nanofillers in polymers shows positive potential towards flame retardancy, many obstacles remain. Moreover, most of the literature on these materials is qualitative, and often points to conflicting/misleading suggestions from the perspectives of short-term and long-term fire exposure tests. Hence, there is a renewed need to fundamentally understand the fire response of such materials, and complement experimental results with theoretical modelling and/or numerical simulation.

A part of this review will highlight the ecological impacts of using conventional flame retardants, thereby signifying the necessity to use eco-friendly agents. In other sections, we explore the use of various nanofillers for this purpose, compare their performance with traditional systems, provide insights into different testing standards and combustion mechanisms, modelling aspects of the combustion behavior, and identify novel approaches that could be considered for meeting the fire safety standards with eco-friendly materials.

Contents

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List of Abbreviations

General

CAFE	Clean Air for Europe
EEA	European Environment Agency
EPA	Environmental Protection Agency
EU	European Union
FAA	Federal Aviation Administration
FRs	flame retardants
IARC	International Agency for Research on Cancer
NIST	National Institute of Standards and Technology
REACH	Registration Evaluation Authorization and Restriction of Chemical substances
TEF	toxic equivalency factor
TEQ	toxic equivalent
UL	Underwriters Laboratories
WHO	World Health Organization

Polymers and other organic compounds

ABS	acrylonitrile-butadiene-styrene copolymer
AETMC	2-(acryloxyethyl)trimethylammonium chloride
AO	antimony trioxide
APP	ammonium polyphosphate
BA	boric acid
EVA	ethylene-vinyl-acetate copolymer
HBCD	hexabromocyclododecane
HDPE	high density polyethylene
HIPS	high impact polystyrene
LDPE	low density polyethylene
MP	melamine phosphate
MPP	melamine polyphosphate
ODA	4,4-oxydianiline
PA	polyamide
PAA	polyamic acid
PAH	polycyclic aromatic hydrocarbon
PBB	polybrominated biphenyl
PBDE	polybrominated diphenyl ether
PBT	polybutylene terephthalate
PCB	polychlorobiphenyl
PCDD	polychlorinated dibenzodioxin
PER	pentaerythrithol
PET	polyethylene terephthalate
PLA	polylactic acid
PMDA	pyromellitic dianhydride
PMMA	poly(methyl methacrylate)
POP	persistent organic pollutant
PP	polypropylene
PPh	phenyl phosphonate
PPS	polyphenylene sulfide
PU	polyurethane
PVC	poly(vinyl chloride)
SAN	acrylonitrile-styrene
SDS	sodium dodecyl sulphate
TBBPA	tetrabromo bisphenol A