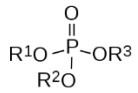
Organophosphates

Organophosphates are a class of phosphate-containing compounds also known as organophosphate esters (OPEs) because they are esters of phosphoric acid. Their basic structure is $O=P(OR)_3$.



The class is best known for use as pesticides which became popular after the banning of organochlorine pesticides such as DDT. The pesticide applications require the addition of sulfur and/or nitrogen groups to the OPE (e.g., malathion)

The second largest industrial use of OPEs is as flame retardants. The functional groups of the flame retardants are:

- phenyl groups (e.g., triphenyl phosphate)
- aliphatic chlorinated or brominated groups (e.g., TCEP, TDCPP, TBEP)
- or a combination
- and more recently, aromatic diphosphates (Resorcinol bis(diphenylphosphate))

Alternately the functional groups of the OPE flame retardants can be categorized as such:

- alkyl chains or aryl groups
- halogenated or non-halogenated

In addition to their use as flame retardants, these chemicals are also used as plasticizers in consumer products and construction materials.

The toxic properties of OPE FRs are wide-ranging. Due to their similar chemical structure to the organophosphorus pesticide (i.e., the phosphodiester bond), much attention has been focused on their neurotoxicity.

Exposure to OPE FRs can cause health problems (Dou 2022) including:

- neurotoxicity (Dishaw et al., 2011; Hu et al., 2020; Li et al., 2019b)
- nephrotoxicity (Chen and Ma, 2021; Wang et al., 2018)
- immunotoxicity (Hong et al., 2019; Van der Veen and De Boer, 2012)
- reproductive and developmental toxicity (Chen et al., 2020a; Cong et al., 2020; McGee et al., 2012; Meeker and Stapleton, 2010; Yuan et al., 2016)
- genotoxicity (Yuan et al., 2018)
- endocrine disruption (Giraudo et al., 2015; Hou et al., 2019)
- carcinogenicity (Dishaw et al., 2011; Van der Veen and De Boer, 2012)

Environmentally, exposure to OPE FRs may result in adverse outcomes in fish, daphnia, birds and rodents (Gu 2023), such as:

- growth inhibition (Hou et al., 2016),
- tissue lesions (Du et al., 2015),
- developmental and reproductive toxicity (Yuan et al., 2018), and

- neurotoxicity (Van der Veen and de Boer, 2012)

OPEs at typical environmental concentrations could result in various adverse effects on aquatic organisms including (Gu 2023):

- fecundity reduction (Zhu et al., 2015),
- endocrine disruption (Wang et al., 2013) and
- toxicity (Han et al., 2014) in Zebrafish (Danio rerio), and
- neurotoxicity in Chinese minnow (Gobiocypris rarus) (Yuan et al., 2016).

OPEs in the water environment could be bioaccumulated in various aquatic organisms (Xie et al., 2022b).

Presence in regions far from manufacture and use indicates environmental persistence.

Note: Links to the Dou and Gu works are provided. All other studies are referenced in these two. This list of works is only a small fraction of the studies available on OPE flame retardants.