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Flame retardants found in groundwater

Organophosphates (OPs) used to protect materials from fire and in other industrial processes have affected the quality of groundwater, particularly in urban areas and near landfill sites, according to recent research.

In 2006, it was estimated that the EU consumed 91,000 metric tonnes of OP-based compounds in manufacturing processes. OPs containing chlorine, such as tris(2-chloroethyl) phosphate (TCEP), tris(2-chloro-1-methylethyl) phosphate (TCPP), and tris(1,3-dichloro-2-propyl) phosphate (TDCP) have a wide range of usage to reduce the flammability of materials: for example, added as flame retardants to polyurethane foam, used in furniture and building materials. Non-chlorinated OPs, such as tris(2-butoxyethyl) phosphate (TBEP), tri-iso-butyl phosphate (TiBP), and tri-n-butyl phosphate (TnBP) are used to increase the flexibility of materials, as antifoaming or flame retarding agents, and as additives to hydraulic fluids and lubricants. Previous research has suggested that some of these OPs can be harmful to human and ecological health. TnBP, TCEP, and TDCP are known to potentially cause cancer in animals, for example.

Emissions of OPs, caused by the wear and breakdown of materials, and release from road traffic, are transported through the atmosphere. OP emissions are deposited or washed out by rainfall onto soil and surface waters.

In this study, researchers analyzed 72 groundwater samples from Germany to determine whether and to what extent groundwater is contaminated by OPs during groundwater recharge in natural aquifers. The sampled groundwater monitoring wells represented possible ways shallow and deep groundwater can be recharged or infiltrated with water: for example, infiltration of surface water via a riverbank or infiltration of precipitation (e.g. rainfall).

In general, highest OP levels were found in groundwater recharged through OP-contaminated surface water filtered through riverbanks and from leaching of OP contaminants from a landfill site. In rural areas, OPs had very little effect on groundwater only recharged by the infiltration of precipitation (e.g. rain), whereas in urban areas, groundwater is suspected to be affected by OP-contaminated rainfall, the runoff from roofs, roads and other surfaces and contaminated wastewater discharges. OPs were not detected in deep groundwater wells and springs that were unaffected by surface runoff or treated wastewater discharges.

TCEP and TCPP were found most frequently in the study samples and concentrations of both OPs in the range of 3-9 nanograms per litre (ng L^{-1}**)** in groundwater aged from 20 – 45 years, reflecting their persistence in groundwater.

OPs were found at all except two sampling sites affected by infiltration via riverbank filtration. Maximum concentrations of OPs were above 0.1 micrograms per litre (µg L^{-1}) for TCEP, TCPP, TBEP, and TiBP. Of the six OPs detected, TCPP was the most frequently found, which confirms the well known occurrence of chlorinated OPs in wastewater-impacted surface waters. In addition, the median concentration of TCPP (38 ng L^{-1}**)** was higher than the median TCEP concentration (7 ng L^{-1}).

For the shallow aquifer located next to a sealed landfill site, groundwater samples were contaminated by seepage of TCEP, TCPP, TiBP, and TnBP resulting in median concentrations between 90-191 ng L^{-1}. Concentrations of TDCP were low, indicating that this OP was not widely used as a flame retardant in the landfilled products buried between 1925 and 1968, when the site was closed. Compared with expected concentrations of TCPP and TCEP, actual concentrations indicate that groundwater of this aquifer is further influenced by seepage from urban precipitation and surface runoff from nearby highways.

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