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Potential environmental risks of water-soluble polymers

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The potential environmental risks of plastics and microplastics have been widely studied, yet research into the impacts of other polymer types including water-soluble polymers remains scarce. Given their widespread usage in household products, wastewater treatment, and agriculture, and thus multiple pathways of emission, it is likely water-soluble polymers are present in the environment; however, their potential environmental risk is uncertain. Research into tools and techniques for risk assessment of these polymers, as well as efforts to address data gaps, are essential to characterise environmental risk.

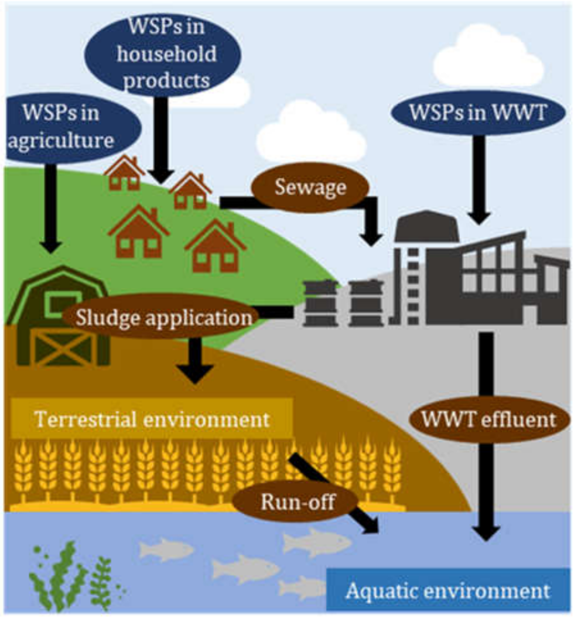

Figure 1. *Routes of environmental emission of water-soluble polymers (WSPs) used in household products, wastewater treatment (WWT), and agriculture.*

Polymers are high molecular weight molecules with widespread usage in a number of sectors, including as packaging materials, and in vehicles and construction, electrical and electronic materials, wastewater treatment and agriculture, and household products. In particular, plastic polymers have gained significant attention due to their ubiquitous presence in the environment and poor biodegradability, with both large-scale plastic debris and plastic particles such as microplastics being the focus of environmental research efforts. However, other types of polymers such as water-soluble polymers (WSPs) have received comparatively little attention (*1*). Given the previous lack of regulation of polymers due to the assumption that their high molecular weights indicate minimal ecological hazard, there is a need to determine the potential extent of environmental exposure and the hazards of WSPs.

"A number of applications of water-soluble polymers involve direct pathways of emissions into the environment"

Usage and emission pathways

WSPs are widely used in a number of sectors, with annual production of WSPs in Europe estimated in the range of millions of tonnes (*2*). A number of applications of WSPs involve direct pathways of emission into the environment, including in wastewater treatment as flocculants, in agriculture as soil conditioners, or in pesticide and fertiliser formulations, and in household products such as detergents, cleaning products, and personal care products, which may be released down-the-drain (*2*). Common polymer types used in household products include polycarboxylates (used as 'builders' and anti-redeposition agents in detergents), polyquaterniums (anti-static and film-forming agents in personal care products), and polyethers (often bonded to hydrophobic groups to act as surfactants). WSPs released down the drain which are not degraded during wastewater treatment have the potential to be released in effluent waters or applied to agricultural soils if in the sludge.

Presence in the environment

Thus far, there have been relatively few studies focussed on measurement of environmental WSPs originating from household and personal care products released down the drain. Polyether polymers and oligomers have been most frequently studied, with alcohol ethoxylates, alcohol ethoxysulfates, and polyethylene glycol measured in surface waters in the range of ngL^{-1} to μgL^{-1} (*3-6*). Polydimethylsiloxane has also been monitored in surface waters, but found to be below the limit of detection (< 5 $\mu g\ L^{-1}$) in most cases (*7*). However, measured environmental concentrations for other types of WSPs remain scarce. A lack of specific and sufficiently sensitive analytical methods for detection of WSPs is a key issue, with the potential complexity of polymer mixtures requiring additional considerations for analysis (*2*).

Modelling approaches are key in predicting environmental concentrations of potential environmental contaminants where measured data are not available. Predicted environmental concentrations have been calculated for several alcohol ethoxylates and alcohol ethoxysulfates, a select number of polycarboxylates, and polyquaterniums (*8,9*); however, these data cover only a small number of WSPs in current use. In addition, a lack of publicly available data on usage and production volumes of polymers hinders many typical modelling approaches, with a lack of data on environmental fate of water-soluble polymers, preventing the use of higher tier models for more in-depth exposure predictions. Given the widespread usage and direct emission pathways of WSPs, it is likely that several WSP types are present in the environment; however, there remains uncertainty around actual environmental concentrations and potential risk.

Potential environmental risk

Environmental risk assessments (ERAs) of most WSPs in current use are scarce. Whilst most polymers, in general, have been previously assumed to pose little ecological hazard due to their high molecular weights (and thus low solubility/environmental mobility), some polymer classes are considered to be a potential cause for concern. For example, polyquaterniums (characterised by cationic quaternary ammonium groups along the polymer chain) have been recognised as having potential aquatic toxicity (*10*). In addition, the widespread usage of other polymer types indicates a need for risk assessment regardless of prior assumptions of low toxicity. ERAs of alcohol ethoxylates, alcohol ethoxysulfates, and polycarboxylates used in household cleaning products have been previously performed, with no environmental risk identified as likely, since they biodegrade in sediments (*8*). However, these risk assessments again cover only a small selection of the WSPs that are in current use, with a number of WSPs used in household products being shown to have insufficient data available to conduct an ERA (*11*).

Conclusions

Given the widespread usage of WSPs, with many applications resulting in the potential for direct emissions to the environment, there is a clear need to characterise their potential environmental risks. Addressing knowledge gaps in both exposure and potential hazard of WSPs in the environment is key, with a need to develop analytical methods for sensitive and specific WSP characterisation as well as modelling approaches which account for the specific and complex nature of polymers. The previous regulatory exemptions of polymers have resulted in the need to confirm a lack of environmental risk moving forward.

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