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Special Series

Ecological risk assessment of per- and polyfluorinated alkyl substances: Foreword

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EDITOR'S NOTE:

This article is part of the special series, "Ecological Risk Assessment of Per- and Polyfluorinated Alkyl Substances." The series documents and advances the current state of the practice, with respect to ecotoxicological research, environmental exposure monitoring and modeling, ecologically based screening benchmarks, and risk assessment frameworks.

Abstract

During the last 5 years, data and guidance to support ecological risk assessment of per- and polyfluorinated alkyl substance (PFAS) have become increasingly available. The studies presented in this special series exemplify and advance this progress. Among the highlights are a whole-colony honey bee toxicity study, a critical evaluation of contrasting evidence to understand avian toxicity of PFAS, a bioaccumulation model incorporating PFOS precursor transformation, and an assessment of PFAS monitoring and regulatory needs on the African continent. This foreword closes with a summary of research needs identified from the special series. *Integr Environ Assess Manag* 2021;17:670–672. © 2021 SETAC

KEYWORDS: Ecological risk assessment, PFAS, Research needs

Public, regulatory, and scientific concerns regarding risks posed by various environmental contaminants often follow a common path: A chemical is first detected in people or in food or water intended for people, which launches concerted focus on the effects of that contaminant on human health. Years may then pass before serious attention is given to the potential effects of that contaminant on ecological receptors. This pattern of inquiry, exemplified by research on polychlorinated biphenyls (PCBs), dioxins and furans, and mercury, is evident again with per- and polyfluoroalkyl substances (PFAS). While human health protection justifiably remains a top priority, this special series enters publication at a moment when ecological risk science for PFAS is beginning to bloom. We still largely lack answers as to whether PFAS are causing ecological harm in the environment, but the tools to perform such investigations are taking shape, at least for a subset of the PFAS of interest.

Scientific and regulatory attention on the ecological effects of PFAS is rapidly gaining ground. Guidance to support site-specific ecological risk assessments (ERAs) for PFAS-contaminated sites has recently become available (Conder et al., 2020; ITRC, 2020, Johnson et al., 2021), and state-of-the-science reviews have been published (Ankley et al., 2021, McCarthy et al., 2017). Further detailed information is available from a special issue of *Environmental Toxicology and Chemistry* (2021, Volume 40, Issue 3), focused on environmental risks of PFAS. To date, aquatic toxicity of certain PFAS compounds (primarily perfluorooctanesulfonate [PFOS] and perfluorooctanoic acid [PFOA]) has been relatively well studied, supporting detailed chemical-specific ERA for aquatic life (e.g., Salice et al., 2018). This special series presents a broad array of further contributions to ecological effects and exposure science for PFAS. The work underway—particularly in the areas of effects on pollinators, amphibians, and birds—is promising and offers views on the quite varied sensitivity of different species to different PFAS.

The special series opens with a study on the effects of environmentally relevant concentrations of PFOS in sugar syrup on honey bee colonies (Sonter et al., 2021). The authors' findings of adverse effects on behavior and biology (including survival and reproduction) provide the first clear evidence that PFOS exposure negatively affects honey bee colonies and may transfer to honey. Although such adverse effects may translate to commercial losses in the honey industry and/or increased exposure to humans with

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consumption of honey, the most concerning implications relate to the pollination services that already are under stress from land-use change and intensification, pests, diseases, and exposure to a multitude of environmental contaminants.

A second ecotoxicological study (Tornabene et al., 2021) focuses on acute toxicity of three PFAS compounds for nine species of larval amphibians. This study aids in prioritizing test species and development stage based on sensitivity, as well as on the relative toxicity of different PFAS compounds. As such, the information it presents should benefit future chronic ecotoxicological study designs and development of ecologically based benchmarks for PFAS.

Custer's insightful commentary hypothesizes reasons for apparent disconnects between outcomes of field-based and laboratory studies on the reproductive effects of PFAS on bird populations (Custer, 2021). Conflicting outcomes for different lines of evidence tend to be the rule, rather than the exception in ecotoxicological studies. The suggestions she offers for better linking laboratory and field studies inform PFAS-related avian research, as well as study designs focused on other environmental contaminants.

McCarthy et al. (2021) follow with a review of approaches to elucidate effects of PFAS mixtures. Mechanistic approaches include developing single-chemical toxicity thresholds and selecting a method to integrate exposure–response data for multiple compounds, depending in part on mechanisms of action. Top-down approaches include site-specific toxicity testing and/or biological field investigations, which will also likely be integral to meaningful ecological risk analyses for PFAS-contaminated sites. Both approaches will be needed, considering the wide range of PFAS compounds and their use and environmental release as mixtures, such as in aqueous film-forming foam (AFFF) fire suppressants.

The series then transitions from ecotoxicological effects to articles that present a variety of tools and solutions for screening and assessing fate, transport, exposure, and hazard of PFAS. Recognizing the need for bioaccumulation modeling to support ERA, Glaser et al. (2021) explore PFOS bioaccumulation modeling approaches that account for PFOS precursors when predicting uptake of PFOS by ecological receptors.

Two of the papers in the series explore the very different needs of Switzerland and African countries, with respect to scientific and regulatory needs around PFAS in the environment. Casado-Martinez et al. (2021) describe a preparatory study carried out in Switzerland for purposes of developing a strategy around sediment quality and risk assessment of PFAS. Groffen et al. (2021) explore fundamental needs related to monitoring, analysis, and regulation of PFAS in Africa, a continent with generally lower PFAS contamination than is present in most other geographies and that stands to benefit from the lessons learned in Australia, North America, and Europe.

Morganti et al. (2021) critically review bird egg monitoring as a tool for ERA, identifying strengths and limitations of this approach and discussing several considerations for the design of egg monitoring programs. They present a case study of egg monitoring near an Italian fluoropolymer manufacturing site, which provides insight into exposure pathways and bioaccumulation potential of legacy and current-use PFAS.

The series concludes with a review by Conder et al. of strategic resources for assessing ecological risks of PFAS (Conder et al., 2021), focusing on four free and publicly available guidance documents recently released by the US Department of Defense's Strategic Environmental Research and Development Program: (1) guidance for assessing the ecological risks of PFAS to threatened and endangered species, (2) PFAS risk-based screening levels; (3) investigating potential risk to threatened and endangered species; and (4) a framework for assessing bioaccumulation and exposure risks.

Although considerable progress has been made in the last few years related to understanding the ecological risks posed by PFAS, the papers in this series identify a number of research and information needs:

- Improved understanding is needed for PFAS that are not currently quantified using typical analytical methods, including PFAS precursor compounds that may degrade to persistent PFAS.
- Information needed to support risk assessment of PFAS includes ecotoxicity bioassay results for receptors that are currently under-represented (e.g., birds, reptiles, etc.).
- Characterization of modes of toxic action and mixture toxicity is needed to address the effects of complex PFAS mixtures.
- More robust sediment toxicity studies could help reduce uncertainty and conservatism in sediment quality guidelines for PFAS, while ensuring that such guidelines are protective of all relevant receptors.
- In addition to designing studies to methodically test mixtures of multiple PFAS, testing should consider whether there are synergistic effects due to common stressors found in the wild (e.g., temperature, food availability) or water quality.
- Field studies are needed to validate and calibrate the predictions of risk assessments that are entirely reliant on desktop and laboratory studies.
- Efforts to validate field studies will be more fruitful if laboratory studies more consistently report bird egg concentrations for the dosage groups. Procuring and analyzing diet items should be a priority in field studies.
- Characterization of regional concentrations of PFAS in various environmental media would enable evaluation of whether concentrations detected in the environment are consistent with (anthropogenic) background and help prevent definition of cleanup goals that are lower than background.
- Information needed to support mechanistic modeling includes parameters for bioaccumulation modeling,

including partitioning properties of PFAS in biological media and empirical uptake factors.

DATA AVAILABILITY STATEMENT

There are no data associated with this paper.

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