Emerging Contaminants 1 (2015) 54–63

Contents lists available at ScienceDirect

Emerging Contaminants

journal homepage: http://www.keaipublishing.com/en/journals/emerging-contaminants/

Review article

Use of wild trout for PBDE assessment in freshwater environments: Review and summary of critical factors

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ARTICLE INFO

Article history:
Received 27 April 2015
Received in revised form
28 August 2015
Accepted 28 August 2015
Available online 17 October 2015

Keywords:
Critical factors
Freshwater environments
PBDE
Trout
Global hotspots

ABSTRACT

Certain wild animals represent sentinels to address issues related to environmental pollution, since they can provide integrative data on both pollutant exposure and biological effects. Despite their technological benefits, PBDEs are considered a threat to environmental health due to their persistence, toxicity, and capacity to be accumulated. These pollutants have been found geographically widespread in fish, particularly in predator species such as trout. The aim of this work is to critically review the applicability and usefulness of wild trout for assessing PBDEs in freshwater environments. Reviewed reports include data from highly industrialized areas as well as areas from remote regions with relatively low human activity, including European and North American great lakes and freshwater environments in Europe, Greenland, subarctic areas and Patagonia, respectively. A summary of relevant factors were grouped into organism-specific factors (food habits, age, size, lipid content, sex and reproduction, tissue type, mechanism of contaminant uptake and metabolism), and PBDE levels in the surrounding environment (sediment). Five wild trout species [rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), lake trout (*Salvelinus namaycush*), arctic char (*Salvelinus alpinus*), and brook trout (*Salvelinus fontinalis*)], collected worldwide within the 1994 to present time frame, were considered. Multivariate techniques (principal component analysis-PCA) and mapping approach, showed clear differences in geographic distribution patterns of PBDE levels in trout depending on the region studied: wild trout from European and North American great lakes have the highest PBDE loads. This pattern could be due to high industrial activity at these locations. A correlational approach used to explore intraspecific relationships between PBDE levels and morphometry, showed positive relationships only for brown trout. Further, brown trout showed the highest trout-to-sediment ratios, which is suggestive of a relatively greater capacity of this species to accumulate PBDEs in relation to sediment levels. Overall, results suggest that adult wild trout could be useful as a PBDE bioindicator.

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Peer review under responsibility of KeAi Communications Co., Ltd.

Production and Hosting by Elsevier on behalf of KeAi

http://dx.doi.org/10.1016/j.emcon.2015.08.002

Contents

1. Introduction

A challenge task in environmental assessments has been to measure pollutant concentrations in key ecological compartments (e.g. air, soil, sediment and biota) and then make toxicological judgements based on their known or suspected health effects [1,2]. Certain wild animals represent models, or sentinels, to address issues related to environmental pollution, since they can provide integrative data on both exposure (i.e., information on type, amount, distribution of contaminants) and effects (i.e., information on biological responses). Several freshwater invertebrates and vertebrates were claimed as valuable models for monitoring PBDEs: amphipod crustaceans (*Echinogammarus stammeri*) [3], decapod crustaceans (*Macrobrachium nipponense* and *Eriocheir sinensis*) [4], birds (*Larus argentatus*, *Uria aalge* and *Sturnus* spp) [2,5], and fish species, especially those with fish-eating behaviour like salmonids [6,7].

Polybrominated diphenyl ethers (PBDEs) save lives by serving as flame retardants in a wide variety of commercial and household products [2]. Despite their benefits, PBDEs pose a threat to environmental and human health due to their persistence, bioaccumulation potential, and adverse effects on the nervous, reproductive, and endocrine systems [8,9]. PBDEs are categorized into three technical formulations according to their degree of bromination; penta-, octa-, and deca-BDE commercial mixtures. Penta- and octa-BDE formulations are included in the Stockholm Convention [10]. Even though many countries have banned or restricted the use of two (penta- and octa-) of the three technical mixtures, the presence of lower brominated diphenyl ethers which are predominant in the so-called penta-BDE mixture has been detected in freshwater organisms (invertebrates, fish, birds) collected worldwide [2,9].

Trout are a member of the Salmonidae family, distributed worldwide in cold and temperate aquatic ecosystems, and easily reared in captivity [11,12]. Freshwater wild trout species have characteristics helpful to being included in environmental pollution studies [13,14]. Furthermore, humans and many species of trout inhabit similar ecosystems and are exposed to common climates, food sources, and pollutants [15–17]. To assess the extent of PBDE contamination in freshwater environments, trout present several advantageous biological characteristics (including being at top of the food web, having lipid-rich tissues, pollutant concentration capacity, a wide geographic distribution due to their phenotypic plasticity that allows them to successfully invade new ecosystems), in addition to their sporting and gastronomic worth [18–22]. Therefore, information derived from wild trout may be more useful to the study of PBDE levels and distribution than models of lower aquatic trophic levels [23,24]. Over the last 20 years, there has been a widespread use of wild trout for PBDE assessment in freshwater environments (Table A.1, Fig. 1). This review summarizes this field of research, and considers the implications of the reported data with the aim to explore the feasibility of wild trout as a sentinel species for PBDEs in environmental health assessments.

2. Strategy of this review

Relevant biological features of trout and key results from reports on PBDE levels in wild trout species inhabiting freshwater environments were summarized. Subsequently, certain critical factors were statistically analysed to explore patterns of PBDE levels among trout species worldwide. Since other top predator fish, such as wild anadromous salmon species, have been claimed as a suitable tool for PBDE assessments [6]; this review focuses this issue on freshwater wild trout species. Because free-living wildlife can integrate ecological factors and real world complexities, only field studies within the 1994 to present time frame were referred to. Therefore, studies conducted on farmed trout were not included in this review. In order to capture target publications, the literature was examined using the key words: trout* AND char* AND PBDEs* AND BFRs* AND polybrominated* AND sediment* AND freshwater environment*. Each publication fitting the above criteria was compiled in a database containing the following information: trout species, PBDE levels in different tissue types, including muscle, liver or whole body; lipid content; and trout morphometry. Additionally, PBDE levels in sediment of the studied region were considered. In all cases, the average PBDE levels reported were used. Both, georeferenced sampling sites and the year when samples were taken were included in the database. Most publications provided data in