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Preliminary data on polybrominated diphenyl ethers (PBDEs) in farmed fish tissues (*Salmo salar*) and fish feed in Southern Chile

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Abstract

Polybrominated diphenyl ethers (PBDEs) have become an issue of global concern. Recent studies have shown that farmed salmon can accumulate high levels of brominated compounds in their tissues and consequently there is a growing concern on its industrial and public health impacts. Little information is found in the international literature on PBDEs in the biotic compartment of the Southern Hemisphere. This paper reports the levels of several PBDE congeners found in the tissues of farmed fish from five different farming areas of Southern Chile. PBDEs were analyzed by HRGC-MS. More analytical data were obtained by analyzing these same pollutants in fish feed. Our results indicate a general trend of PBDE levels averaging 1.46 ng g^{-1} wet weight (wwt). The observed congeneric distribution that resulted was quite similar to data previously reported in the open literature. PBDE profiles were found to be dominated by BDE 47. No correlation was observed between levels found in the tissues and the lipid content in such tissues, although a high correlation with the fish feed data was observed indicating that this could probably be the main PDBE entry source into fish, although other sources cannot be excluded. Even though the samples were obtained from different geographical areas, they presented fairly similar profiles, indicating a potential common source. We concluded that PBDE levels in the farmed Chilean salmon are in the low average range of values published in the open literature.

Keywords: PBDEs; Salmon; Fish feed; Chile; Lipids; POPs; Pollution; Farmed fish

1. Introduction

Polybrominated diphenyl ethers (PBDEs) are a group of organic chemical substances, with limited natural sources (Teuten et al., 2005), formed by a family of 209 congeners, and which have become an important commercial chemical product due to their properties as flame retardants. This flame retardant property has produced a variety of applications in both industrial and consumer sectors forming part of products such as polyurethanes, electric circuits, furniture, textiles, plastics, and packing and insulation material (Alaee et al., 2003). The commercial production of PBDEs began in

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the 70s in Germany (ATSDR, 2004). The production continues until today, but since 1980 their production and use have experienced a drastic increase (Alcock et al., 2003).

There are three principal commercial PBDE formulations: penta-BDE, octa-BDE and deca-BDE. Penta-BDE and octa-BDE are mixtures of several congeners (Alaee et al., 2003). Almost all of deca-BDE (also known as BDE-209) consists of the congener BDE-209. The use of these three additives in Europe in 1999 was estimated in 210, 450 and 7500 tonnes, respectively, where deca-BDE is the most utilized and has the most diverse uses. The production and commercial use of PBDE formulations in North America considerably exceed the levels in Europe. Currently, the EU and Norway have banned the marketing of articles or products containing 0.1% penta-BDE or octa-BDE (August 15, 2004, Council Directive 76/769/EEC).

These compounds possess properties similar to other persistent organic pollutants such as the polychlorinated biphenyls (PCBs), they are highly hydrophobic ($\log K_{ow}$ 5.7–8.3), resistant to degradation, and have low vapor pressure among other characteristics (Braekevelt et al., 2003).

Although the first reports on their presence in fauna are from the 1980s, the generalized nature of PBDE contamination was not recognized until the beginning of the 1990s (Sellström et al., 1993). Since then, the PBDEs have been found in almost all natural mediums including air (Strandberg et al., 2001), sediments (Lacorte et al., 2003.), biota (Dodder et al., 2002) and even in whales of profound oceans and the Arctic (De Boer et al., 1998). PBDE concentrations in most of these environmental compartments are exponentially increasing as a function of time (Zhu and Hites, 2004).

PBDEs are also common contaminants in humans, with detectable levels found by studies in Europe (Schroeter-Kermani et al., 2000), Canada (Ryan et al., 2002), United States (Betts, 2002; Hites et al., 2004). PBDE concentrations in human blood demonstrated the existence of a tendency towards increased levels in the last two decades (Thomsen et al., 2002). The presence of deca-BDE in human serum despite it great molecular size demonstrates its bioavailability. Even though it is probable that the principal exposure route is through food, especially those with high fat content like some fish (especially for the most bioaccumulative PBDEs), it is likely that other exposure sources are significant, including direct contact with PBDE-containing products. These compounds have been detected in interior environments and/or in work place dust (Jakobsson et al., 2002).

Even though their toxicity mechanisms are gradually being clarified, their long-term toxicity, at low doses, is only vaguely described. Their toxicity in chronic exposure (especially intrauterine) has been shown to affect cerebral and osseous development in rats (Eriksson et al., 2001; Meerts et al., 2002), which in turn could produce permanent neurological effects (Eriksson et al., 2001). It has been signaled that common PBDE metabolites, such as TBBP-A, place obstacles to the union of thyroid hormones (Meerts et al., 2002), increasing their diverse potential effects on growth and development. Helleday et al. (1999) report on PBDEs' genotoxic effects on mammal cell cultures, and the EPA has classified deca-BDE as a possible carcinogen in human beings.

The increase in PBDE concentrations has created interest in investigating the bioaccumulation patterns of these compounds in aquatic biota since it is one of the principal alimentation sources for humans. Considering that salmon farming has increased its production between 1990 and 1998 (FAO, 1998), this situation is especially worrisome because recently published studies, found that the PBDE concentrations in farmed salmon are higher than in wild salmon, and indicate that the increase in salmon consumption could present a risk to human health (Hites et al., 2004).

A study performed by Schecter et al. (2004), evaluating distinct food products in US supermarket chains, found that the salmon filets are the ones that possess the highest total PBDE concentrations, reaching 3078 pg g^{-1} (fresh weight)—higher than the values found in ground beef, bacon, turkey, pork, duck, and pork hotdogs. Elevated concentrations in salmon have been reported in lakes in the US (Manchester-Neesving et al., 2001) and Europe (Vives et al., 2004; Zennegg et al., 2003).

Given that salmon production could be affected by a possible risk for human transmission or exposure to this type of organobrominates, studies are required to evaluate the situation. The present study will contribute by evaluating the PBDE levels present in salmon tissue coming from different salmon farms in Southern Chile, and comparing values to those levels detected in other salmon production areas in the world.

2. Materials and methods

2.1. Sampling

Samples were obtained from five farming areas located in Southern Chile (Fig. 1). Three samples were obtained by each zone, except in the zone 5 where only two samples were obtained. In addition, 5 fish feed samples (one sample by each zone) were analyzed for the same congeners. Samples were stored in precleaned aluminium foil, then sealed in a plastic bag and stored at −20 °C until sent to Germany by courier.

The samples were subjected to a custody chain during their transport to the laboratory, in the laboratory (accredited ISO 17025) samples were analyzed according the protocol described below.