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Occurrence, bioaccumulation, and trophic magnification of pharmaceutically active compounds in Taihu Lake, China

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HIGHLIGHTS

- PhACs were ubiquitous in surface water and sediments from Taihu Lake.
- PhACs displayed low bioaccumulation potential in aquatic organisms.
- Trophic magnification of PhACs in the food web of Taihu Lake was researched.
- TMFs for RTM, PRP and DCF were estimated in the Taihu Lake food web.

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ABSTRACT

The occurrence, bioaccumulation, and trophic magnification of pharmaceutically active compounds, (PhACs) including antibiotics (roxithromycin and erythromycin), non-steroidal anti-inflammatory drugs (ibuprofen and diclofenac), a non-selective β-adrenoceptor blocker (propranolol), an antiepileptic drug (carbamazepine), and steroid estrogens (17β-estradiol and 17α-ethynylestradiol), were investigated in Taihu Lake, China. All eight PhACs were widely detected in surface water and sediment samples with maximal concentrations in the range of 8.74–118 ng L^{-1} and 0.78–42.5 ng g^{-1} dry weight (dw), respectively. The investigated organisms in the natural freshwater food web in Taihu Lake included phytoplankton, zooplankton, zoobenthos, and fish, and the maximal concentrations of target compounds in these biota samples ranged from 0.65 to 132 ng g^{-1} dw. Bioaccumulation factors (BAFs) for all target PhACs were lower than 1000 L kg^{-1}, suggesting their low bioaccumulation potential in aquatic organisms from Taihu Lake. Trophic magnification factors (TMFs) were estimated at 1.11 for roxithromycin, 0.31 for propranolol, and 1.06 for diclofenac, indicating none of these PhACs underwent trophic magnification in this freshwater food web.

1. Introduction

Pharmaceutically active compounds (PhACs) have attracted growing attention in recent years as emerging contaminants due to their possible threats to the aquatic environment and human health. They consist of diverse groups of organic compounds designed to prevent, cure and treat diseases and improve health, such as antibiotics, hormones, anti-inflammatory drugs, antiepileptic drugs, blood lipid regulators, β-blockers, contrast media, and cytostatic drugs. These chemicals have been produced and used in significant quantities throughout the world. For example, in 2011, more than 1500 types of active pharmaceutical ingredients were produced in China, and the estimated domestic production was approximately two million tons (Liu and Wong, 2013). Because of incomplete elimination and sporadic direct wastewater discharge, PhACs and their metabolites continuously enter the aquatic environment, largely through effluents from sewage treatment plants (STPs) (Daughton, 2004). Although the risk of acute toxic effects from PhACs at environmentally relevant concentrations is believed to be unlikely, chronic effects could not be excluded. The continuous input of PhACs into the environment may lead to their accumulation and to irreversible harm to wildlife and human beings (Fent et al., 2006; Liu and Wong, 2013).

In addition to their toxicity, prevalence, and environmental persistence, bioaccumulation in aquatic organisms is another vital criterion for assessing the ecological risk of PhACs. In a recent study, 92 out of 275 drugs detected in the environment were rated as potentially bioaccumulative using quantitative structure property relationships or scientific judgment (Howard and Muir, 2011). The term bioaccumulation is defined as the absorption of a chemical substance by organisms in the natural environment, and the

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degree to which bioaccumulation occurs is expressed as the bioaccumulation factor (BAF). Distinctly, bioconcentration is the process by which a chemical substance is absorbed by an organism from the ambient environment only through respiration and dermal contact. The bioconcentration factor (BCF) can only be determined under controlled laboratory conditions where dietary intake of the chemical is not considered. Field BAFs are generally greater than laboratory BCFs, and emphasize the importance of environmental measurements for reliable assessment (Arnot and Gobas, 2006). Unfortunately, most studies have focused on laboratory BCFs of PhACs, while data on the bioaccumulation of PhACs in biota from field studies are quite limited (Zenker et al., 2014). Compared to BCFs or BAFs, trophic magnification factors (TMFs), which measure the average biomagnifications of contaminants through food webs, have been suggested as a more reliable tool for evaluation of chemicals' behavior in food webs (Arnot and Gobas, 2006; Borgå et al., 2012b). TMFs account for ecological complexity in trophic interactions and measure biomagnification across entire food webs rather than for individual species. Investigating the trophic transfer of PhACs in aquatic ecosystems will improve our understanding of the environmental disposition and impacts of PhACs. To date, there is a scarcity of studies of trophic transfer of PhACs. So far, only one study has reported trophic dilution of diphenhydramine across trophic positions of an effluent-dependent wadeable stream (Du et al., 2014). Previous findings suggested that regional variability in ecosystem characteristics would influence the trophic transfer of chemicals (Houde et al., 2008; Borgå et al., 2012b). Thus, more studies are needed to understand the trophic transfer of PhACs in freshwater ecosystems.

Taihu Lake, located in eastern China and adjacent to Jiangsu and Zhejiang Provinces, is the second largest freshwater lake in China. The lake water has been used for agricultural and industrial purposes and as the major drinking water source for several cities, including Shanghai, Suzhou, and Wuxi. With the rapid economic growth and urban development since the 1980s, the lake has been seriously polluted by wastewaters and wastes from industry, agriculture, and daily life. As a result, the occurrence of heavy metals and persistent organic pollutants (POPs) has been reported in the water, sediments, and organisms from the lake (Feng et al., 2003; Wang et al., 2011; Yu et al., 2012). In our previous studies, several PhACs were detected in water bodies in the northern part of Taihu Lake (Yan et al., 2012; Lu et al., 2013). Additional research on organisms at different trophic levels (TLs) is urgently needed to provide a better understanding of the ecological risks of PhACs in this lake. Therefore, the objective of this study was to investigate the occurrence and spatial distribution of PhACs in water and sediments from the entirety of Taihu Lake and to clarify their bioaccumulation and biomagnification effects in this freshwater food web.

2. Materials and methods

2.1. Sample collection

The sampling sites in Taihu Lake are shown in Fig. 1. The sampling campaign was performed in May 2013. The samples included surface water ($n = 32$), sediment ($n = 32$), phytoplankton (mainly *Chlorophyta*, *Bacillariophyta* and *Cyanophyta*, $n = 16$), zooplankton (mainly *Copepoda*, *Cladocera*, and *Rotifers*, $n = 16$), three zoobenthos

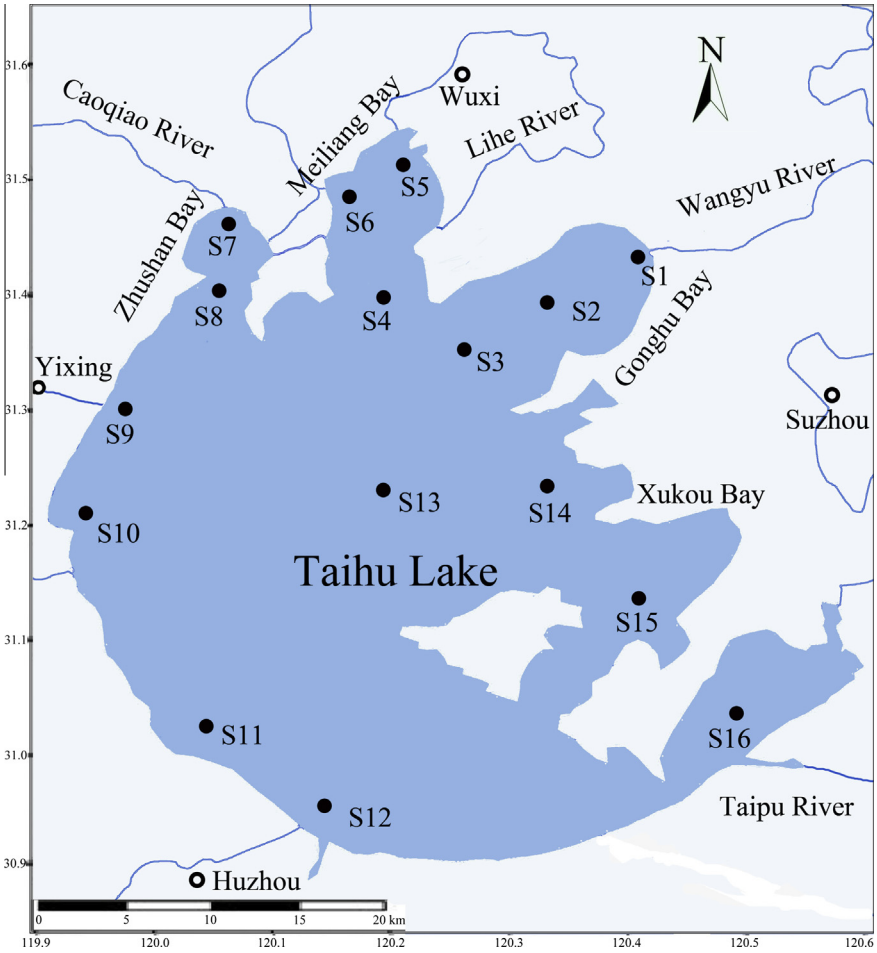

Fig. 1. Sampling sites in Taihu Lake.