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ORIGINAL PAPER

Occurrence of estrogens in water, sediment and biota and their ecological risk in Northern Taihu Lake in China

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Abstract Occurrence of five estrogens, including estrone (E1), 17β-estradiol (E2), estriol (E3), 17α-ethynylestradiol (EE2) and bisphenol A (BPA) in water, sediment and biota in Northern Taihu Lake, were investigated and their ecological risk was evaluated. Most of the target estrogens were widely distributed in the eight studied sampling sites, and their levels showed a regional trend of Gong Bay > Meiliang Bay > Zhushan Bay. The average concentrations of E1, E2, E3, EE2 and BPA ranged from 3.86 to 64.4 ng l^{-1}, 44.3 to 64.1 μg kg^{-1} dry weight and 58.6 to 115 μg kg^{-1} dry weight in water, sediments and biota, respectively. In most cases, the average concentrations of BPA and E2 were higher than those of other estrogens. E1, E3 and EE2 were found to be accumulated in river snails with bioaccumulation factor values as high as 14,204, 35,327 and 20,127 l kg^{-1}, respectively. E3 was also considered to be accumulated in clams. The evaluation of environmental risk showed that the occurrence of E2 and EE2 in lakes might pose a high risk to aquatic organisms. These findings provide important information for estrogen control and management in the studied area.

Keywords Estrogens · Taihu Lake · Water · Sediment · Biota · Risk assessment

Introduction

In past decades, the occurrence of estrogens in aquatic environments has attracted increasing attention because they can exert their biological activity on non-targeted organisms and be harmful to the ecosystems and the health of animals and humans (Gineys et al. 2010). Many estrogens are continuously released into the environment through wastewater treatment plant (WWTP) effluents, surface non-point runoff of manure and sewage sludge used in agriculture, and atmospheric deposition of particulates and aerosols (Björkblom et al. 2008; Kuster et al. 2004). Estrogen residues have been widely detected in surface water, sediment, groundwater and aquatic biota. Although these compounds are usually detected in the environment at trace levels (Arditsoglou and Voutsa 2012; Isobe et al. 2006; Lei et al. 2009; Rocha et al. 2013; Shi et al. 2013), it has been proven that estrogens can induce toxic effects, for example, feminization of fishes, even at low ng g^{-1} concentrations (Froehner et al. 2012; Hernando et al. 2006). Thus, the characterization and risk assessment for estrogens are very

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necessary for their environmental control and management.

Taihu Lake is the third largest freshwater lake in China (Qin et al. 2007), located in the southeastern Yangtze River Delta with an average water depth of 1.9 m and a surface water area of 2,338 km^2. Over 100 rivers discharge into the lake, and the surroundings comprise one of the most industrialized areas in China with high population density, urbanization and economic development. The lake water is used for agricultural and industrial purposes, and it is the source of drinking water for Shanghai, Suzhou and Wuxi. However, the water supply faces potential ecological and human risks due to the increasing population, industrial and agricultural development, and deteriorated water quality (Qiao et al. 2006). Estrogens, as one of the important pollutants, have been found in the aqueous phage of Taihu Lake. Shen et al. (2001) investigated hormone-disrupting activity in water collected at Meiliang Bay, Taihu Lake, and found that the estrogenic activities (estradiol equivalents: 2.20–12.1 ng l^{-1}) were mainly caused by natural and synthetic hormones. Lu et al. (2011). Yan et al. (2012) detected environmental estrogens in Taihu Lake water and assessed the estrogenic biological effects and feminization risk in fish. The available research has focused on the measurement and assessment of estrogens in the aqueous phage. Given the relatively low polarity of estrogens, with octanol-water partition coefficients (K_{ow}) mostly between 10^3 and 10^5 (Kuster et al. 2004), they are easily adsorbed into sediment and accumulated and magnified in the biota (Lai et al. 2002), which might pose a threat to ecological health. However, little literature on the status of estrogens in the sediment and biota in Taihu Lake is available. Thus, it is necessary to determine the levels of estrogens in the sediment and biota in Taihu Lake and to evaluate their potential ecological risk.

In this study, five estrogens, including estrone (E1), 17β-estradiol (E2), estriol (E3), 17α-ethynylestradiol (EE2) and bisphenol A (BPA), were chosen as target estrogens. E1, E2, E3 and EE2 are steroidal estrogens (Kuster et al. 2004); BPA, the monomer used in the manufacture of epoxy resins and polycarbonate plastics, is another example of important environmental estrogens (Sun et al. 2012). We simultaneously investigated their status in water, sediment, and biota in Northern Taihu Lake. Their concentrations were compared with other locations, and their bioaccumulation factors (BAFs) were calculated. Finally, their potential ecological risk to aquatic organisms was evaluated. The results will provide important information for estrogen control and management of this area.

Materials and methods

Study areas and sampling locations

The sampling sites were set in several districts in the northern part of Taihu Lake according to the flow characteristics of Taihu Lake and the water transfer route of the diversion project. A total of three regions (8 sampling sites) were chosen, including Gong Bay (S1, the outlet of Wangyu River; S2, Xiaogongshan; S3, Dagongshan), Meiliang Bay (S4, Tuoshan; S5, Yuantoubao; S6, Zhihu Harbor) and Zhushan Bay (S7, Caoqiao River; S8, the outlet of Zhushan Bay). Their locations are shown in Fig. 1. The sampling was performed in May 2013.

Surface water, sediment and biota samples were collected simultaneously, placed on ice and transported to the laboratory as soon as possible. Eight water samples were collected in glass bottles that had been pre-cleaned and rinsed with methanol, stored at 4 °C and extracted within 48 h. The pH, dissolved oxygen and temperature of water samples are shown in Table S1. Eight sediment samples were collected with a Peterson grab sampler from 10 cm below the sediment surface. The sediments were freeze-dried, ground and sieved at 0.125 mm. For biota samples, fish and two mollusc species (river snail and clam) were collected in each sampling site. However, in S7, we did not find the clam. Thus, a total of 23 samples were found. Fish fillets as well as the visceral mass of crustaceans were homogenized separately. Sediment and biota samples were stored at −20 °C until further analysis.

Chemicals and materials

The standard mixture of five estrogens (each at 1 mg ml^{-1}) in methanol was purchased from Sigma-Aldrich (St. Louis, MO, USA). The deuterated internal standard was 5 mg ml^{-1} [2, 4, 16, 16-$^2H_4$] 17β-estradiol (E2-d_4) in methanol, purchased from J&K Chemical, Ltd. (Beijing, China). HPLC grade methanol (MeOH), acetonitrile (ACN), hexane and acetone were purchased from Merck (Darmstadt, Germany).

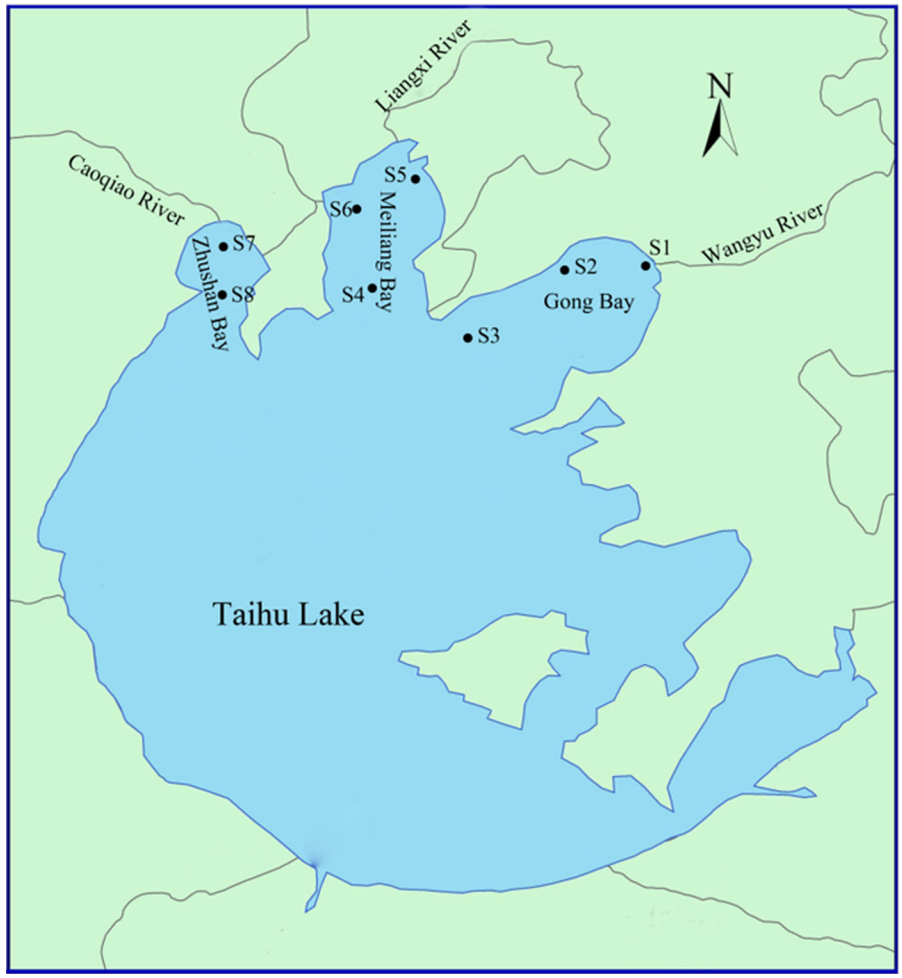

Fig. 1 Sampling sites in Northern Taihu Lake

Analytical grade ammonia, ammonium acetate and hydrochloric acid were obtained from Sinopharm Chemical Reagent Co., Ltd. (Shanghai, China). Neutral alumina (75–147 μm) was purchased from Sinopharm Chemical Reagent Co., Ltd (Shanghai, China). Before usage, it was heated in a muffle furnace at 450 °C for 4 h. All standards and working solutions were stored at 4 °C in silanized brown glass bottles with Teflon-lined caps. Deionized water was obtained from a Milli-Q water purification system (Millipore, Bedford, MA).

Analytical procedures

Water sample preparation and analysis

First 50 ng E2-d_4 was added to a 0.5-l water sample as the internal standard, and the pH was adjusted to 4 with diluted hydrochloric acid. Then the sample was vacuum-filtered through a 0.45-μm glass fiber filter to remove particles. An Oasis HLB (hydrophilic-lipophilic balance) cartridge (500 mg, 6 ml, Waters, USA) was used to extract analytes. Before extraction, the cartridge was sequentially pre-conditioned with 5 ml MeOH and 10 ml deionized water. The sample was passed through the cartridge at a flow rate of about 5 ml min^{-1}. Then the cartridge was vacuum dried for 30 min to remove excess water. The analytes were eluted with 10 ml ACN containing 5 % ammonia at a flow rate of about 1 ml min^{-1}. The eluate was concentrated to 1 ml by a quantitative concentrator (Buchi R-200, Flawil, Switzerland). The analysis was conducted using a high-performance liquid chromatography/tandem mass spectrometry (HPLC/MS/MS) system. The performance parameters are shown in Table S2.

Sediment sample preparation and analysis

The pretreated sediment (5 g) was placed in a 20-ml amber vial and spiked with 250 ng E2-d_4 as internal standard. The mixture was blended and soaked in 10 ml MeOH that was evaporated overnight. The internal standard method was performed following the methods developed by Salvia et al. (2012) and Ding et al.(2011) with minor modification. Then the mixture was placed in a 22-ml stainless steel extraction cell and mixed with diatomaceous earth to increase the contact-surface between the sediment particles and extraction solvent and prevent clogging of the extraction cell.

Extraction was performed by pressurized liquid extraction (PLE) using a Dionex ASE 350 (Dionex, Germany). Optimized extraction conditions were as follows: extraction solvents, acetone/MeOH (1:1, v:v); extraction temperature, 100 °C; static extraction time, 10 min; number of cycles, 2; flush volume, 60 %; nitrogen purge time, 120 s. The obtained 25 ml extract was concentrated to about 1 ml by a quantitative concentrator and then was mixed with 200 ml of deionized water. Subsequent depuration of extract was performed by the methods used in water samples. Finally, the eluate was concentrated to 1 ml. The analysis was carried out using HPLC/MS/MS (Table S2).

Biota sample preparation and analysis

Freeze-dried biota sample (1 g) was spiked with E2-d_4 (50 μg kg^{-1}), mixed with diatomaceous earth and placed in a 22-ml stainless steel extraction cell containing 5 g neutral alumina. Different PLE conditions were tested, and the optimized conditions were as follows: extraction solvents, ACN/MeOH (1:1, v:v); extraction temperature, 60 °C; static extraction time, 5 min; number of cycles, 3; flush volume, 60 %; nitrogen purge time, 120 s. After extraction, approximately 40 ml of extract was stored at −20 °C overnight to make fatty deposits. The deposited fat was removed by passing through a 0.22-μm polytetrafluoroethylene filter. Then the extract was concentrated to about 20 ml by a quantitative concentrator and mixed thoroughly with 20 ml of ACN and hexane. The mixture was allowed for the decantation, and the supernatant was abandoned. This step was repeated once. Finally, the extract was concentrated to 1 ml and analyzed by HPLC/MS/MS (Table S2).

The BAF was used to quantitatively describe bioaccumulation in this study. The BAF is defined as the ratio of the target compound concentration in the aquatic organisms to the concentration in water. The weight of the organism is presented on a wet weight basis and the unit of BAF is l kg^{-1} (Arnot and Gobas 2006). Water contents of the river snail, clam and fish samples are 80.4, 79.7 and 84.9 %, respectively.

Quality control

The concentrations of different compounds and matrices were determined using an internal standard method. Calibration curves of method were verified by analyzing seven concentrations of mixture standard solutions with linearity in the range of 1–1,000 ng l^{-1}, 1–500 and 1–500 μg kg^{-1} for water, sediment and fish, respectively. The linearity of calibration curve was confirmed. The relative standard deviations (RSDs) were determined by triplicate analyses of samples spiked at 100 ng l^{-1}, 50 and 50 μg kg^{-1} for water, sediment and fish, respectively. The RSD values were less than 14.7 %, indicating satisfactory precision. The limits of detection (LODs) were calculated at a signal-to-noise ratio (S/N) of 3. The linearity range, correlation coefficient and LODs are listed in Table 1.

Results and discussion

Estrogens in water

Concentrations of the target estrogens in the surface water in Northern Taihu Lake are listed in Table 2. The concentrations of E2 ranged from 40.0 to 117 ng l^{-1}, with the highest mean concentration (65.4 ng l^{-1}), which was slightly higher than that of BPA (64.4 ng l^{-1}). However, BPA had the highest maximum concentration up to 194 ng l^{-1}, far higher than E2 (117 ng l^{-1}). The frequent detection of BPA probably results from the extensive manufacturing, usage and industrial discharge in the Northern Taihu basin. Although the detection frequency of E1 was high, E1 had relatively low concentrations ranging from 1.81 to 28.8 ng l^{-1}. On the contrary, although EE2 concentrations in the aqueous phase were higher than those of E1, EE2 was detected less frequently. The possible reason is that EE2 is easily transformed

Table 1 Linearity range, correlation coefficient (R^2) and limit of detections (LODs) of five estrogens

Compound	Water			Sediment			Fish		
	Linearity (ng L^{-1})	R^2	LODs (ng L^{-1})	Linearity (ng g^{-1})	R^2	LODs (ng g^{-1})	Linearity (ng g^{-1})	R^2	LODs (ng g^{-1})
EE2	2.6–1,000	0.9956	0.8	2–500	0.9902	0.5	1.8–600	0.9783	0.5
E3	3–1,000	0.9987	1	2.5–500	0.9748	0.8	3–600	0.9356	1
E2	2.6–1,000	0.9566	0.8	2–500	0.9224	0.5	1.8–600	0.9899	0.5
E1	2.6–1,000	0.9999	0.8	2–500	0.9999	0.5	1.8–600	0.9649	0.5
BPA	2.6–1,000	0.9859	0.8	2–500	0.9999	0.5	1.8–600	0.9945	0.5

into phase II metabolites (conjugates of glucuronic acid and sulfate) in the liver of the organism and expelled into the intestines or gut (Blewett et al. 2013). The concentration and detection frequency of E3 were similar to those of EE2. The infrequent detection of E3 is possibly due to the degradation of E3 in the aquatic environment (Gomes et al. 2004). Similar detection frequencies of EE2 and E3 were also observed in Jiulongjiang River (Zhang et al. 2012), in which EE2 was not detected in any samples from Jiulongjiang River, and the detection frequency of E3 was only 16 %. However, the results were not exactly consistent with the previous study in Taihu Lake (Yan et al. 2012), in which E2, E3 and BPA were detected at all sites, while the others were detected at most sites.

The total concentrations of estrogens at different positions were quite different. The spatial differences might be due to the water in the lake. The diverting water from the Yangtze River enters into the lake from Gong Bay (S1, S2 and S3). High estrogen concentrations were detected in the Yangtze Rive, which might be one of the results of high estrogen concentrations in this bay (Hu et al. 2013). S1 was located at the outlet of Wangyu River, which has the highest estrogen levels. Due to dilution, the concentrations of $\sum$5ES at S2 and S3 were lower. The Meiliang Bay (S4, S5, and S6) and Zhushan Bay (S7 and S8) are near the Wuxi and Yixing, respectively. They receive a large amount of effluent from WWTPs as well as untreated domestic sewage (Shen et al. 2001), which might be the main source of estrogens in both bays (Zhang et al. 2014).

The occurrence of estrogens has been widely reported in surface water around the world (Table S3). In this study, the concentrations of estrogens in Northern Taihu Lake were slightly higher than those in rivers in Portugal (Rocha et al. 2013), the Aegean Sea in Greece (Arditsoglou and Voutsa 2012) and lakes in Korea (Kim et al. 2007), but much lower than in streams in the USA (Kolpin et al. 2002). In comparison to other locations in China, the levels of estrogens in Taihu Lake were much lower than in the Jiulongjiang River (Zhang et al. 2012), higher than in the Yellow River (Wang et al. 2012) and similar to the rivers in Tianjin (Rao et al. 2013). Compared with other available investigations on estrogens in Taihu Lake (Shen et al. 2001; Yan et al. 2012), the results of the present study were slightly higher.

Estrogens in the sediments

Concentrations of estrogens in surface sediments in Northern Taihu Lake are shown in Table 2. All estrogens were detected at all sites. Concentrations of E1, E2, E3, EE2 and BPA ranged from 5.49 to 164 μg kg^{-1} (mean 44.3 μg kg^{-1}, dw), 9.78 to 151 μg kg^{-1} (mean 46.0 μg kg^{-1}, dw), 8.66 to 203 μg kg^{-1} (mean 58.2 μg kg^{-1}, dw), 4.32 to 184 μg kg^{-1} (mean 45.5 μg kg^{-1}, dw) and 6.31 to 291 μg kg^{-1} (mean 64.1 μg kg^{-1}, dw), respectively. The $\sum$5ES levels in sediment samples (as well as water and animals) collected from Gong Bay showed a trend of S1 > S2 > S3. In addition, the concentration of $\sum$5ES at S1 was also the highest among the eight sediment samples (Table 2), which was the same as their concentrations in water. Since estrogens have low polarity and high octanol-water partition coefficients, they are easily adsorbed into the sediment (Lei et al. 2009; Zhang et al. 2014). Thus, the high estrogen level in the sediment might be from water. However, no linear relationships were found between the estrogen levels in water and sediments in this study. Several studies suggested that the sorption of estrogens onto sediments had a relationship with the properties of estrogens (such as the octanol-water

Table 2 Concentrations of estrogens in water, sediment and biota samples from Taihu Lake

Compound	Water (ng l^{-1})						Sediment (μg kg^{-1}, dw)						Biota[a] (μg kg^{-1}, dw)					
	E1	E2	E3	EE2	BPA	∑5ES	E1	E2	E3	EE2	BPA	∑5ES	E1	E2	E3	EE2	BPA	∑5ES
S1	8.53	89.0	n.d.[a]	21.1	194	313	164	151	203	184	291	993	364	562	456	417	475	2,274
S2	2.18	58.3	n.d.	n.d.	63.3	124	70.5	85.6	96.1	96.7	135	484	13.5	37.7	13.9	25.3	37.3	128
S3	11.4	40.0	8.48	n.d.	57.4	117	15.8	19.4	8.66	18.7	20.3	82.9	4.91	50.9	4.18	21.3	45.0	126
S4	1.81	56.3	n.d.	n.d.	54.9	113	71.8	66.5	98.9	38.1	33.0	308	14.0	52.6	20.3	49.7	44.1	181
S5	28.8	42.0	22.4	n.d.	71.0	164	11.8	12.3	22.0	10.5	6.31	62.9	28.6	74.1	34.9	38.7	78.7	255
S6	8.31	44.0	n.d.	n.d.	22.5	74.8	7.28	13.5	10.9	6.69	7.84	46.2	22.9	47.7	24.3	50.1	72.5	218
S7	2.10	76.7	n.d.	n.d.	28.1	107	5.49	9.99	9.19	4.32	10.8	39.8	14.4	39.4	n.d.	24.1	79.0	157
S8	4.80	117	n.d.	33.5	24.0	179	7.83	9.78	16.9	4.79	8.6	47.9	6.36	68.7	28.0	22.6	90.0	216

[a] Not detected

partition coefficient and solubility in water) and sediment [such as the organic carbon content and particle size (Sun et al. 2012)], pH and salinity of the water (Li et al. 2007) and coexisting substances [such as organic compounds (Yu and Huang 2005), heavy metals and surface-active compounds (Li et al. 2007)] in water. The high concentrations in the sediment of North Taihu Lake might be due to these conditions, which need to be further analyzed.

There are many studies in the literature on the status of estrogens in sediments (Table S4). Compared with these investigations, higher concentrations of estrogens were found in this study. The EE2 concentrations were much higher than those in the Aegean Sea (Arditsoglou and Voutsa 2012), Brazilian mangrove sediments (Froehner et al. 2012), Tokyo Bay (Isobe et al. 2006) and rivers in Tianjin, China (Lei et al. 2009). Although the BPA concentrations were lower than those in the Pearl River Delta, China (Gong et al. 2011), the concentrations in this study were still high.

Estrogens in biota samples

Estrogens with high sorption efficiencies are predicted to be bioaccumulated in aquatic and terrestrial species (Nallani et al. 2012). However, limited studies on their occurrence in fish and other aquatic organisms are available (Liu et al. 2011). Concentrations of estrogens in the biota from Taihu Lake are shown in Table 2. As can be seen, the concentrations of estrogens in biota samples collected at S1 ranged from 364 to 562 μg kg^{-1}, which were much higher than those collected at other sites in Northern Taihu Lake. The high concentrations might be due to the high estrogen levels in water and sediment. The average concentration of E2 (117 μg kg^{-1}) was found to be the highest among the five estrogens, while the level of E1 (58.6 μg kg^{-1}) was the lowest. The concentrations of estrogens in different species at each site are shown in Fig. 2. E1, E2 and BPA were detected in all 23 samples, while the detection frequencies of EE2 and E3 were 91.3 and 65.2 %, respectively. River snails had the highest estrogen concentrations in S1. However, in S7 and S8, fish had the highest estrogen concentrations. The S1 had the highest estrogen concentrations in sediment (Table 2). Snails live in sediment; thus, the estrogen concentrations in sediment might have major influences on its accumulation in snails. On the other side, in S7 and S8,

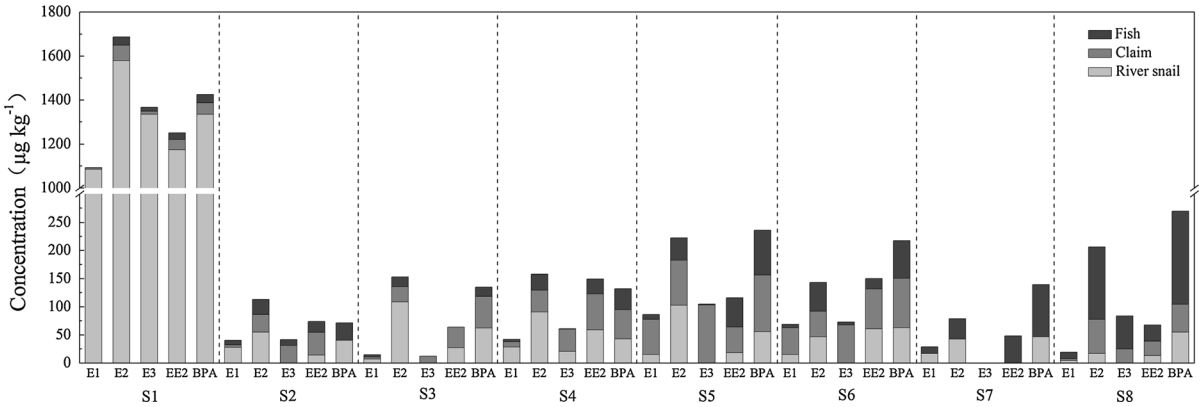

Fig. 2 Concentrations of estrogens in different species of biota samples at each site

Table 3 BAFs (l kg^{-1}) of target estrogens in different aquatic species

Species	E1	E2	E3	EE2	BPA
River snail ($n = 8$)	17,667	3,902	43,939	25,033	3,302
Clam ($n = 6$)	2,066	792	9,459	6,061	899
Fish ($n = 8$)	828	697	3,070	4,115	1,025

the estrogen concentrations in sediment were very low, and the estrogen level in snails in this site was also very low.

The calculated BAFs are shown in Table 3. Because the bioaccumulation is species-specific, significant differences were observed for the BAFs of the three aquatic species, however, it showed the following trend: river snail > clam > fish. BAFs did not increase with the trophic level; this result was consistent with the study of Lai et al. (2002). The bioaccumulation is also dependent on a range of factors such as gender, reproductive status, life stage, size as well as the environmental conditions (Liu et al. 2011). Therefore, it is difficult to compare BAFs from one location to another. In general, if BAFs are greater than 5,000 in aquatic organisms, the chemical is considered to be "bioaccumulative" (Kelly and Gobas 2001). In the present study, E3, EE2 and E1 were found to be bioaccumulated in river snail, because their BAFs were as high as 35,327, 20,127 and 14,204 l kg^{-1}, respectively. The BAF of E3 in clams was 7,539 l kg^{-1}, so the compound was also considered to be bioaccumulated in clams.

Ecological risk assessment

The possible risk from the presence of estrogens in water was also evaluated in the present study on the basis of the calculated risk quotient (RQ). RQs were expressed as the ratio of the measured environmental concentrations (MECs) to the predicted no-effect concentrations (PNECs). Maximum concentrations detected in surface water were used in this study. An assessment factor of 1,000 was used for the determination of PNECs from the lowest values of EC_{50} or LC_{50} or NOEC obtained from the literature (Hernando et al. 2006; Kolpin et al. 2002; Martin et al. 2012; Roepke et al. 2005; Rose et al. 2002; Stasinakis et al. 2012; Tompsett et al. 2013), where EC_{50}, LC_{50} and NOEC are the median effect concentration, median lethal concentration and non-observed effect concentration, respectively.

Different risk assessment levels were established as follows. Compounds with an RQ lower than 0.1 pose a low risk to aquatic organisms, a medium risk for values between 0.1 and 1, and a high risk for values higher than 1 (Hernando et al. 2006; Verlicchi et al. 2012). As shown in Table 4, the RQ values from E2 and EE2 were 9,070 and 4,653, respectively, which are responsible for the highest environmental risk and suggest high risk to aquatic organisms. BPA exhibited medium risk with an RQ value of 0.071, although its MEC was the highest among the five estrogens. E1 exhibited medium risk as well. The RQ value of E3 was 0.015, so low risk was suspected to occur in Taihu Lake. Sun et al. (2013) collected the MEC data from the scientific papers published in the last decade, then

Table 4 Ecotoxicological data of target estrogens and RQ values

Compound	EC_{50} or LC_{50} or NOEC (ng l^{-1})	PNEC (ng l^{-1})	MEC (ng l^{-1})	RQ	Risk level
E1	100,000	100	28.8	0.288	Medium
E2	12.9	0.0129	117	9,070	High
E3	1,515,400	1,515.4	22.4	0.015	Low
EE2	7.2	0.0072	33.5	4,653	High
BPA	2,730,000	2,730	194	0.071	Medium

evaluated the ecological risk of eight typical estrogenic EDCs in effluents from sewage plants. They found EE2, E2 and E1 had high ecological risk. The RQ of EE2 was highest and ranged from 10 to 103. The RQ of E3 was lowest in the four steroidal estrogens. BPA had smaller RQ values compared with steroidal estrogens. These results and trends were consistent with our present study. It should be noted that the toxicity of estrogens might exhibit a difference due to synergistic or antagonistic effects. In this study, RQs were calculated for individual compounds.

Conclusions

Among five studied estrogens, E1, E2 and BPA were widely distributed in water, while E3 and EE2 were less frequently detected. All the target estrogens were widely found in sediments and biota. The concentrations of estrogens in sediments collected from Gong Bay were relatively higher than those from other locations. E1, E3 and EE2 were considered to be accumulated in river snails with values of BAF higher than 5,000, and E3 was predicted to be accumulated in clams. The risk assessment showed that E2 and EE2 might pose high risk to aquatic organisms. This study provided the first information on the status and potential risk of estrogens in Northern Taihu, which is very useful for the environmental management of estrogens in the studied area.

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