

HCHs and DDTs in sediment-dwelling animals from the Yangtze Estuary, China

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Abstract

HCHs and DDTs in sediment-dwelling animals including mollusks and crabs from the Yangtze Estuary were determined by GC-ECD. Levels of *t*-HCH were in the range of 1.2–5.5 ng g⁻¹ and averaged 3.5 ng g⁻¹ in mollusks, while *t*-DDT concentrations ranged from 26.0 to 68.8 ng g⁻¹, with a mean of 34.5 ng g⁻¹. In crabs *t*-HCH concentrations varied from 2.0 to 25.7 ng g⁻¹ and averaged 13.8 ng g⁻¹, whereas the concentrations of *t*-DDT were in the range of 1.5–24.8 ng g⁻¹ with a mean value of 5.9 ng g⁻¹. The HCHs and DDTs levels depend on geographical position and sources, showing the high levels at fresh water area in the estuary, such as XP, CM and LHK sites, and lower at brackish water area, such as FX site, and little difference between species. Results also indicate there was no significant relationship between *t*-HCH (*t*-DDT) concentrations and lipid contents both in mollusks and crabs because of non-equilibrium state under a specific estuarine dynamics; smaller individuals accumulated more HCHs and DDTs than larger individuals of mollusks at LHK site, showing different uptake rate for these pesticides; moreover, HCHs and DDTs levels were lower in female crab bodies than male crab bodies suggesting that the release of spawning. BSAFs (Biota-Sediment Accumulation Factors) from sediment-dwelling animals for HCHs and DDTs show a significant “one high with two low” and “one low with two high” effect in the Yangtze Estuary.

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1. Introduction

Organochlorine pesticides (OCPs), such as hexachlorocyclohexanes (HCHs) and dichlorodiphenyl-trichloroethanes (DDTs) are known to be exclusively

anthropogenic persistent organic pollutants (POPs) found in various components of the environment (Ballschmiter, 1992; Sánchez et al., 1993). HCHs, DDTs and its derivatives have been subjected to intensive study world-wide in the last ten years because of their high rates of production and consumption, their considerable environmental persistence, toxic potential, high levels of bioaccumulation and harmful biological effects, including their mutagenic and carcinogenic properties (Lee

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et al., 1996; Baumard et al., 1998). Also they are considered to be environmental hormones which disturb the reproductive cycles of human and wildlife (Colborn and Smolen, 1996). Despite the ban and restriction on the usage of HCHs and DDTs in developed countries since the 1970s, some developing countries are still using for agricultural and public health purposes because of their low cost and versatility against various insects (Tanabe et al., 1994). In aquatic environment, organochlorine compounds are removed from the water column and adsorbed on the particulate matters due to their high affinity for organic matter, and finally accumulated in sediments, which may play a role as a secondary contamination source. These contaminants also accumulate in the sediment-dwelling organisms which may be transferred to higher trophic levels through the food chain.

Many studies have focused on the distribution of HCHs and DDTs in aquatic environments in an attempt to predict the factors influencing the accumulation of these contaminants by biota. Mussels have generally been used as biomonitors because of their wide geographical distribution, sessile behaviour, comparatively low P450 activities, and their pronounced ability to sequester POPs, such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and chlorinated pesticides. Programs such as the National Oceanic and Atmospheric Administration's National Status and Trends program (Sericano et al., 1995) and the California mussel watch (Martin, 1992) exemplify the utility of this approach to pollutant monitoring. Recent mussel-based monitoring of persistent organochlorine compounds in Asia-Pacific waters has also proven effective (Monirith et al., 2003). Crabs also were chosen as an appropriate indicator organism because they are the most abundant group of aquatic sediment macrofauna within tropical areas in terms of their numbers and biomass (Smith et al., 1991), as well as being relatively immobile relative to other organisms such as fish. The ability of local species to accumulate persistent organic matters and trace metals has been demonstrated (Asanullah and Ying, 1993; Mortimer and Connell, 1993; Mortimer and Miller, 1994). Numerous studies elsewhere have shown that crabs are suitable organisms for use as sentinel organisms (Talbot and Chegwidan, 1982; Devi and Rao, 1989).

The Yangtze Estuary together with nearby coastal areas is a major commercial artery and a region of high urbanization and industrialization for a long period. Recently, the distribution of PAHs, PCBs and OCPs in tidal flat surface and core sediments in this study area were reported (Liu et al., 1998, 2000, 2003). Little attention, however, has been paid to animals, especially sediment-dwelling animals such as bivalves and crabs which are the main food source for certain fishes and birds. Therefore, the aim of this study is (1) to quantify HCHs

and DDTs in sediment-dwelling mollusk and crab animals which are dominant species in the study area, (2) to probe the factors which influence the accumulation of contaminants and (3) to determine the biota-sediment accumulation factors (BSAFs) for their bioavailabilities in the Yangtze estuarine and tidal ecosystem. To our knowledge, this is the first report dealing with the bioaccumulation of HCHs and DDTs in sediment-dwelling animals in the study area.

2. Material and methods

This work was performed in the Yangtze Estuary and its coastal areas. As the one of largest river in the world and the main shipping route in China, the Yangtze River on average transports a runoff discharge of $29000 \text{ m}^3 \text{ s}^{-1}$ that carries about 480 million tonnes of sediment to the estuarine and the coastal area (Chen and Zhong, 1998). The Yangtze River is a primary source of sediments for the widely developed continental shelf of the East China Sea. About 78% of the suspended matter is transported during high runoff periods of the river. About 25% of suspended sediment is deposited in the near shore area off the river mouth; in addition, 25% is transported southwards where it settles and remains in the coastal zone. Very little suspended sediment is transported offshore and even less escapes to the north (Milliman et al., 1985). The environmental quality in the estuarine and nearby coastal area is severely affected by runoff and anthropogenic inputs.

2.1. Sample collection

Samples were taken in intertidal mud flats along the Yangtze Estuary and nearby coastal areas in July 2002, including Chongming (CM), Xupu (XP), Baimao (BM), Liuhekou (LHK), Wusongkou (WSK), Luchao (LC), and Fengxin (FX) sites. The organisms selected were mollusks including *Corbicula fluminea* and *Sinonovacula constricta*, and crabs *Sesarma denaani*, which are common littoral sediment-dwelling animals in the study area. Samples of *C. fluminea* were taken at CM, XP, LHK sites by hands, and *S. constricta* collected at CM and FX sites with a woody pike, where as crabs were captured at CM, BM, WSK, LC and FX sites. Each animal contained at least 30 individuals and associated-animal sediments (0–5 cm) were also sampled simultaneously. The sampling sites are shown in Fig. 1. In the laboratory, all samples were placed overnight in filtered seawater without sediment. This allowed them to empty their gut, without eliminating hydrophobic contaminants. The following morning, the animals were blotted dry and stored at -20°C before further processing (Kukkonen and Landrum, 1995; Kaag et al., 1998).

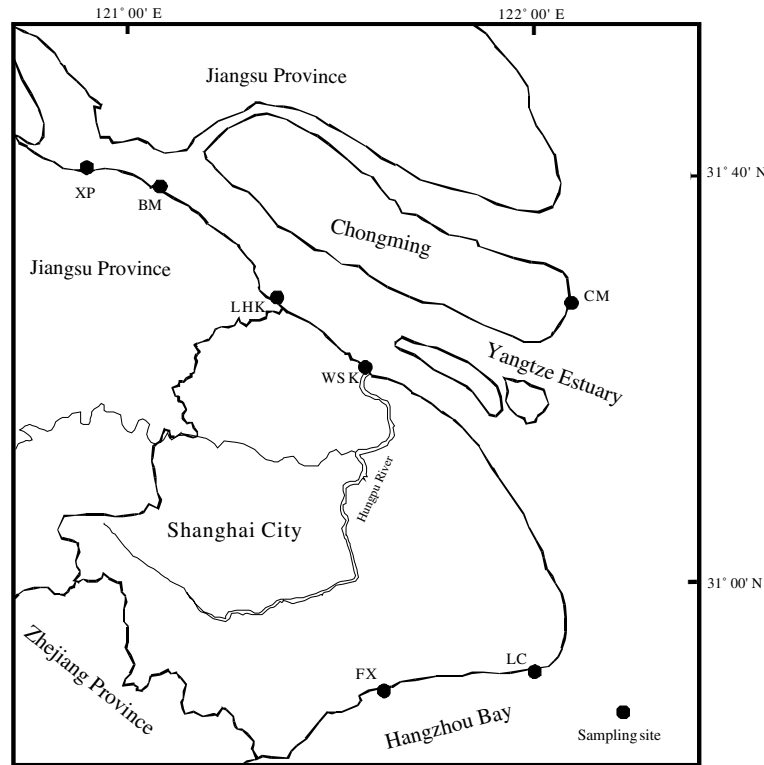


Fig. 1. Map of the Yangtze Estuary and sampling sites.

2.2. Chemical analyses

Mollusk samples were defrosted, shucked and the soft tissues homogenized in a blender, and crab samples were homogenized with their whole bodies. About 5 g of homogenized wet tissue were saponified with NaOH (18 h, 40 °C) and extracted with 100 ml acetone: *n*-hexane (1:1) in a Soxhlet apparatus, then extracted in duplicate with *n*-hexane. After concentrating the extracted solvents, lipid content was determined gravimetrically from an aliquot of the extract. The combined extracts were concentrated with a rotary evaporator at 40 °C, further purified on a multi-layer alumina column, prepared in the following order: anhydrous sodium sulphated (bottom layer, 1 cm); 8 g of Florisil silica gel (activated at 500 °C for 4 h and partially deactivated with 1% water) and of anhydrous sodium sulphated (top layer, 2 cm). The column was pre-washed with 15 ml *n*-hexane, and as the solvent reached the top layer, the extract was added and slowly eluted with 50 ml of *n*-hexane solvent. After concentration, the extracts were further purified by treatment with concentrated sulphuric acid (10:1) and the acid was removed using a separating funnel. The acid-treated extract was eluted by the multi-layer Florisil silica gel column again with hexane, and finally reduced to 2 ml with nitrogen gas.

HCHs and DDTs were analyzed in a Finnigan TRACE2000 gas chromatography system (GC) equipped with a ⁶³Ni electron capture detector (ECD). A fused-silica DB-1701 capillary column (30 m × 0.25 mm i.d., 0.25 μm film thickness) was used for the separation with helium as the carrier gas. A 2 μl volume was injected by the sampler applying a hot splitless injection technique. The temperature programme of the oven started at 100 °C and increased at the rate of 10 °C min⁻¹ to 270 °C for 10 min. HCHs and DDTs present in the samples were identified on the basis of their retention time and the pattern of the peaks, and quantified by comparing their retention times and peak areas with standard's ones.

2.3. Analytical quality assurance

Standards utilized included HCHs (α -HCH, β -HCH, γ -HCH, δ -HCH) and DDTs (*p,p'*-DDE, *p,p'*-DDT, *o,p'*-DDT, *p,p'*-DDD). All the congeners present in the samples were identified on the basis of their retention times and the patterns of the peaks. The percentage recovery of HCHs and DDTs varied from 60.43% to 116.16%. The detection limits of the procedure were 0.1–0.6 ng g⁻¹. Ten grams of quartz sands were analyzed as blanks by the same procedure as for the samples and did not reveal any contamination.

3. Results and discussion

3.1. HCH and DDT concentrations in Mollusks

Concentrations of HCHs and DDTs measured in mollusk tissues along the Yangtze Estuary are summarized in Table 1. Levels of *t*-HCH were in the range of 1.2–5.5 ng g⁻¹, with a mean value of 3.5 ng g⁻¹. The highest level for total HCHs (*t*-HCH) was found in mollusk at XP site, followed by CM, LHK and FX. Because β-HCH has the lowest water solubility and vapour pressure, and is most stable and resistant to microbial degradation, and δ-HCH has the longest half-life of the HCH isomers (Willett et al., 1998), they could exist in the environment several years or longer (Simonich and Hites, 1995). Hence, it is not surprising that these two isomers were dominant of HCHs in mollusk tissues at different sampling sites (Fig. 2). γ-HCH levels were low because of its technical grade composition. Compared to surface sediments in this study area (Liu et al., 2003), α-HCH concentrations were below the detection limit value in all mollusk samples.

Total DDTs (*t*-DDT) concentrations ranged from 26.0 to 68.8 ng g⁻¹, much higher than that of *t*-HCH with a mean value of 34.5 ng g⁻¹. Relative to HCHs, mollusk tissues show high levels of DDTs at four sampling sites (Table 2). Similarly to *t*-HCH, mollusks at XP had the highest level of *t*-DDT while the lowest level appeared at FX site. This fact indicates that HCHs and DDTs levels depend on geographical position and

sources, showing the high levels at the fresh water area of the estuary such as XP, CM and LHK sites, and lower at the brackish water area such as FX site. In addition, higher *p,p'*-DDE levels detected in all samples suggested that DDTs endured the aerobic transform in organisms, although the enzyme systems metabolising organic contaminants in mussels exhibit rather a low activity in comparison to high trophic levels such as fish and marine mammals (Boon et al., 1989; Stegeman and Lech, 1991).

The concentration difference for HCHs and DDTs between species is not obvious. However, smaller individuals accumulated more organic contaminants than larger individuals at LHK, showing individual size may affect HCHs and DDTs levels in mollusks.

3.2. HCH and DDT concentrations in Crabs

HCHs and DDTs were determined in both female and male crab bodies sampled along the Yangtze Estuary (Table 3 and Fig. 3). Except at WSK, almost all crab samples accumulated higher level of *t*-HCH than that of *t*-DDT. An obvious character is that both HCHs and DDTs concentrations were lower in female crab bodies than in male crab bodies, probably showing different animal feed and life habits.

t-HCH ranged from 2.0 to 25.7 ng g⁻¹, with a mean value of 13.8 ng g⁻¹. The spatial distribution had the character of the highest level at BM and CM sites, followed by LC, and the lower level at WSK and FX sites.

Table 1
Summary of sediment-dwelling animal samples, collected along the Yangtze Estuary and its coastal areas

Dates	Sites	Species		Size (cm)	Weight (g)	Lipid (%)
09/07/2002	CM	<i>Corbicula fluminea</i>		2.27 ± 0.2	4.42 ± 2.12	1.99
		<i>Sinonovacula constricta</i>		3.04 ± 0.16	5.36 ± 1.22	1.64
		<i>Sesarma denaani</i>	Female	2.94 ± 0.21	14.51 ± 3.67	2.37
			Male	3.26 ± 0.25	25.56 ± 4.63	2.7
18/07/2002	XP	<i>Corbicula fluminea</i>		2.15 ± 0.21	4.89 ± 2.45	2.06
	BM	<i>Sesarma denaani</i>	Female	2 ± 0.64	4.70 ± 3.67	2.25
			Male	2.04 ± 0.44	5.31 ± 3.99	1.71
	19/07/2002	WSK	<i>Sesarma denaani</i>	Female	2.13 ± 0.29	5.93 ± 2.38
			Male	2.64 ± 0.19	13.85 ± 4.49	2.72
LHK		<i>Corbicula fluminea</i>	>2 cm	2.59 ± 0.20	3.69 ± 0.74	1.68
			<2 cm	1.74 ± 0.13	3.05 ± 0.61	1.83
21/07/2002	LC	<i>Sesarma denaani</i>		2.25 ± 0.10	5.89 ± 1.60	1.64
	FX	<i>Sesarma denaani</i>	Female	2.96 ± 0.32	15.33 ± 5.29	1.53
			Male	3.1 ± 0.37	18.83 ± 4.18	1.17
		<i>Sinonovacula constricta</i>		5.10 ± 0.37	6.78 ± 4.12	1.85

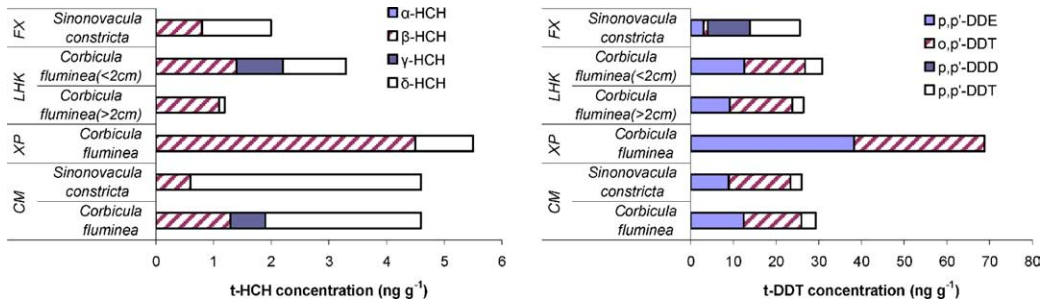


Fig. 2. HCHs and DDTs in mollusks from the study areas.

Table 2
HCHs and DDTs in mollusks from study areas (ng g⁻¹, wet weight)^a

Samples	α -HCH	β -HCH	γ -HCH	δ -HCH	<i>t</i> -HCH	<i>p,p'</i> -DDE	<i>o,p'</i> -DDT	<i>p,p'</i> -DDD	<i>p,p'</i> -DDT	<i>t</i> -DDT
CM <i>Corbicula fluminea</i>	nd	1.3	0.6	2.7	4.6	12.4	13.5	nd	3.4	29.3
CM <i>Sinonovacula constricta</i>	nd	0.6	nd	4	4.6	8.9	14.5	nd	2.6	26.0
XP <i>Corbicula fluminea</i>	nd	4.5	nd	1	5.5	38.3	30.5	nd	nd	68.8
LHK <i>Corbicula fluminea</i> (>2 cm)	nd	1.1	nd	0.1	1.2	9.1	14.7	nd	2.6	26.4
LHK <i>Corbicula fluminea</i> (<2 cm)	nd	1.4	0.8	1.1	3.3	12.6	14.2	nd	4	30.8
FX <i>Sinonovacula constricta</i>	nd	0.8	nd	1.2	2	3	1	9.8	11.8	25.6

^a nd=< (detection limit value); *t*-HCHs = the sum of α -HCH, β -HCH, γ -BHC and δ -HCH isomers; *t*-DDT = the sum of *p,p'*-DDT, *o,p'*-DDT, *p,p'*-DDE and *p,p'*-DDD metabolites.

Table 3
HCHs and DDTs in crabs (*Sesarma denaani*) from study areas (ng g⁻¹, wet weight)^a

	α -HCH	β -HCH	γ -HCH	δ -HCH	<i>t</i> -HCH	<i>p,p'</i> -DDE	<i>o,p'</i> -DDT	<i>p,p'</i> -DDD	<i>p,p'</i> -DDT	<i>t</i> -DDT
CM-F	7.5	12.2	2.1	nd	21.8	nd	2.8	nd	nd	2.8
CM-M	7.8	13.1	2.9	nd	23.8	0.5	3.6	nd	nd	4.1
BM-F	6.7	13.4	4.2	nd	24.3	nd	1.6	nd	nd	1.6
BM-M	7.4	15.9	2.4	nd	25.7	nd	2.1	nd	nd	2.1
WSK-F	nd	4.5	nd	0.2	4.7	9.7	1	nd	nd	10.8
WSK-M	nd	5.6	nd	1.2	6.8	24.4	0.4	nd	nd	24.8
LC	4.3	6.8	nd	nd	11.1	nd	3.3	nd	nd	3.3
FX-F	nd	1.1	0.2	0.7	2	1.1	0.4	nd	nd	1.5
FX-M	nd	1.4	0.4	2.2	4	1.7	0.3	nd	0.5	2.5

^a nd = < (detection limit value); *t*-HCHs = the sum of α -HCH, β -HCH, γ -BHC and δ -HCH isomers; *t*-DDT = the sum of *p,p'*-DDT, *o,p'*-DDT, *p,p'*-DDE and *p,p'*-DDD metabolites; F means female and M male.

β -HCH was the dominant isomer, occupying 35–95.74% of *t*-HCH. It may be related to HCHs isomer chemical properties and sources. Except at WSK and FX sites, other crab samples accumulated higher levels of α -, γ -HCH; in contrast, δ -HCH was detected only in crabs from WSK and FX sites.

Concentrations of *t*-DDT were in the range of 1.5–24.8 ng g⁻¹, with a mean value of 5.9 ng g⁻¹. It was obvious that highest level was found at WSK sites, and that no significant spatial deference was showed between other samples. It reveals the Huangpu River may contribute to a significant input for DDTs at WSK site.

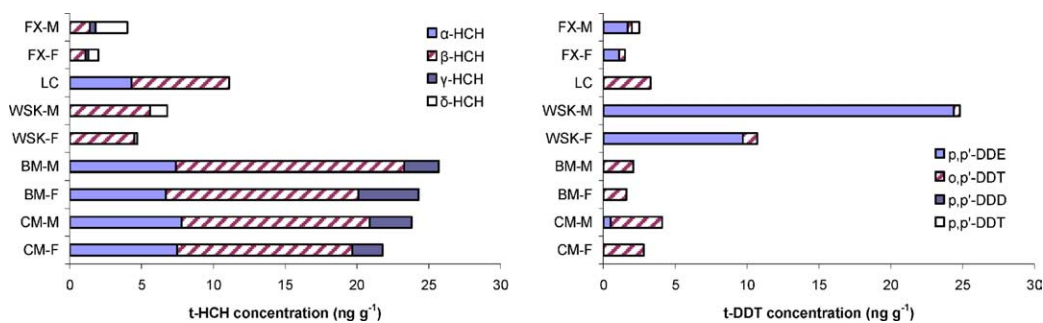


Fig. 3. HCHs and DDTs in crabs from study areas.

p,p'-DDE was the dominant metabolite in crabs from sampling sites, and higher levels appeared at WSK and FX sites. *p,p'*-DDD and *p,p'*-DDT were almost below the detection limits in all samples.

3.3. Effect of Physiological parameters

Contaminant accumulation in sediment-dwelling animals is regulated by several physiological parameters such as age, size, and lipid content (Strong and Luoma, 1981; Muncaster et al., 1990). Because lipid reserves are a primary site of nonpolar, hydrophobic xenobiotic storage, lipid content is an important factor for determining hydrophobic compound accumulation. The relative size of the lipid pool affects the movement of hydrophobic chemicals into the pool such that mollusks and crabs with higher lipid levels have faster uptake and slower elimination of hydrophobic contaminants. This results in a greater total contaminant accumulation in the high lipid tissues than in those with smaller lipid reserves (Stegeman and Teal, 1973; Hansen et al., 1978). However, this fact was not found in our study with no significant relationship between *t*-HCH (*t*-DDT) concentrations and lipid contents both in mollusks and in crabs, reflecting a non-equilibrium situation in which lipid levels in these sediment-dwelling invertebrate animals have not changed proportionally to HCHs or DDTs load (Kelly and Campbell, 1994). Meanwhile, the special location of study area also was the possible reason for this phenomenon, because the Yangtze Estuary is a complex dynamic system having various potential sources of organic matters.

Body size also influences contaminant accumulation in bivalves. In our study, smaller individuals accumulated more organic contaminants than larger individuals of mussels at LHK site, which was in accordance with several studies, showing that smaller individuals generally have faster rates of uptake and accumulate greater contaminant concentrations than larger individuals (Muncaster et al., 1990). Physiological differences in metabolic demand are the primary cause for the differential contaminant accumulation, although size-dependent

feeding behavior, surface to volume ratios and concentrations of enzymes that influence uptake may also play a role (Newman and Mitz, 1988).

The lower HCHs and DDTs level found in female crabs than in males would be a consequence of eggs releasing during spawning, which have large quantities of lipid soluble contaminants. Meanwhile, that males carry out the low detoxification capacity (Von Westernhagen et al., 1995) also was the possible reason. As a result, the HCH and DDT tissue burdens are generally lower in females than in males (Lanfranchi et al., 1998).

3.4. Biota-sediment accumulation factors (BSAFs)

Biota-sediment accumulation factors (BSAFs) are a valuable tool for predicting bioaccumulation of lipophilic compounds which are primarily associated with tissue lipid and sediment organic carbon (Ferguson and Chandler, 1998; Nilsson et al., 2003). Therefore, in the study BSAF was taken as a measure of the biotic fate of these hydrophobic chemicals. BSAF, which is also inferred to by other names such as “accumulation factor” is defined as

$$\text{BSAF} = \frac{C_b/f_1}{C_s/f_{oc}} \quad (\text{Wong et al., 2001})$$

where C_b is the biota contaminant concentration (ng g^{-1} wet weight), f_1 is the biota lipid concentration (fraction by weight), C_s is the sediment contaminant concentration (ng g^{-1} dry weight), and f_{oc} is the organic carbon fraction of the sediment (fraction by weight).

BSAFs of *t*-HCH and *t*-DDT in sediment-dwelling animals were estimated according to the concentrations of *t*-HCH and *t*-DDT in associated sediments (Table 4). BSAFs of *t*-HCH in mussels ranged from 0.81 to 2.34, with the highest in samples from FX, although its concentration in sediment was the lowest. In contrast, there was the lower BSAF of 0.91 for *t*-HCH in samples from XP, with the highest level of contaminants in its associated sediment. BSAFs of *t*-DDT, higher than those of *t*-HCH, were in the range of 1.13–27.89. Similarly to *t*-HCH, there were the higher BSAFs in mussels from

Table 4
BSAFs and sediment characters of *t*-HCH and *t*-DDT in sediment-dwelling animals from study area

Sites	Species	BSAF		Sediment		
		<i>t</i> -HCH	<i>t</i> -DDT	<i>t</i> -HCH (ng g ⁻¹)	<i>t</i> -DDT (ng g ⁻¹)	TOC (%)
CM	<i>Corbicula fluminea</i>	0.89	6.93	3.8	3.1	1.46
	<i>Sinonovacula constricta</i>	1.08	7.47	3.8	3.1	1.46
XP	<i>Corbicula fluminea</i>	0.91	27.89	4.9	2.0	1.67
LHK	<i>Corbicula fluminea</i> (>2 cm)	0.81	1.13	2.1	33.1	2.37
	<i>Corbicula fluminea</i> (<2 cm)	2.04	1.21	2.1	33.1	2.37
FX	<i>Sinonovacula constricta</i>	2.34	16.61	0.5	0.9	1.08
CM	Crabs (female)	1.87	0.69	3.8	3.1	1.46
	Crabs (male)	2.1	1.04	3.8	3.1	1.46
BM	Crabs (female)	1.05	0.1	32.7	22.7	3.18
	Crabs (male)	1.46	0.17	32.7	22.7	3.18
WSK	Crabs (female)	0.39	1.73	17.5	9.1	4.01
	Crabs (male)	0.57	4.02	17.5	9.1	4.01
LC	Crabs	2.15	1.7	7.7	2.9	2.45
FX	Crabs (female)	2.82	1.18	0.5	0.9	1.08
	Crabs (male)	7.38	2.56	0.5	0.9	1.08

XP and FX, in which the concentrations of *t*-DDT were the lowest, whereas at LHK site there was the lowest BSAF although *t*-DDT level was the highest. However, it is noticeable that higher BSAF occurred at lower polluted site with lower total organic carbon (TOC), while lower BSAF found at higher contaminated site with higher TOC. Ferraro et al. (1990) found bivalve BSAF values to be lower in highly polluted, high organic carbon sediment and to be sometimes higher in low pollutant, low organic carbon sediment, and Lake et al. (1990) also found lower BSAF of PCBs in high organic carbon sediment. We would like to call this effect as “one high with two low” and “one low with two high” effect. It means that where there was a higher BSAF, there probably was a lower value of contaminant concentration (*t*-HCH or *t*-DDT) and a lower TOC; however, where there was a lower BSAF, there probably was a higher value of contaminant concentration and a higher TOC. This effect was due to HCHs and DDTs having greater affinity for polluted, anthropogenic organic carbon; therefore, the hydrophobic organic contaminants (HOCs) would be less bioavailable to organisms.

Total HCHs BSAFs for crab samples ranged from 0.39 to 7.38, with the highest value at FX site, and the lowest at WSK site. The “One high with two low” and “one low with two high” effect was also obvious for *t*-HCH in crabs. There was the highest BSAF at CM site with lowest concentration of *t*-HCH and TOC; the lowest BSAF occurred at WSK site with highest TOC, while lower BSAF value at BM with highest *t*-HCH concen-

tration and higher TOC. However, BSAF of *t*-DDT was not very obvious. Although the lowest BSAF occurred at BM in which sediments was polluted by DDT with high TOC, and the higher BSAF occurred at FX where was clean and lowest TOC in sediments, there was the highest BSAF at WSK site with moderate DDT concentration and highest TOC in its sediments. We had a hypothesis that it was probably attributed to the specific disequilibrium conditions existed in study area, considering the Yangtze estuarine area is a complex dynamic system with various potential sources of organic matters.

4. Conclusions

Total HCHs ranged from 1.2 to 5.5 ng g⁻¹ in mollusks from the Yangtze estuarine and tidal flat, and were dominated by two isomers of β -HCH and δ -HCH. Compared to *t*-HCH, *t*-DDT concentrations were much higher in mollusks, with a value of 26.0–68.8 ng g⁻¹. It was found that the spatial distributions of HCHs and DDTs in mollusks were strongly dependent on geographical position and their sources. It was also shown that there was no significant difference in the concentrations of HCHs and DDTs between species of mollusks, but individual size affected HCHs and DDTs levels. *t*-HCH varied from 2.0 to 25.7 ng g⁻¹ in crabs, and were mainly dominated by β -HCH occupying 35–95.74% of *t*-HCH. Concentrations of *t*-DDT in crabs were in the range of 1.5–24.8 ng g⁻¹, *p,p'*-DDE was the dominant

metabolite. It was revealed that both HCHs and DDTs concentrations were lower in female crabs than in males, which may be attributed to their different animal feed and life habits. BSAFs of *t*-HCH and *t*-DDT ranged from 0.81 to 2.34 and 1.13 to 27.89 in mussels, respectively, while they respectively varied from 0.39 to 7.38 and 0.1 to 4.02 in crabs. It was observed that BSAFs from sediment-dwelling animals for HCHs and DDTs show a significant “one high with two low” and “one low with two high” effect in the Yangtze Estuary.

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