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HCH and DDT residues in molluscs from Chinese Bohai coastal sites

R.Q. Yang ^a, Z.W. Yao ^b, G.B. Jiang ^{a,*}, Q.F. Zhou ^a, J.Y. Liu ^a^a Key Laboratory of Environmental Chemistry and Ecotoxicology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China^b National Marine Environmental Monitoring Center, P.O. Box 303, Dalian 116023, China

Organochlorine pesticides (OCPs) are known for their environmental persistence, high bioaccumulation potential in organisms and long-term adverse effects on ecosystems and human health (Doong et al., 2002). Hexachlorocyclohexane (HCH) and DDT are typical representatives. Although many countries have withdrawn the registered usage of OCPs during the last 30 years, these toxic chemicals still widely exist in various environmental matrices. Moreover, some OCPs such as DDT, HCH and lindane are still used in some tropical and subtropical countries for agricultural and medicinal purposes (de Brito et al., 2002). In China, a broad spectrum of pesticides has been used for agricultural activities, as well as for vector control. HCH and DDT were employed extensively during 1960s to 1983. Total cumulative global consumption of technical HCH has been estimated as high as six million tonnes; estimates of the amount of technical HCH used in China and South Asia in the late 1970s were about 60,000 tonnes annually, and an estimated two million tonnes of DDT have been produced and applied world-wide since 1940s (Willett et al., 1998). Large amounts of pesticides have been released into the environment, and their recalcitrance suggests that they could lead to serious environmental problems for a number of years.

An assessment of oceanic status to predict pollution trends is indispensable to the integrity of marine systems and human health (Kim et al., 2002). As sensitive sentinel organisms, mussels have been used frequently to assess chemical contamination of marine ecosystems. In particular, mussels have been of considerable use in the surveillance of OCP contamination. The analysis of OCPs in seafood can also help to estimate food safety risks to consumers, and to obtain important information on bioaccumulation of xenobiotics by aquatic organisms (Sericano et al., 1993; Albalat et al., 2002; Colombo et al., 1995).

In the present study, 87 mollusc samples, including 20 different species, were collected from 10 typical coastal sites along the Bohai Sea. Most of the test samples were commercially valuable seafood items and are highly suitable for culture in these coastal areas. Having high protein content, molluscs are a popular diet for people throughout China. However, to our knowledge, few data on OCP pollution in molluscs of the Bohai Sea are available. The aim the present paper is to elucidate the contamination status, the distribution of OCPs, and to assess the risks to aquatic organisms and human health.

Fig. 1 shows the 10 sampling sites. Eight sites were located along the Bohai Sea and the other two sites (Yantai and Weihai) lay on the edge of the Yellow Sea. These sampling sites are located in the northeast of China, an area of heavy industry and fishing. The area is relatively high developed, and serious environmental pollution is thought to occur in this semi-enclosed

* Corresponding author. Tel.: +86-10-6284-9334; fax: +86-10-6284-9339.

E-mail address: gbjiang@mail.rcees.ac.cn (G.B. Jiang).

Fig. 1. Sampling sites of molluscs collected from the Bohai Sea.

aquatic system. All sampling was carried out during July–August, 2002. Different species were identified according to the catalog of marine molluscs provided by Qi et al. (1989) and Zhao et al. (1982). After shucking, the soft tissues were thoroughly rinsed with de-ionized water, blended and then stored at -18°C in glass bottles until analysis took place.

The analytical procedure was a modification of the method described by Tanabe et al. (2000). Briefly, 10 g of well homogenized tissues were mixed with anhydrous Na_2SO_4 until the homogenate was free-flowing. It was then extracted using 80 ml hexane–dichloromethane mixture (1:1 v/v) with sonication for 60 min, stood overnight (about 10 h), then further sonicated for 40 min. The extracts were decanted, 20 ml hexane added to the original homogenate, and the mixture again sonicated for 20 min. The combined extract was concentrated on a rotary evaporator to about 10 ml and purified using 10 ml concentrated sulphate, and then washed twice with 50 ml 5% NaCl solution. The extract was concentrated to about 1 ml again, and further purified using a 2 g silica gel and 2 g florisil column (i.d. 12 mm). Before the extracts were loaded, 2 g of anhydrous Na_2SO_4 was added on the top of the column, which was washed with 20 ml of hexane. The analytes were eluted using 20 ml hexane, then 20 ml dichloromethane–hexane solution in a 1:9 ratio. The two fractions were combined and adjusted to a final volume of 1 ml under a gentle stream of nitrogen.

OCP concentrations were measured using an Agilent 6890A gas chromatograph. One microliter of sample was introduced into the injector at 250°C with a splitless mode, separated in a HP-1 fused-silica capillary column (30 m $\times$ 0.25 mm internal diameter and 0.25 μm film thickness, Agilent, USA) with a temperature program ($80\text{--}200^{\circ}\text{C}$ for 1 min at $10^{\circ}\text{C}/\text{min}$) and detected using a ^{63}Ni electron capture detector (micro-ECD) (Agilent, USA) at 280°C . GC peaks were identified with the

Table 1

Recoveries, detection limits (LODs), and the relative standard derivations (RSD^a) of the method

Pesticides	Recovery (%)	LODs (ng g^{-1} ww)	RSD (%)
α -HCH	95	0.08	7
β -HCH	87	0.44	11
γ -HCH	94	0.11	5
δ -HCH	88	0.24	9
<i>p,p'</i> -DDE	104	0.12	7
<i>p,p'</i> -DDD	92	0.16	6
<i>o,p'</i> -DDT	90	0.41	8
<i>p,p'</i> -DDT	89	0.46	12

^a Repeated 5 times.

accurate assignment of retention times of OCPs standards (the National Research Center for Certified Reference Materials of China), and further confirmed by an Agilent 6890N GC-MS system.

The residues of OCPs were quantitatively determined using calibration curves of the standards. The correlation coefficients (r) were greater than 0.998. The limits of detection (LODs) of OCPs were described as three times the signal-to-noise ratio (S/N). For every set of 10 samples, a procedural blank and a spiked sample consisting of all chemicals were run to check for interference and cross-contamination. Table 1 illustrates the recoveries, LODs and relative standard derivation (RSD) of the method. The recoveries of OCPs from spiked samples were in the range of 87–104%, and the RSD values ranged from 5% to 12%.

All OCP concentrations are expressed as ng g^{-1} wet weight, and are summarized in Table 2. DDTs were the dominant contaminants with total concentrations ranging from the limit of detection (<0.12)– 151.01 ng g^{-1} . The mean level was 29.40 ng g^{-1} . $\sum$ HCHs were in the range <0.08 – 5.92 ng g^{-1} with a mean of 1.27 ng g^{-1} . OCP contamination occurred widely in the organisms. Amongst all 87 samples, 79 were found to contain detectable OCPs. The detection frequencies of HCHs and DDTs were 79.3% and 90.8%, respectively. OCP residue levels varied with different sampling sites (see Fig. 2). The highest mean $\sum$ HCH was found in Laizhou (2.08 ng g^{-1}). The most contaminated DDT samples were collected from Weihai, followed by Tianjin (average $\sum$ DDT, 48.11 and 42.97 ng g^{-1} , respectively).

Concentrations of OCPs varied amongst the species, even when they were collected from the same sites. The highest level of $\sum$ OCPs (sum of HCHs and DDTs, 153.15 ng g^{-1}) was found in bivalves of *Sinonovacula constricta* from Yantai. Fig. 3 shows a comparison of OCP concentrations among some typical species, which are the most popular seafood items and which are widely distributed along Chinese coastal sites. The highest mean concentration of 62.83 ng g^{-1} was found in *S. constricta*, which showed this species might have a high ability to accumulate OCPs from coastal environments.

Table 2

Residue levels of HCHs and DDTs in molluscs from the Bohai Sea, China (ng g⁻¹ wet weight)

Sampling sites	Species	α -HCH	β -HCH	γ -HCH	δ -HCH	Σ HCH	p,p' -DDE	p,p' -DDD	o,p' -DDT	p,p' -DDT	Σ DDT
Dalian	<i>Mytilus edulis</i> (Linnaeus, 1758)	<0.08	0.87	0.14	<0.24	1.01	15.72	12.4	<0.41	11.06	39.18
	<i>Meretrix meretrix</i> (Linnaeus, 1758)	0.32	1.39	0.37	0.33	2.41	10.04	4.80	<0.41	6.69	21.53
	<i>Ruditapes philippinarum</i> (Adams, 1850)	0.10	<0.44	<0.11	<0.24	0.10	10.26	12.00	<0.41	<0.46	22.26
	<i>Ostrea talienwhanensis</i> (Crosse, 1862)	<0.08	0.58	0.15	<0.24	0.73	9.63	4.61	<0.41	6.42	20.66
	<i>Scapharca subcrenata</i> (Schrenck, 1869)	<0.08	<0.44	<0.11	<0.24	nq	<0.12	<0.16	<0.41	<0.46	nq
	<i>Sinonovacula constricta</i> (Lamarck, 1818)	0.23	0.69	0.15	<0.24	1.07	16.01	7.66	1.61	15.05	40.33
	<i>Chlamys farreri</i> (Jones & Preston, 1904)	0.54	1.88	0.73	0.39	3.54	3.54	1.69	1.39	5.89	12.51
	<i>Pecten albicans</i> (Schroter, 1802)	<0.08	<0.44	<0.11	<0.24	nq	4.56	2.18	<0.41	6.00	12.74
	<i>Neverita didyma</i> (Röeding, 1848)	0.53	1.45	0.13	<0.24	2.11	2.69	1.29	1.10	<0.46	5.08
Yingkou	<i>Neptunea cumingi</i> (Crosse, 1862)	0.12	1.44	<0.11	<0.24	1.56	30.66	14.66	<0.41	20.42	65.74
	<i>Mytilus edulis</i> (Linnaeus, 1758)	0.20	<0.44	<0.11	<0.24	0.20	2.70	1.29	0.86	6.42	11.27
	<i>Meretrix meretrix</i> (Linnaeus, 1758)	0.15	<0.44	<0.11	<0.24	0.15	0.28	<0.16	<0.41	<0.46	0.28
	<i>Ruditapes philippinarum</i> (Adams, 1850)	0.11	<0.44	<0.11	<0.24	0.11	12.30	6.50	<0.41	46.20	65.00
	<i>Sinonovacula constricta</i> (Lamarck, 1818)	0.38	0.69	0.21	<0.24	1.28	15.43	8.42	1.23	22.25	47.33
	<i>Pecten albicans</i> (Schroter, 1802)	0.26	<0.44	0.19	<0.24	0.45	4.67	2.23	<0.41	4.52	11.42
	<i>Rapana venosa</i> (Valenciennes, 1846)	0.35	2.44	0.13	0.43	3.35	2.28	1.09	<0.41	<0.46	3.37
	<i>Neverita didyma</i> (Röeding, 1848)	0.40	1.05	0.28	<0.24	1.73	4.11	2.11	<0.41	2.35	8.57
Jinzhou	<i>Clementia vatheleti</i> (Mabille, 1901)	0.50	1.22	0.55	<0.24	2.27	4.35	2.08	<0.41	<0.46	6.43
	<i>Meretrix meretrix</i> (Linnaeus, 1758)	<0.08	<0.44	<0.11	<0.24	nq	<0.12	<0.16	<0.41	<0.46	nq
	<i>Ruditapes philippinarum</i> (Adams, 1850)	0.09	<0.44	<0.11	<0.24	0.09	0.44	0.32	<0.41	<0.46	0.76
	<i>Macra veneriformis</i> (Deshayes, 1854)	0.10	<0.44	<0.11	<0.24	0.10	12.28	8.00	<0.41	12.88	33.16
	<i>Scapharca subcrenata</i> (Schrenck, 1869)	0.23	0.89	0.20	0.24	1.56	12.63	10.82	2.64	14.88	40.97
	<i>Scapharca broughtonii</i> (Schrenck, 1867)	0.21	<0.44	0.11	<0.24	0.32	3.00	<0.16	<0.41	2.91	5.91
	<i>Rapana venosa</i> (Valenciennes, 1846)	<0.08	<0.44	<0.11	<0.24	nq	4.75	3.57	<0.41	3.97	12.29
	<i>Neverita didyma</i> (Röeding, 1848)	0.23	<0.44	0.11	<0.24	0.34	12.26	10.00	<0.41	28.00	50.26
Huludao	<i>Mytilus edulis</i> (Linnaeus, 1758)	0.12	0.44	<0.11	<0.24	0.56	12.04	5.45	<0.41	7.16	24.65
	<i>Meretrix meretrix</i> (Linnaeus, 1758)	0.32	0.50	<0.11	<0.24	0.82	3.86	1.85	2.84	10.16	18.71
	<i>Ruditapes philippinarum</i> (Adams, 1850)	<0.08	<0.44	<0.11	<0.24	nq	23.90	11.43	4.14	22.56	62.03
	<i>Scapharca subcrenata</i> (Schrenck, 1869)	1.32	0.78	0.28	<0.24	2.38	12.26	5.86	3.92	6.53	28.57
	<i>Sinonovacula constricta</i> (Lamarck, 1818)	0.27	1.56	0.28	<0.24	2.11	20.12	9.62	1.27	13.46	44.47
	<i>Pecten albicans</i> (Schroter, 1802)	<0.08	<0.44	<0.11	<0.24	nq	<0.12	<0.16	<0.41	<0.46	nq
	<i>Rapana venosa</i> (Valenciennes, 1846)	0.38	1.26	0.24	<0.24	1.88	8.58	4.11	<0.41	4.57	17.26
	<i>Neverita didyma</i> (Röeding, 1848)	1.25	1.02	0.44	0.25	2.96	2.80	1.34	<0.41	<0.46	4.14
Tianjin	<i>Mya arenaria</i> (Linnaeus, 1758)	0.11	0.48	<0.11	<0.24	0.59	12.63	6.04	2.58	22.69	43.94
	<i>Ostrea talienwhanensis</i> (Crosse, 1862)	0.59	0.82	0.47	<0.24	1.88	18.30	8.75	5.17	12.19	44.41
	<i>Scapharca subcrenata</i> (Schrenck, 1869)	0.40	1.07	<0.11	<0.24	1.47	7.44	3.56	<0.41	4.96	15.96
	<i>Sinonovacula constricta</i> (Lamarck, 1818)	0.47	0.72	0.18	<0.24	1.37	10.14	4.85	<0.41	76.75	91.74
	<i>Pecten albicans</i> (Schroter, 1802)	<0.08	<0.44	<0.11	<0.24	nq	<0.12	<0.16	<0.41	<0.46	nq
	<i>Neverita didyma</i> (Röeding, 1848)	0.21	3.21	0.55	0.25	4.22	31.79	15.21	3.88	38.06	88.94
	<i>Rapana venosa</i> (Valenciennes, 1846)	0.10	<0.44	<0.11	<0.24	0.10	3.10	1.48	<0.41	11.20	15.78
Yangkou	<i>Ostrea talienwhanensis</i> (Crosse, 1862)	0.58	1.03	0.45	<0.24	2.06	6.87	3.28	5.29	7.07	22.51
	<i>Macra veneriformis</i> (Deshayes, 1854)	0.23	0.55	0.53	<0.24	1.31	2.74	1.31	<0.41	<0.46	4.05
	<i>Scapharca subcrenata</i> (Schrenck, 1869)	0.34	1.32	0.32	0.32	2.30	17.55	8.39	<0.41	9.35	35.29
	<i>Scapharca broughtonii</i> (Schrenck, 1867)	0.39	0.99	0.55	0.25	2.18	17.70	8.47	2.72	12.32	41.21
	<i>Sinonovacula constricta</i> (Lamarck, 1818)	0.23	<0.44	0.12	<0.24	0.35	2.64	0.59	0.42	3.14	6.79
	<i>Chlamys farreri</i> (Jones & Preston, 1904)	<0.08	<0.44	<0.11	<0.24	nq	<0.12	<0.16	<0.41	<0.46	nq
	<i>Rapana venosa</i> (Valenciennes, 1846)	0.28	1.06	0.15	<0.24	1.49	4.46	2.13	1.90	11.07	19.56
	<i>Neverita didyma</i> (Röeding, 1848)	<0.08	<0.44	<0.11	<0.24	nq	2.90	1.39	<0.41	<0.46	4.29
Laizhou	<i>Mytilus edulis</i> (Linnaeus, 1758)	0.10	0.45	0.12	<0.24	0.67	2.70	1.76	<0.41	<0.46	4.46
	<i>Meretrix meretrix</i> (Linnaeus, 1758)	0.40	2.24	<0.11	<0.24	2.64	4.52	2.16	<0.41	<0.46	6.68
	<i>Ruditapes philippinarum</i> (Adams, 1850)	1.11	2.72	1.23	0.86	5.92	3.32	1.59	<0.41	<0.46	4.91
	<i>Ostrea talienwhanensis</i> (Crosse, 1862)	0.85	0.93	0.21	<0.24	1.99	6.72	2.65	0.84	3.30	13.51
	<i>Solen strictus</i> (Ground, 1861)	0.98	0.74	0.22	0.61	2.55	8.46	4.05	3.05	7.92	23.48
	<i>Sinonovacula constricta</i> (Lamarck, 1818)	0.10	1.50	0.12	<0.24	1.72	7.82	3.74	<0.41	<0.46	11.56
	<i>Rapana venosa</i> (Valenciennes, 1846)	0.86	2.14	<0.11	<0.24	3.00	16.62	20.68	1.00	3.47	44.77
	<i>Neverita didyma</i> (Röeding, 1848)	0.14	<0.44	0.12	<0.24	0.26	41.08	21.56	5.21	29.43	97.28
Yantai	<i>Mytilus edulis</i> (Linnaeus, 1758)	0.18	<0.44	0.12	<0.24	0.30	8.26	3.95	<0.41	5.50	17.71

(continued on next page)

Table 2 (continued)

Sampling sites	Species	α -HCH	β -HCH	γ -HCH	δ -HCH	Σ HCH	p,p' -DDE	p,p' -DDD	o,p' -DDT	p,p' -DDT	Σ DDT
	<i>Meretrix meretrix</i> (Linnaeus, 1758)	<0.08	<0.44	<0.11	<0.24	nq	0.30	<0.16	<0.41	<0.46	0.30
	<i>Macoma incongrua</i> (Martens, 1865)	<0.08	<0.44	<0.11	<0.24	nq	<0.12	<0.16	<0.41	<0.46	nq
	<i>Ostrea talienwhanensis</i> (Crosse, 1862)	0.48	1.83	0.84	0.34	3.49	7.46	3.57	<0.41	4.97	16.00
	<i>Scapharca subcrenata</i> (Schrenck, 1869)	0.10	<0.44	<0.11	<0.24	0.10	<0.12	<0.16	<0.41	<0.46	nq
	<i>Sinonovacula constricta</i> (Lamarck, 1818)	0.49	1.43	0.23	<0.24	2.15	19.27	13.22	8.16	110.35	151.00
	<i>Mya arenaria</i> (Linnaeus, 1758)	1.68	1.28	0.55	<0.24	3.51	6.95	3.32	<0.41	4.27	14.54
	<i>Pecten albicans</i> (Schroter, 1802)	0.27	0.62	0.28	<0.24	1.17	20.83	9.96	3.63	13.87	48.29
	<i>Scapharca broughtonii</i> (Schrenck, 1867)	<0.08	<0.44	<0.11	<0.24	nq	8.85	4.23	<0.41	8.42	21.50
	<i>Neptunea cumingi</i> (Crosse, 1862)	0.15	1.44	<0.11	<0.24	1.59	40.01	25.83	6.10	48.35	120.29
Penglai	<i>Mytilus edulis</i> (Linnaeus, 1758)	<0.08	<0.44	<0.11	<0.24	nq	4.12	2.12	<0.41	<0.46	6.24
	<i>Solen strictus</i> (Gould, 1861)	0.69	0.71	0.25	<0.24	1.65	9.90	4.20	<0.41	3.92	18.02
	<i>Ostrea talienwhanensis</i> (Crosse, 1862)	0.25	0.67	0.26	<0.24	1.18	3.58	1.71	<0.41	<0.46	5.29
	<i>Ruditapes philippinarum</i> (Adams, 1850)	<0.08	<0.44	<0.11	<0.24	nq	23.68	11.33	5.77	15.54	56.32
	<i>Standella capillacea</i> (Habe, 1964)	<0.08	<0.44	<0.11	<0.24	nq	<0.12	<0.16	<0.41	<0.46	nq
	<i>Saxidomus purpuratus</i> (Sowerby, 1855)	0.08	<0.44	<0.11	<0.24	0.08	0.28	<0.16	<0.41	<0.46	0.28
	<i>Sinonovacula constricta</i> (Lamarck, 1818)	0.88	0.74	0.21	<0.24	1.83	20.43	9.77	3.09	10.88	44.17
	<i>Chlamys farreri</i> (Jones & Preston, 1904)	0.20	0.46	0.15	<0.24	0.81	23.95	11.45	3.67	15.03	54.10
	<i>Neverita didyma</i> (Röeding, 1848)	1.25	1.32	<0.11	0.25	2.82	20.79	9.94	2.97	<0.46	33.70
Weihai	<i>Mytilus edulis</i> (Linnaeus, 1758)	0.17	1.29	0.26	<0.24	1.72	15.03	7.19	2.97	103.81	129.00
	<i>Meretrix meretrix</i> (Linnaeus, 1758)	0.13	<0.44	<0.11	<0.24	0.13	10.14	5.85	<0.41	8.65	24.64
	<i>Ruditapes philippinarum</i> (Adams, 1850)	<0.08	<0.44	<0.11	<0.24	nq	1.90	0.91	<0.41	<0.46	2.81
	<i>Ostrea talienwhanensis</i> (Crosse, 1862)	0.63	0.66	0.20	<0.24	1.49	17.30	8.27	2.84	107.57	135.98
	<i>Scapharca subcrenata</i> (Schrenck, 1869)	<0.08	<0.44	<0.11	<0.24	nq	<0.12	<0.16	<0.41	<0.46	nq
	<i>Sinonovacula constricta</i> (Lamarck, 1818)	0.24	1.66	0.23	<0.24	2.13	50.28	24.05	5.69	33.49	113.51
	<i>Chlamys farreri</i> (Jones & Preston, 1904)	2.33	1.54	0.18	0.33	4.38	18.24	10.62	2.32	14.38	45.56
	<i>Pecten albicans</i> (Schroter, 1802)	0.45	1.02	0.32	<0.24	1.79	10.07	4.82	<0.41	6.71	21.60
	<i>Mya arenaria</i> (Linnaeus, 1758)	0.68	<0.44	0.32	<0.24	1.00	2.39	1.42	<0.41	<0.46	3.81
	<i>Solen gracilis Philippi</i> (Kuroda, 1847)	<0.08	<0.44	<0.11	<0.24	nq	15.14	5.65	1.32	14.18	36.29
	<i>Rapana venosa</i> (Valenciennes, 1846)	1.11	0.85	0.13	<0.24	2.09	12.30	12.00	1.70	14.98	40.98
	<i>Neverita didyma</i> (Röeding, 1848)	0.28	<0.44	0.12	<0.24	0.40	10.91	5.22	<0.41	7.27	23.40

Nq: not quantified.

Fig. 2. Comparison of the mean Σ HCH and Σ DDT concentrations (ng g^{-1} wet weight) in molluscs from different sampling sites.

Ostrea talienwhanensis and *Mytilus edulis* are two the most popular bivalves used to monitor marine pollution world-wide. The residue levels in these organisms were 38.74 and 33.91 ng g^{-1} , respectively. The lowest level of Σ OCP (11.19 ng g^{-1}) was found in *Meretrix meretrix*.

HCH isomer compositions differed in the organisms (Table 2). β -HCH was the major contaminant, varying from <0.44 to 3.21 ng g^{-1} with a mean 0.70 ng g^{-1} . Typical commercial HCHs contain α -, β -, γ -, and δ -isomers of 55–80%, 5–14%, 8–15%, and 2–16%,

Fig. 3. Comparisons of OCP levels in different organisms (sample sites $n \geq 6$ for the comparative species). S1: *O. talienwhanensis*, S2: *M. edulis*, S3: *Pecten albicans*, S4: *S. constricta*, S5: *Ruditapes philippinarum*, S6: *M. meretrix*, S7: *Scapharca subcrenata*, S8: *Neverita didyma*, S9: *Rapana venosa*.

respectively (Willett et al., 1998), and a predominance of the α -isomer in environmental samples reflects the continuing use of technical mixtures of HCH (Doong et al., 2002). In our samples, isomers of α -, β -, γ -, and δ -HCH were observed to contribute about 27.1%, 55.3%, 13.3% and 4.3%, respectively. The contribution of β -HCH was elevated about 4–14 times compared with the original composition, which might be attributed to different properties of the isomers. Migration and trans-

formation may contribute to β -HCH being the major contaminant among the observed isomers.

Technical DDT generally contains 75% *p,p*-DDT, 15% *o,p'*-DDT, 5% *p,p'*-DDE, and <5% others (Kim et al., 2002). DDT can be biodegraded to DDE under aerobic conditions and to DDD under anaerobic conditions. A high percentage of *p,p'*-DDT has been regarded as an indication of new inputs to an environment (Willett et al., 1998). The mean compositions of *p,p'*-DDT, *o,p'*-DDT, *p,p'*-DDE, and *p,p'*-DDD in this study were 42.1%, 4.0%, 35.1%, 18.8%, respectively. Since the production and usage of DDT and HCH in China were legally banned in 1983, this higher percentage of *p,p'*-DDT in mollusc tissues indicates the possible recent use of DDT. Several other studies have reported high DDT residues in sediments or animal tissues, and have also revealed new inputs of DDT in China (Klumpp et al., 2002; Mai et al., 2002; Wu et al., 1999; Ma et al., 2001).

The WHO and FAO have proposed acceptable daily intakes (ADI) for DDT at $5000 \text{ ng kg}^{-1} \text{ d}^{-1}$ (Zhulidov et al., 2002). For a 70-kg human, this would be equal to a DDT dose of $350,000 \text{ ng d}^{-1}$. If it is assumed that such a person consumes 1 kg of seafood products with a mean DDT level of 29.40 ng g^{-1} from Bohai Sea, then the intake amount would be $29,400 \text{ ng d}^{-1}$. This value is well below the proposed ADI. However, in Canada and the USA, the ADIs of DDT are 400 and $600 \text{ ng kg}^{-1} \text{ d}^{-1}$, respectively (Liu et al., 1990). The mean residue levels in our study thus exceed Canadian guidelines and are close to USA norms. Our study indicates that 37% of sample residue levels exceed the Canadian guideline values. In addition, as OCPs are lipophilic and capable of being biomagnified, they could pose a serious threat to upper trophic levels of aquatic communities and potentially to humans. Many studies have reported that people consuming large amounts of contaminated seafood may have elevated concentrations of pollutants in their tissues compared with the general population (e.g., Asplund et al., 1994; Dewailly et al., 1994). From the human health viewpoint, the presence of OCPs in seafood should be of great concern due to their potential risks as they can cause a range of adverse human health effects, such as cancer, reproductive effects, and acute and chronic injury to the nervous system (Hayes et al., 1971).

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