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DDT levels in human milk in Hong Kong, 2001–02

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ABSTRACT

High levels of *p,p′*-DDT were detected in Hong Kong breast milk sampled in 1976 and 1985. Monitoring DDT levels in human breast milk in this region is important to identify trends in exposure. As part of the 2002–03 WHO/EURO coordinated exposure study, the concentrations of DDT and its metabolites were determined in 10 pooled milk samples classified by geographic origin and dietary history, comprising milk samples from 238 primiparous mothers giving birth in Hong Kong. Analysis was performed by Gas Chromatography (GC) with electron capture detector and confirmed by GC/Mass Spectrometry. The sum-DDT concentration (range: 0.92–2.05 mg/kg fat) was age-dependent and indicated a decreasing trend since the 1970s. Mothers who recently came from mainland China had higher *p,p′*-DDT to *p,p′*-DDE ratios, suggesting a more recent exposure compared to women mainly residing in Hong Kong. The average Hong Kong sum-DDT level (1.50 mg/kg fat) was among the highest of the contemporary levels (range: 0.12–1.97 mg/kg fat; median: 0.40 mg/kg fat) in the 16 countries/regions participating in the 2002–03 WHO/EURO exposure study. This is probably due to the previous extensive DDT exposure and continuing use of DDT in agriculture in mainland China. Despite the apparent decrease of DDT body load over 30 years, the environmental health hazard from DDT contamination in the Pearl River Delta region remains a concern. Measures to eradicate illegal use of DDT in mainland China and regular food monitoring programs are needed in the region. Despite the presence of DDT and other persistent organic pollutants in human breast milk, breastfeeding should continue to be strongly supported for its life-long benefits to infants.

1. Introduction

DDT (Dichlorodiphenyltrichloroethane) was extensively used worldwide in the 1960–80s, with large quantities released for both agricultural and vector control applications. China has been one of the nations with the highest production and consumption of DDT. Between the 1950s and the 1980s, the amount of DDT production in China was 0.4 million tons, accounting for 20% of the total world production (Hua and Shan, 1996). The high lipid solubility combined with persistence leads to the retention of DDT and its metabolites in fatty tissue of organisms along the food chain and food is the major source of human exposure. They are also present in the optimal food for infants, human breast milk, and their levels had been measured since 1960s. The main metabolite in human milk is p,p'-DDE with levels up to a factor of 20 times higher than *p,p′*-DDT levels. Following the international bans on DDT since the 1970s because of its ecological consequences, a drop in the levels of DDT in human tissues or breast milk was observed worldwide (Smith, 1999). The same was observed in the Special Administrative Region of Hong Kong, adjacent to the southern aspect of mainland China where widespread use of DDT in agriculture was common before the bans. Since the ban of DDT in China in 1983 and Hong Kong in 1987, the *p,p*'-DDT and *p,p*'-DDE levels in breast milk have fallen from a high level (respectively, 5.2 and 13.67 mg/kg fat) in the 1970s (Ip, 1983) to, respectively, 2.17 and 11.67 mg/kg fat in 1980s (Ip and Phillips, 1989) and much lower levels (0.39 and 2.48 mg/kg fat) in the 2000s (Wong et al., 2002).

However, recently concerns for environmental contamination by DDT in the Pearl River Delta were raised by reports of increased DDT levels found in the riverine and estuarine sediments (Mai

Abbreviations: DDT, dichlorodiphenyltrichloroethane; DDE, dichlorodiphenyldichloroethylene; DDD, dichlorodiphenyldichloroethane; GC/MS, gas chromatography/mass spectrometry; HCH, hexachlorocyclohexanes; IARC, International Agency for Research on Cancer; WHO, World Health Organisation.

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et al., 2002) and water column (Luo et al., 2004; Zhou et al., 2001). There is speculation that environmental contamination by DDT in the Pearl River Delta region is still continuing (Fu et al., 2003). As new source, dicofol contributed up to 93%, 81% and 22% to the current DDT pollution in atmosphere, water and sediments, respectively, in the Taihu Lake region, China (Qiu, 2005). This contamination was correlated with a particularly high level of o,p′-DDT.

IARC (1991) concluded that there is insufficient evidence in humans but sufficient evidence in experimental animals to classify DDT as a possible carcinogenic to humans (Group 2B). However, body loads of DDT also raise concerns about potential effects on developing infants and children because DDT transfers across the placenta from mother to fetus and exposure continues through breastfeeding after birth (Shen et al., 2007). Inconclusive findings have been reported for the effect of DDT exposure on growth (Karmaus et al., 2002; Gladen et al., 2000; Rogan et al., 1986; Gladen et al., 2003; Longnecker et al., 2001), mental and psychomotor development (Ribas-Fito et al., 2003; Rogan and Gladen, 1991; Gladen et al., 1988; Dorner and Plagemann, 2002) and other health outcomes including neurological development, immunity and infections (Dewailly et al., 2000; Karmaus et al., 2003; Hardell et al., 2002; Rogan et al., 1987) of infants and children. Increases in the odds of preterm birth and small-for-gestational-age (Longnecker et al., 2001), adverse effects on psychomotor development at two years (Rogan and Gladen, 1991) and brain development in school age children (Dorner and Plagemann, 2002) have been suggested. As a precautionary approach to protect the health of the developing fetus and children from possible adverse effects of DDT, reinforcement of the restrictions on the illegal use of DDT is needed. Monitoring DDT levels in human breast milk, which indicates the degree of its exposure, is also of importance. Such monitoring will now become more important since in 2006, after a ban for almost 30 years, WHO recommended the use of indoor residue spraying of DDT for controlling malaria in areas with high rates of transmission (Rehwagen, 2006).

The WHO Regional Office for Europe (WHO/EURO) initiated a series of international studies to monitor the concentrations of PCDDs, PCDFs and PCBs in breast milk of primiparous women (Malisch and van Leeuwen, 2003; Yrjanheikki, 1989; WHOEURO, 1996). Hong Kong participated for the first time in the 2002–03 third round study with analyses of dioxins (Hedley et al., 2006), and other persistent organic pollutants. We report here the levels of DDT in 10 breast milk pools from Hong Kong and their comparison with the median levels among 16 countries/regions participating in the same study.

2. Materials and methods

2.1. Sample and data collection

In December 2001 to September 2002, we recruited 316 primiparae who gave birth to a singleton in Hong Kong to donate milk samples at 2–6 weeks postpartum. Mothers were interviewed face-to-face to collect dietary and residential information. The questionnaire design, milk sampling method and pooling strategy were adapted from the protocol for the 2002–03 WHO/EURO coordinated dioxin exposure study and are detailed elsewhere (Hedley et al., 2006). The food intake of the subjects was assessed by a semi-quantitative food frequency questionnaire containing 102 potential dioxin-rich food items.

DDT and its metabolites, including *o,p′*-DDE (dichlorodiphenyldichloroethylene), *p,p′*-DDE, *o,p′*-DDT, *p,p′*-DDT, *o,p′*-DDD (dichlorodiphenyldichloroethane) and *p,p′*-DDD were determined in 10 milk pools comprising 238 individual milk samples. The pools were created to represent relatively homogenous characteristics in terms of the mothers' residential background (Hong Kong, mainland China, China immigrants with varying periods of residence in Hong Kong), dietary habits (consumption of dairy products, fish and seafood, including riverine and marine sources, in Pools 2–7) or smoking (Pool 1) (Table 1). There were three milk pools of 78 milk samples without DDT content determined due to insufficient milk fat or heterogeneous geographic characteristics of the mothers within the pools.

The mean age of donors in each of the 10 milk pools ranged from 26.5 years to 32.6 years. The mean age of babies at the time of sampling the mothers was 4.1–4.6 weeks among pools. The majority of the mothers were never-smokers ($n = 202$, 85%). The mothers who were ever-smokers (26.7 ± 5.0years) were significantly younger than the non-smokers (30.1 ± 4.6years). The mean levels of consumption of dairy products, fish and seafood were comparatively lower in the pools designed to represent mothers with low dietary exposure to dioxins and dioxin-like PCBs (Pools 4 and 6). Mothers who recently came from mainland China (Pools 6–8) were likely to be younger, less educated and with less household income compared with mothers who resided in Hong Kong for longer periods (Pools 1–5 and 9–10).

Due to the low breastfeeding rate in Hong Kong, partially breastfeeding mothers were also included. Fifty-nine percent of our subjects practiced exclusive breastfeeding (100%) at sampling while 23% predominately breastfed (>80%) their infants. Mothers from mainland China were more likely to practice exclusive breastfeeding. However, the levels of dioxin and dioxin-like PCBs concentrations in the partially breastfeeding mothers were no different to those of the exclusively breastfeeding mothers when controlled for mother's age. (Nelson et al., 2006) All participants gave written consent before taking part in the study. The study was approved by the Ethics Committees of the University of Hong Kong, the Chinese University of Hong Kong and the Department of Health, Hong Kong SAR Government.

2.2. Chemical analyses

Mass concentrations of DDT and its metabolites were determined routinely by gas chromatography (GC) with electron capture detector (ECD) and confirmed by GC with mass spectrometry (GC/MS) in the State Institute for Chemical and Veterinary Analysis of Food, Freiburg, Germany in 2003–04. The pesticide laboratory has successfully participated in 35 proficiency tests in 1994–04. The quality control procedures for pesticide residues analysis followed the Guidelines for Residues Monitoring in the European Union (Document N° SANCO/10476/2003). The recovery rates of internal standards and analyses were in the range of 70–120% which met the requirements of the Guidelines.

As part of the determination of PCDD/Fs, dioxin-like PCBs and marker PCBs, fat and other contaminants of interest were extracted from freeze-dried human milk samples by means of continuous hot extraction device (Twisselmann extractor) with Ethanol/Toluene (70/30) for 8 h. The hot extraction has a similar functional principle as Soxhlet extraction but it allows the highest possible temperature to be maintained in the sample during extraction and therefore increases the solubility of substances, allowing extraction in a faster time. The crude fat extract was purified with butyl methyl ether (Malisch and van Leeuwen, 2002). Up to 0.5 g of the fat extract was redissolved in cyclohexane/ethyl acetate and the internal standards 2,4,5-trichlorobiphenyl and Mirex, solved in cyclohexane, were added.

The applied clean up-parts of the analytical method follow the principles of the European standardized methods, Fatty food-Determination of pesticides and PCBs, EN 1528 part 1–4, 1996–10 (confirmed 2001). To remove the fat, gel permeation chromatography was performed on a chromatography column

Table 1
Concentrations of DDT and its metabolites in 10 pooled milk samples

	Pool[b]	Concentrations mg/kg fat[a]										
		% Fat	No of milk samples	*o,p′*-DDE	*p,p′*-DDE	*o,p′*-DDT	*p,p′*-DDT	*o,p′*-DDD	*p,p′*-DDD	Sum DDT	*o,p′*-DDT: *p,p′*-DDT (%)	*p,p′*-DDT: *p,p′*-DDE (%)
1	HK – smoking	3.7	25	0.003	1.02	0.008	0.075	<0.0005	0.004	1.11	10.3	7.3
2	HK – high dairy	3.5	17	0.004	1.31	0.008	0.062	<0.0005	0.004	1.38	12.2	4.8
3	HK- High Seafood	2.8	17	0.004	1.91	0.015	0.110	<0.001	0.009	2.05	13.6	5.8
4	HK – Low Dairy & Seafood	3.7	32	0.005	1.83	0.012	0.091	<0.0005	0.006	1.94	13.4	5.0
5	HK – high dairy/seafood	3.8	29	0.004	1.78	0.012	0.081	<0.001	0.008	1.88	14.8	4.6
6	ML – low dairy & seafood	3.4	21	0.006	0.81	0.014	0.091	<0.0005	0.005	0.92	15.2	11.3
7	ML – high dairy/seafood	3.9	34	0.009	1.22	0.027	0.166	<0.0005	0.009	1.43	16.5	13.7
8	CI – 2–6 years in HK	3.5	22	0.006	0.95	0.013	0.103	<0.0005	0.006	1.07	12.2	10.9
9	CI – 7 years + in HK	3.6	23	0.006	1.49	0.013	0.101	<0.0005	0.007	1.61	12.9	6.8
10	OS – 1–10 years	3.5	18	0.004	1.36	0.008	0.071	<0.0005	0.005	1.45	10.8	5.2
	Average[c]			0.005	1.38	0.014	0.099	<0.0005	0.006	1.50	13.2	7.5
	95% Confidence intervals[d]			(0.004, 0.007)	(1.16, 1.59)	(0.010, 0.018)	(0.081, 0.121)	–	(0.005, 0.008)	(1.27, 1.71)	–	–

[a] If the level was found to be between LOD and Limit of Quantification (LOQ), it will be stated as <LOQ (0.0005 mg/kg fat except for Pools 3 and 5 whose LOQ is 0.001 mg/kg fat).
[b] HK refers to mothers residing in Hong Kong since birth; ML refers to mothers came from mainland China for delivery in Hong Kong; CI – 2–6 years in HK refers to China immigrants who stayed in Hong Kong in the recent 2–6 years; CI – 7 years + in HK refers to China immigrants who have stayed in Hong Kong for over 7 years; OS – 1–10 years refers to Hong Kong born mothers but lived in overseas countries for 1–10 years. Smoking includes ever-smokers and current smokers. High Dairy means 17 highest dairy product intake and dairy product intake >2.5 × seafood intake. (Seafood includes riverine and marine fish and seafood). High Seafood means 17 highest seafood intake and seafood intake >2.5 × dairy product intake. Low Daily & Seafood means <2 kg/month dairy product intake and <2 kg/month seafood intake. High Dairy/Seafood means ⩾2 kg/month dairy product intake OR ⩾2 kg/month seafood intake.
[c] Average concentrations were calculated by averaging the pooled DDT content weighted by the number of milk samples in each pool.
[d] Bootstrap 95% confidence intervals based on 1000 resamples.

with end adapters (length 580 and 25 mm i.d., filling level 330 mm) using Bio-Beads S-X3 with cyclohexane/ethyl acetate as eluting solvent. The eluate was concentrated, iso-octane added and evaporated to about 1 ml. Chromatography on a small column of partially deactivated silica gel was determined as a final clean up step using toluene as eluent. The silica gel (70–230 mesh) was heated overnight at 130 °C and allowed to cool in a desiccator. After adding 1.5% of water, it was shaked for 30 min and then stored in a tightly sealed container. The chromatographic tube was packed with 1 g of deactivated silica gel.

Routine determination was performed with GC/ECD using a GC (Fisons Mega 2) with two columns of different polarity parallel (fused silica no. 1: 30 m PS-088 [97.5% dimethyl-2.5% diphenyl siloxane copolymer], 0.32 mm i.d., 0.32 μm film thickness, fused silica no. 2: 30 m OV-1701-OH, 0.32 mm i.d., 0.25 μm film thickness, both columns were custom-made). Results were confirmed by GC-LRMS (GC: HP 6890/MS: HP 5973; 30 m HP5-MS, 0.25 mm i.d., 0.25 μm film thickness + 2.5 m pre-column; detection mode: MSD-EI). The concentration of DDT and its metabolites were reported as mg per kg of milk fat (mg/kg fat) and the limit of quantification (LOQ) was 0.0005 mg/kg fat (except for Pools 3 and 5 where the LOQ was 0.001 mg/kg fat).

2.3. Statistical analysis

The mean level of six DDT metabolites among the 10 Hong Kong pools were calculated by averaging the pooled DDT concentrations weighted by the number of milk samples in each pool. We estimated 95% confidence intervals by bootstrapping (Shao and Tu, 1995). Spearman correlation coefficients (r) were calculated to assess the relationship between DDT concentrations and pool characteristics. For the WHO exposure study, if two or more samples were used to represent one country, the arithmetic mean (without weighting the number of subjects in each pool) was used to represent the concentrations of DDT metabolites for that country. We used the Statistical Package for Social Sciences (SPSS for windows, version 10.1; SPSS Inc., Chicago, IL, USA) and R version 2.3.1 (R Development Core Team, Vienna, Austria) to conduct the data analyses.

3. Results and discussion

3.1. DDT concentrations in breast milk

The mass concentrations of *o,p′*-DDE, *p,p′*-DDE, *o,p′*-DDT, *p,p′*-DDT, *o,p′*-DDD, *p,p′*-DDD and sum DDT in the 10 pooled milk samples are presented in Table 1. The sum DDT ranged from 0.92 to 2.05 mg/kg fat with mean level of 1.50 mg/kg fat. *p,p′*-DDE was the most abundant residue of DDT metabolite found in the pooled milk samples with concentrations ranging from 0.81 to 1.91 mg/kg fat (mean: 1.38 mg/kg fat) while the concentrations of *p,p′*-DDT, the major constituent in technical DDT, ranged from 0.062 to 0.166 mg/kg fat (mean: 0.099 mg/kg fat). *o,p′*-DDD was not detected in any of the 10 milk pools and the limit of quantification (0.001 mg/g fat for Pools 3 and 5 and 0.0005 mg/g fat for the others) is presented instead. A simple linear regression of sum-DDT level (y) on mean age of the mothers in each pool (x) obtained the equation $y = -2.47 + 0.13x$ (adjusted R^2 = 0.55). An increased sum-DDT with increasing age was observed (Fig. 1a) but this age-dependent pattern was not found for *p,p'*-DDT (Fig. 1b). The lower sum DDT level in pools comprising milk samples of mothers from mainland China, i.e. Pools 6–9, (0.92–1.61 mg/kg fat) is therefore probably attributable to their younger age and shorter exposure duration. The younger mean age of the ever-smoking donors in the Hong Kong smoking pool could partly explain the lowest sum DDT concentration (1.11 mg/kg fat) among the five Hong Kong pools (1.11–2.05 mg/kg fat). The highest sum-DDT concentration was found in pool 3 comprising mothers born in Hong Kong with relatively higher fish and seafood consumption (6.9 kg/month). Nevertheless our data from all 10 pools did not suggest a strong positive correlation between seafood and other fish consumption and total DDT body load ($r = 0.38$). Since this study was primarily designed for detecting the dioxin content in breast milk (Hedley et al., 2006), only consumption patterns of foods with higher dioxin content, such as fish and seafood, dairy products, meat and eggs were documented, so the classification of dietary exposure in the pools may not fully address the contribution of different foods to DDT consumption.

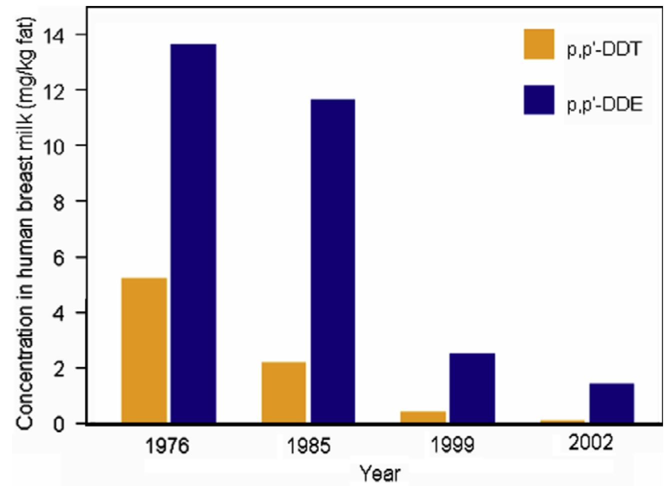

Fig. 2. Time trend for the concentrations of DDT in Hong Kong human milk samples since 1970s.

3.2. Time trend of DDT in breast milk

The DDT levels in breast milk determined in this study indicate a marked decline in DDT human body load in Hong Kong in the past thirty years, assuming reasonable comparability of assay results in different previous surveys (Ip, 1983; Ip and Phillips, 1989). The sum DDT level was also slightly lower than those in more recent breast milk samples (Wong et al., 2002). Both *p,p'*-DDT and *p,p'*-DDE concentrations in breast milk in Hong Kong decreased over time (Fig. 2). The ratio of *p,p'*-DDT to *p,p'*-DDE decreased from 0.38 in 1976 to 0.07 in 2002. This observation is consistent with a worldwide downward trend in DDT body load (Smith, 1999) and it was even suggested that the decline in average levels of DDT in breast milk in most countries was strongly correlated with the length of time since DDT restriction. However, the time trend in mainland China is not clear because there is only published data on the DDT body load in mainland China in recent years (Nakata et al., 2002; Kunisue et al., 2004).

Historical use of organochlorine pesticides partly contribute to their current levels of body burden (Mueller et al., 2008). The level of DDT in human breast milk in Hong Kong was the second highest in the 1970s among 21 countries worldwide (Solomon and Weiss, 2002), probably due to the use of DDT in former agricultural activity in Hong Kong. It was suggested that from 1979 to 1982 between 5023 and 5996 kg of DDT pesticide was imported into Hong Kong annually (EPD, 2002). The DDT produced and applied in south-east mainland China, where DDT had been extensively used, could also be an important source of exposure to Hong Kong residents. High levels of DDT in foodstuffs in Hong Kong have been reported (Ip, 1990). The drop of DDT body load in Hong Kong since the 1970s is probably an outcome of the shrinking farming industry in Hong Kong and the bans on agricultural use of DDT in both mainland China and Hong Kong in 1983 and 1987, respectively.

3.3. Comparison with DDT levels measured in the 2002–03 WHO exposure study

The sum-DDT level among 16 countries/regions (including Hong Kong represented by Pools 3 and 5 which were randomly selected) participating in the 2002–03 WHO/EURO exposure study ranged from 0.12 to 1.97 mg/kg fat (Malisch and van Leeuwen, 2006). Despite the apparent decrease in DDT body load in Hong Kong, all of the 10 Hong Kong pools contained sum-DDT levels higher than the mean (0.58 mg/kg fat) and median levels (0.40 mg/kg fat) for this WHO study. In fact, the sum DDT level in one breast milk pool representing Hong Kong in the WHO study (Pool 3, from resident mothers with high seafood intake), ranked highest among the 27 international samples. The mean concentrations of *p,p'*-DDT (0.099 mg/kg fat) and its main metabolite, *p,p'*-DDE (1.38 mg/kg fat), of the 10 Hong Kong pools were higher than the mean (*p,p'*-DDT: 0.047 mg/kg fat; *p,p'*-DDE: 0.52 mg/kg fat) and median (*p,p'*-DDT: 0.022 mg/kg fat; *p,p'*-DDE: 0.37 mg/kg fat) for the WHO study. The comparatively high levels of total DDT body load in Hong Kong is likely to be partly due to the delayed effect

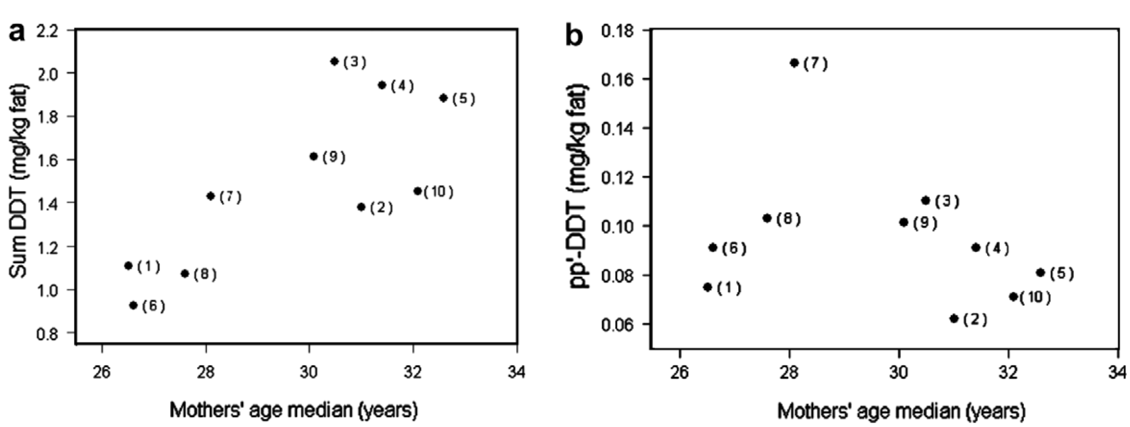

Fig. 1. Relationship between age and (a) sum-DDT and (b) *p,p'*-DDT (Pool numbers are in brackets).

of the previous high exposure (Ip, 1983; Ip and Phillips, 1989) with the higher levels of *p,p'*-DDT, representing the degree of recent exposure also above the WHO average. This suggests that Hong Kong residents were exposed to DDT comparatively more recently and it is possible that contamination of the food chain is still occurring from DDT use.

3.4. Ratios of o,p′-DDT to p,p'-DDT and p,p'-DDT to p,p'-DDE as indicators of recent DDT exposure

The ratio of *o,p′*-DDT to *p,p'*-DDT in the 10 milk pools was calculated (Table 1) in view of a recent report on high air concentrations of *o,p′*-DDT in mainland China (Qiu et al., 2004). It was estimated that the ratio of *o,p′*-DDT to *p,p'*-DDT in air over Taihu Lake, China, was 7.0 which was similar to that in dicofol and much higher than that in technical DDT (0.2–0.3). The ratio of *o,p′*-DDT to *p,p'*-DDT ranged from 10% to 17% across the pools, which was even lower than that in technical DDT (20–30%) and thus did not suggest a significant contribution of DDT body load from dicofol.

On the other hand, an apparent decline in both the individual concentrations of *p,p'*-DDT to *p,p'*-DDE (Fig. 2) and the ratio of *p,p'*-DDT to *p,p'*-DDE [from 38% in 1970s (Ip, 1983), 18.6% in 1980s (Ip and Phillips, 1989) to 15% in 1999 (Wong et al., 2002) and 5–14% in this study undertaken in 2002] was observed, indicating a reduction in the release of DDT in the region in the past two decades. The highest ratios of *p,p'*-DDT to *p,p'*-DDE (11–14%) were found in three pools comprising mothers mainly living in mainland China before delivery (Pools 6–8) compared to the rest of the pools (5–7%). Mothers who migrated from mainland China but resided in Hong Kong for more than seven years had a ratio of *p,p'*-DDT to *p,p'*-DDE similar to Hong Kong born mothers. These results indicate more recent DDT exposure for mothers who lived in mainland China, where a number of reports have suggested a recent increase in DDT use. For example, DDT was detected in agricultural products in Hubei province in recent years resulting from an increase in misuse of pesticides for crop protection in that region (Wang et al., 1999). Exceptionally high levels of DDT were detected in some food samples in a recent study in Shanghai and the author suggested this might be due to sporadic use of DDT for both agriculture and aqua-culture (Nakata et al., 2002). In south-east China the relatively high level of DDT found in sediments in Minjiang River Estuary in 1999 (Zhang et al., 2003) also raised concerns about illegal DDT application in agriculture. A high proportion of DDT in total DDT found in surface sediments of the sea area between Xiamen and Jinmen (Chen et al., 1996), water columns (Luo et al., 2004; Zhou et al., 2001) and sediments (Zhou et al., 2001; Mai et al., 2002) in the Pearl River Delta indicated use of DDTs in the region after the bans. Even in Hong Kong the ratio of *p,p'*-DDE to DDTs (48%, 63%) in small cetaceans suggested that contamination of Hong Kong coastal waters was still occurring (Minh et al., 1999). These observations emphasize the need to control illegal use of DDT in the region.

3.5. Local efforts in controlling DDTs in diet

In Hong Kong, the governmental Food and Environmental Hygiene Department conducted a Food Surveillance Programme to monitor the levels of DDT, HCH and other environmental persistent pollutants in foods. From 2002 to June 2004, about 3300 samples including vegetables, fish, milk and dairy products, meat and poultry products were tested for DDT and all samples were reported to be satisfactory. A marked decline in the DDT residues in foodstuffs over the past thirty years was noted in mainland China (Nakata et al., 2002). Even so DDT residues are found in a typical diet in Hong Kong and the mainland. A survey of organochlorine pesticides in retail milk in China has reported higher DDT residues in cow milk samples from south China compared to the north (Zhong et al., 2003). It has also been speculated that the substantial increase in DDE levels of cow's milk available in Hong Kong in 1993–95, compared to 1984–87 samples, was due to the shift of local dairy industries to mainland China (Wong and Lee, 1997). Given the widespread occurrence of DDT in the food supply and the probable health risks associated with exposure mainly from the diet, continuing monitoring of foodstuff should be carried out and prevention of further food contamination must be an environmental health policy priority. Unfortunately, there are reports of illegal production, use and sales of DDT worldwide after the bans (Fedorov, 1997; Dinham, 1997). The recent WHO recommendation on the use of DDT in malaria control (Rehwagen, 2006) may worsen the situation if control measures are not fully enforced to prevent deviation of the use of DDT from public health applications to agricultural purposes.

3.6. Safety of breastfeeding

Dietary consumption of pollutants by children has been a health concern because it was suggested that a child's exposure to the amounts of DDT allowed by the "action level" set by the US Food and Drug Agency would significantly exceed the health based standards set by US EPA (Environmental Protection Agency) and ATSDR (Agency for Toxic Substances and Disease Registry) (Schafer and Kegley, 2002). The problem is potentially more serious for breastfed infants. According to the US ATSDR, the minimal risk level (MRL) for *p,p'*-DDT ingestion is 5×10^{-4} mg/kg/day. For an infant weighing 5 kg consuming 700 ml of breast milk (containing 3% milk fat) a day, the maximum tolerable *p,p'*-DDT level in breast milk is theoretically estimated to be 0.119 mg/kg fat, which is close to or exceeded by the *p,p'*-DDT level in four milk pools (Pools 3, 7–9) in this study. However, the daily total DDT consumption for a 5 kg infants, calculated using the above assumption, was only 19–43% of the Acceptable Daily Intake (0.02 mg/kg/day), as recommended by WHO/FAO. Although discussions on the safety of breastfeeding have come to the firm conclusion that exclusive breastfeeding should continue to be strongly supported and promoted (van Leeuwen and Younes, 2000), the DDT contamination problem should not be ignored. Negative effects on child health will also be caused by placental transfer of DDT (Ribas-Fito et al., 2003), so the ultimate solution to protect infants and human health from exposure to DDT would be to eradicate the illegal use of DDT globally.

4. Conclusion

The 2002–03 WHO/EURO exposure study indicates that although DDT was banned from agricultural use twenty years ago, it could still pose a persistent hazard to human health and the environment today. Previous extensive dietary exposure to DDT is probably the reason for the high sum-DDT concentration in the human milk samples from Hong Kong in the WHO/EURO study. However, additional exposures from the illegal use of DDT in mainland China cannot be ruled out. Despite the apparent decrease of DDT body load in Hong Kong, the public health threat of environmental contamination with DDT in the Pearl River Delta region remains a concern. Measures to intensify safe management of pesticides and regular food monitoring programs should be implemented to eradicate illegal use of DDT and guarantee effective protection of the environment and human health.

Despite the uncertainty about the potential health risks of DDT exposure from breast milk, exclusive breastfeeding should continue to be supported and promoted in Hong Kong and elsewhere. Given the health benefits offered by breastfeeding, breast fed infants are likely to be better protected than formula-fed infants.

Continued breast milk monitoring programs are important exercises as surveillance and early warning systems for abnormal exposure of the population to DDT and other persistent organic pollutants.

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