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Prenatal exposure to organochlorine pesticides and infant birth weight in China

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Abstract

In utero exposure to organochlorine pesticides (OCPs) is thought to be potentially harmful to fetal development. We aimed to investigate the associations of maternal and cord serum OCPs levels with infant birth weight in China. In this study, we measured serum levels of 18 OCPs in 81 mother-infant pairs, including DDT, hexachlorocyclohexanes (BHC), hexachlorobenzene (HCB), heptachlors, chlordanes, endosulfan-I, and mirex using a high-resolution-gas-chromatography with high-resolution-mass-spectrometry method. We found that p,p'-DDE and β -BHC had the highest detection rate in both maternal and cord blood serum (97.2% and 96.7%, respectively), followed by HCB (93.0%, 51.7%), p,p'-DDT (88.7%, 36.7%), and p,p'-DDD (83.1%, 60.0%). Among all OCPs, the concentration of p,p'-DDE was the highest (mothers geometric mean (GM): 203.54

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Conflict of Interest

The authors declared no potential competing financial interests.

ng/g, newborns GM: 116.14 ng/g), followed by HCB (70.62 ng/g, 65.16 ng/g), and β -BHC (67.67 ng/g, 33.39 ng/g). Multiple linear regression analyses showed that each 1 ng/g increment of cord serum p,p'-DDE, total DDT, and β -BHC was associated with a 0.10g, 0.10g, and 0.92g decrease in infant birth weight, respectively, and as the cord serum concentrations of p,p'-DDT, p,p'-DDD, HCB and mirex increased, the infant birth weight was also decreased, although the associations were not statistically significant due to the relatively small sample size. These results suggest that p,p'-DDE, β -BHC, and HCB were the predominant OCPs in the serum of Chinese pregnant women and cord blood of their newborns. Prenatal exposure to DDT, β -BHC, HCB, and mirex were associated with a decrease in birth weight, but these results need validation in larger sample-sized studies.

Keywords

prenatal exposure; organochlorine pesticides; dichloro-diphenyl-trichloroethane; β -hexachlorocyclohexane; hexachlorobenzene; birth weight

1. Introduction

Beginning in the 1940s, organochlorine pesticides (OCPs) have been used extensively around the world as insecticides in agriculture and for mosquito control. The representative chemicals in this group include dichloro-diphenyl-trichloroethane (DDT), lindane, hexachlorobenzene (HCB), heptachlors, chlordane, endosulfan, and mirex. Many OCPs have been banned or restricted by the Stockholm agreement because of concerns about environmental impacts and human health effects (UNEP, 2001). As the largest agricultural country in the world, China has been a major producer and consumer of OCPs. While the production and use of OCPs for agriculture has been banned in China since 1980 (Wong et al., 2005), DDT is still used for vector control while several OCPs including HCB, mirex, and chlordane are used in termiticides. Consequently, China continues to have a heavy burden of OCP exposure in the environment.

Concerns relating to the potential health effects from exposure to OCPs originates from the long half-lives and relative stability of several OCPs in the environment, and their lipophilic properties, which facilitates storage and bioaccumulation in human adipose tissue following exposure (Clarkson, 1995). Although the concentrations of these chemicals in water, air, sediment, field soil, food, and animals have decreased due to degradation in the past 30 years (Hu et al., 2007), levels of OCPs can still be detected in the blood, adipose tissue, and breast milk of the general population (Jonsson et al., 2005). There is particular concern that the fetus and infants are at especially high risk and more vulnerable than adults to the adverse health effects of OCP exposure. Prenatal exposure to OCPs occurs during pregnancy when maternal fat stores are mobilized resulting in transfer of these chemicals to the embryo and fetus through the placenta (ATSDR, 2002). Recent studies have showed that even extremely low levels of *in utero* exposure to OCPs can damage the reproductive and immune systems of the developing fetus, causing irreversible birth defects (Ren et al., 2011). Evidence is also growing that prenatal exposure to OCPs may interfere with the endogenous endocrine system, such as the thyroid hormones of pregnant women (Lopez-Espinosa et al.,

2009), and may lead to intra uterine growth retardation and low birth weight (LBW) in the newborns (Sagiv et al., 2007). However, the relationship between prenatal exposure to OCPs and LBW remains controversial due to inconsistent evidence, and previous studies have mainly focused on populations from North American and European countries, where the levels of current exposure are lower than in China (Wong et al., 2005).

Data are currently scarce in China about the background exposure levels of OCPs in the blood of Chinese pregnant women and their newborns. Therefore, the main objective of this study was to evaluate the distributions and metabolite profiles of the serum concentrations of 18 metabolites of 7 OCPs in Chinese pregnant women and in the cord blood of their newborns, and also to evaluate the associations of these OCP levels with birth weight in the infants.

2. Methods and Materials

2.1 Study design and subjects

A total of 81 pairs of mothers and newborns were enrolled from four hospitals in four different cities of China from June 2010 to August 2010, including 20 pairs from Beijing City, 20 pairs from Lanzhou City, 20 pairs from Taiyuan City, and 21 pairs from Xiamen City. All mothers were interviewed at the time of delivery by a trained interviewer using a standardized questionnaire to collect general information on demographic characteristics (e.g., age, menarche age, self-reported weight before pregnancy, and height), history of hypertension and diabetes, and lifestyle factors during pregnancy (e.g., smoking and passive smoking, alcohol drinking). Information concerning the mothers' history of congenital diseases, history of adverse pregnancy outcomes (e.g., miscarriage, stillbirth), weight at delivery, and information on the newborns' birth date, gender, gestational week, placental weight, and birth weight was obtained from the medical delivery records. A sample of 10 ml of peripheral venous blood from the mothers and 10 ml of umbilical cord blood from the newborns was obtained at birth and the centrifuged serum samples were stored at -70°C until laboratory examination. Each of the mothers and their husbands provided informed consent for participation in the study after receiving a detailed explanation of the study. This study was approved by the Human Investigation Committee at Yale University.

2.2 Measurements of OCPs in serum

Because 10 maternal and 21 newborn cord blood samples were in-vitro hemolyzed, we only carried out the measurement of the 18 OCPs in the remaining 71 maternal serum and 60 cord serum samples. The high resolution gas chromatography with high resolution mass spectrometry (HRGC-HRMS) method was used to measure the concentrations of 18 OCPs in the maternal serum and cord blood. The measured OCPs included 6 metabolites of DDT (p,p' and o,p'-DDT, -DDE, and -DDD), 4 metabolites of hexachlorocyclohexane (BHC) (α -, β -, γ -, and δ -BHC), HCB, heptachlors (heptachlor and heptachlor epoxide B), chlordanes (α -, γ -chlordane, and oxychlordane), endosulfan I, and mirex. The standard materials for the above OCPs were purchased from AccuStandard (Cat No. C-WHO-01 and AE-00010-10ML, New Haven, CT, USA), and all organic solvents (n-hexane,

dichloromethane, methanol, formic acid, and acetonitrile) were of HPLC grade purity obtained from Sigma-Aldrich (Munich, Germany).

The HRGC-HRMS analyses were performed using a Waters AutoSpec Premier mass spectrometer (Waters, USA) coupled to an Agilent 7890 gas chromatography (Agilent, Santa Clara, CA, USA), based on the method previously reported with minor modifications (Zhang et al., 2010). Briefly, 1 mL of serum from each subject was extracted for measurement and each sample was determined in duplicate. The 10 µl mixtures of isotope-labeled ($^{13}\text{C}_{12}$) standards (1000ng/ml, diluted in the n-hexane) and 50µl acetonitrile were added to a glass tube, and 1 ml of serum sample, 1 ml of water, and 1 ml of formic acid were then added, followed by a sonication for 30 minutes. Solid phase extraction of the samples was performed on a Supelco ENVI-C18 SPE tube (500mg/3mL) (Sigma-Aldrich, Munich, Germany), and then cleaned-up and fractionated on a three-column system (Ronn et al., 2011). 100 µl of final extracted volume of each sample was injected on a HRGC/HRMS system. High-purity helium (>99.99%) was used as a carrier gas with a constant flow of 1.2mL/min. The temperature programs were as follows: 80°C for 2 min, 15°C/min to 150°C for 0 min, and 2.5°C/min to 270°C hold for 3 min, and then 15°C/min to 330 °C hold for 1min. The injector and interface was programmed to 290 °C and extracts were separated on a 60m×0.25mm×0.25 µm DB5-MS capillary column. We used perfluorokerosene to calibrate the mass spectrometer and selected ion monitoring mode to keep the solution higher than 10000 (10% valley). The identification of each OC was based on retention times, and the concentrations of identified compounds were calculated using mean relative factors determined from the corresponding calibration curves obtained from separate standard solutions.

In general, adjusting the serum concentrations of OCs for lipids is often a standard procedure for monitoring and epidemiological studies. In order to facilitate the comparison of our findings with the results from previous studies, we chose to report the total lipid calibrated concentrations of serum OCs, which were expressed as ng/g of lipid. The blood lipids such as cholesterol and triglycerides were measured using standard enzymatic methods, and an established summation formula was used to calculate the total serum lipids for each sample (Rylander et al., 2006).

2.3 Quality assurance and quality control (QA/QC)

Each sample was measured in duplicate. Quality control serum samples and method blank samples were incorporated in each batch of 10 samples and treated identically as the serum samples. The recoveries of all compounds varied from 65% to 110% and the limit of detection (LOD) of the targeted compounds was defined as 3 times the ratio of signal-to-noise (S/N=3). The concentrations of all OCPs in the blank samples should not be more than LOD.

2.4 Statistical analysis

The geometric mean (GM), median, minimum, and maximum values of the lipid adjusted concentrations of each OCP in the maternal and cord blood serum were calculated and used as summary statistics. The differences in concentration between maternal and cord blood

serum for each of the OCPs were analyzed by the Wilcoxon matched-pairs signed-ranks test. Multivariate linear regression models were utilized in order to evaluate the associations of each OCP and the birth weight of the newborns, adjusted for maternal age, maternal BMI at delivery, gestational week, and the gender of the newborn. For the maternal and cord serum concentrations of each OCP, those with detection rates >80% were used as continuous variables in the regression models; those with detection rates >50% but <80% were stratified into three groups by using the LOD value and median concentration of the detected samples as the cut points, and those with detection rates >20% but <50% were stratified into two groups by using the LOD as the cut point. All data analyses were carried out with SAS v9.3, and two-sided $p < 0.05$ was considered statistically significant.

3. Results

3.1 General Characteristics

General characteristics of the 81 healthy mother/newborn pairs are shown in Table 1. The age of the mothers ranged from 18 to 44 with a median age of 28 years. None of the mothers in the study reported ever smoking or drinking alcohol during their pregnancy, but 11 mothers (11.1%) were passively exposed to cigarette smoke because their husbands' smoked. One mother had gestational diabetes and sixteen mothers (21.9%) had a history of an adverse event during a prior pregnancy, such as miscarriage or stillbirth.

Of the 81 newborns, 30 were girls and 51 were boys; 11 (13.6%) had a gestational week less than 37 weeks, while the remaining 70 newborns (86.4%) were born following a normal number of weeks of pregnancy (37 to 41 weeks). The birth weights of 8 newborns (9.9%) were less than 2500 grams and 3 newborns (3.7%) had a birth weight more than 4000 grams. The birth length of the newborns ranged from 34 to 56 centimeters with a median length of 50 cm. Data for placental weight was available for only 39 newborns, with ranges from 400 to 730 grams.

3.2 Organochlorine Detection Rates

Because of the high sensitivity and accuracy of the HRGC/HRMS system, the LOD for the serum concentrations of these OCPs using this method was in the range of 0.3 to 90.0 pg/ml (Table 2), and we used 50% of LOD as the default value for the concentrations of those samples below LOD for the further analyses.

All serum samples had detectable levels of one or more chemicals. The detection rates for each OCP in the maternal and newborn cord serum are shown in Table 2. For DDT congeners, p,p'-DDE had the highest detection rate both in the maternal (97.2%) and in cord blood serum (96.7%), followed by p,p'-DDT (88.7% in the maternal and 36.7% in cord blood serum), and by p,p'-DDD in the maternal (83.1%) and in cord blood serum (60.0%). For BHC isomers, β -BHC had the highest detection rate (97.2% in the maternal and 96.7% in cord blood serum) of all the isomers. The fungicide HCB had a detection rate of 93.0% in maternal and 51.7% in cord blood serum while mirex had a detection rate of 66.2% in the maternal and 21.7% in the cord blood serum. However, the detection rates of op'-DDT and

op'-DDE were >25% in the maternal blood (43.7% and 36.6%), but were <25% in the cord blood (18.3% and 3.3%, Table 2).

For the three metabolites of chlordane, oxychlordane was detected in about 23% of the maternal serum samples, while α -chlordane and γ -chlordane were detectable in only one of the maternal samples. In addition, all three chlordane metabolites were detected in 5% of the cord blood samples, with detection rates of 0%, 3.3%, and 5% for α -chlordane, γ -chlordane, and oxychlordane, respectively (Table 2). o,p'-DDD, α -BHC, γ -BHC, δ -BHC, the heptachlors (heptachlor and heptachlor epoxide B), and endosulfan I were detectable at very low levels in both the maternal and cord serum samples (Table 2).

3.3 Concentrations of OCPs in maternal and cord blood

Table 3 shows the GM, median, minimum, and maximum values for each of the OCPs. In both maternal and cord serum samples, the concentration of lipid adjusted p,p'-DDE was the highest (GM in mothers: 203.54 ng/g; GM in newborns: 116.14 ng/g), following by HCB (GM in mothers: 70.62 ng/g; GM in newborns: 65.16 ng/g), β -BHC (GM in mothers: 67.67 ng/g; GM in newborns: 33.39 ng/g), and p,p'-DDT (GM in mothers: 14.68 ng/g; GM in newborns: 5.41 ng/g). The GM concentrations for the other compounds were below 10 ng/g lipid in both maternal and cord serum (Table 3).

3.4 Associations of maternal and cord serum concentrations of OCPs with newborn birth weight

The associations between infant birth weight and concentrations of each of the OCPs with a detection rate >20% in the maternal and cord blood samples, adjusted for putative confounding factors, are shown in Table 4. A reduced birth weight was found to be associated with the lipid adjusted (ng/g) cord serum concentrations of p,p'-DDT, p,p'-DDE, p,p'-DDD, total DDT, β -BHC, HCB, and mirex. A 1ng/g increment of p,p'-DDE, total DDT, and β -BHC in cord blood was associated with a 0.10g, 0.10g, and 0.92g decrease in infant birth weight, respectively (Table 4). The birth weight for infants with cord serum levels of p,p'-DDT and mirex above LOD were 148.6g and 111.6g lower than those infants with no detectable levels of these two chemicals, respectively. When infants were stratified by the LOD and median of p,p'-DDD and HCB, their cord serum concentrations of the two OCPs were increased but their birth weight were gradually decreased ($\beta = -36.8$ and -34.7 , respectively) (Table 4). However, these results were not statistically significant due to relatively small sample size.

4. Discussion

About 1.1 million babies in China are born at a birth weight lower than 2500 grams each year (UNICEF, 2004). It is estimated that about one-third of these LBW infants are due to preterm delivery, and the rest are growth restricted, small for gestational age infants. *In utero* exposure to environmental endocrine disruptors like OCPs is one potential risk factor that may result in the developmental retardation of the fetus. In this study of 81 pairs of mothers and their infants, we evaluated OCP exposure levels in the Chinese pregnant women and their newborn babies, and found that p,p'-DDE, β -BHC, and HCB were the

most frequently quantifiable chemicals with the highest concentrations in both maternal and cord blood. The lipid adjusted cord serum concentrations of each of the OCPs evaluated were all associated with a decrease in infant birth weight after adjustment for the potential confounding factors although the results did not reach statistical significance.

OCPs are dispersed globally and exposure is ubiquitous. Of the pesticides produced on a commercial scale, DDT, HCB, chlordane, and mirex are still being produced in China. People are exposed to DDT mainly by inhalation and ingestion, with the latter considered more important in the community populations (Bosch de Basea et al., 2011). Technical-grade DDT consists of a mixture of around 85% p,p'-DDT and 15% o,p'-DDT isomers (ATSDR, 2002), and DDE and DDD are the major metabolites and breakdown products of DDT. As a result, the p,p'- and o,p'- DDT, DDE, and DDD are determined to give the "total DDT". The most common forms are p,p'-DDT and p,p'-DDE. p,p'-DDT is the isomeric and predominant form of technical DDT, and p,p'-DDE is the primary metabolite of DDT in the environment and in living organisms, which is a chronic exposure marker of DDT in the body with a half-life of more than 8 years (Jaga and Dharmani, 2003).

We found that p,p'-DDE can be detected in almost all of the mother and infant blood samples, and the concentrations of this metabolite were also the highest among the six DDT forms, which accounts for more than 90% of the "total DDT", followed by p,p'-DDT, o,p'-DDT, and p,p'-DDD. Notably, the order of concentrations of these DDT isomers in our study was consistent with a recent study of 1438 infants in Shanghai (Cao et al., 2011). In addition, the cord serum concentrations of p,p'-DDE in our study (median=231.1ng/g) were also similar with a report in Zhejiang, China (median=249.56ng/g) (Zhao et al., 2007). The previous studies have only reported the lipid adjusted concentrations of several OCPs in either the maternal or cord serum of the Chinese population individually, rather than in both the mothers and their infants (Zhao et al., 2007; Qu et al., 2010; Cao et al., 2011) (Table 5). In this study, we reported the lipid adjusted concentrations of 16 OCP metabolites in both maternal and cord serum, which should provide useful information for future research. In addition, the serum concentrations of p,p'-DDE were also the highest among all OCPs detected in the mothers and infants, which suggested that DDT was the predominant pesticide that the Chinese pregnant women were exposed to. DDT can easily be passed through the placenta into the infants cord blood, resulting in a high risk to the fetus from the adverse health effects of DDT exposure. It was also reported in the study of Shanghai infants that p,p'-DDE, HCB, and β -BHC were the major OCPs with the highest concentration levels in the umbilical cord serum, which is consistent with our findings. However, the cord serum concentrations of p,p'-DDE, HCB, and β -BHC in their study (median=1850 pg/ml, 420 pg/ml, and 450 pg/ml, respectively) were much higher than the cord serum levels of these OCPs observed in our study (Cao et al., 2011).

China has consumed the highest amount of technical BHC, accounting for almost half of the total global usage (Li and Macdonald, 2005). Once absorbed, the distribution of β -BHC isomers in humans and animals is primarily in adipose tissue, but is also found in the brain, kidney, muscle, blood, breast milk, and semen (Srinivasan and Radhakrishnamurthy, 1983). α -BHC, β -BHC, γ -BHC, and δ -BHC are the 4 major BHC isomers, and β -BHC is the predominant BHC isomer in the environment and human body because of its resistance to

microbial degradation and strong potential to bioaccumulate (Chen et al., 2009). HCB has not been used as a pesticide in China, but rather as an intermediary in the production of other chlorinated substances, such as sodium-pentachlorophenol (Na-PCP) (Hu et al., 2007). In another study of three Asian countries, β -BHC and HCB were the two most common OCPs in breast milk in Beijing, China, and these concentrations were higher compared to levels from subjects in Korea and Japan, since they did not measure DDT isomers (Fujii et al., 2012).

The OCPs accumulating in the placenta may interact with hormone and nutrient transport systems, thereby affecting the normal development of the child and the pregnancy outcome (Schug et al., 2011). It was previously reported that maternal serum concentrations of DDE were associated with increased odds of premature birth, and independently, with increased odds of small-for-gestational-age birth weight in humans (Longnecker et al., 2001). However, epidemiological studies evaluating the association between exposure to OCPs and LBW have been inconsistent. A large study of U.S. pregnant women suggested a significant dose-response relationship between maternal serum concentration of DDE and LBW in their newborns (Longnecker et al., 2001), but a recent meta-analysis of 12 European birth cohorts did not support these findings (Govarts et al., 2012).

A Spanish study found a marginally significant decrease of 79g and 53g in birth weight for each 10-fold increase in cord serum concentrations of HCB and β -BHC (Lopez-Espinosa et al., 2011), but these associations were not found in another birth cohort in the U.S. (Gladen et al., 2003). These conflicting findings may be due to the distinct exposure levels across those countries and different susceptibility in the studied populations. In our study, we found a decreased birth weight in those infants with increased exposure levels to DDT, β -BHC, HCB, and mirex. However, due to the limited sample size of the present study, we did not find a statistically significant association.

In summary, this study examined background exposure levels and metabolic profiles of OCPs in Chinese pregnant women and their newborn babies in China, and found that p,p'-DDE, β -BHC, and HCB were the predominant OCPs found in both maternal and cord blood. In addition, although not statistically significant, the lipid adjusted cord serum concentrations of p,p'-DDT, p,p'-DDE, p,p'-DDD, β -BHC, HCB, and mirex were associated with decreased birth weight in the newborns. Further research incorporating larger sample sizes are needed to investigate the health impacts of prenatal exposure to OCPs, especially DDT, HCB, and β -BHC, on the birth outcomes of Chinese infants.

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Nonstandard abbreviations

OCP	organochlorine pesticide
DDT	dichloro-diphenyl-trichloroethane
DDE	dichloro-diphenyl-dichloroethylene
DDD	dichloro-diphenyl-dichloroethane
BHC	hexachlorocyclohexane
HCB	hexachlorobenzene
HRGC-HRMS	high resolution gas chromatography with high resolution mass spectrometry
LOD	limit of detection

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Highlights

- *In utero* exposure to organochlorine pesticides was shown to affect fetal growth.
- Serum levels of 18 major OCPs were measured in 81 mother-infant pairs.
- p,p'-DDE, β -BHC, and HCB were the main OCPs in maternal and cord serum in China.
- Cord serum p,p'-DDE, β -BHC, and HCB were associated with decreased birth weight.

Table 1

General characteristics of 81 pairs of mother and newborn.

Characteristics	N	median (min–max) or %
<i>Maternal Parameters</i>		
Age (years)	81	28.5 (18.0–44.0)
BMI (kg/m²)		
Pre-pregnancy	81	20.6 (15.6–35.3)
At delivery	81	26.7 (18.9–39.6)
Passive smoking		
Yes	9	11.1%
No	72	88.9%
Menarche Age	73	14.0 (11.0–19.0)
History of adverse pregnancy	73	
Yes	16	21.9%
No	57	78.1%
<i>Infant parameters</i>		
Sex		
Boy	30	36.4%
Girl	51	63.6%
Term (weeks)	81	39.0 (31.0–41.0)
<37	11	13.6%
37	70	86.4%
Birth weight (g)	81	3300 (1400–4450)
<2500	8	9.9%
2500–4000	70	86.4%
>4000	3	3.7%
Birth Length (cm)	81	50 (34–56)
Placental Weight	39	550 (400–730)

Table 2

The limit of detection (LOD) and percentage of quantifiable samples for each organochlorine pesticide in the maternal and cord serum.

Organochlorine pesticides	LOD (pg/ml)	Mothers (N=71)		Newborns (N=60)	
		n	Q%	N	Q%
<i>DDT</i> s					
p,p'-DDT	7.0	63	88.7	22	36.7
o,p'-DDT	6.0	31	43.7	11	18.3
p,p'-DDE	1.0	69	97.2	58	96.7
o,p'-DDE	2.0	26	36.6	2	3.3
p,p'-DDD	0.3	59	83.1	36	60.0
o,p'-DDD	9.0	0	0	1	1.7
<i>BHC</i> s					
α-BHC	10.0	1	1.4	0	0
β-BHC	2.0	69	97.2	58	96.7
γ-BHC	2.0	1	1.4	0	0
δ-BHC	2.0	0	0	0	0
<i>HCB</i>	90.0	66	93.0	31	51.7
<i>Heptachlors</i>					
Heptachlor	0.8	2	2.8	1	1.7
Heptachlor epoxide B	1.0	3	4.2	2	3.3
<i>Chlordanes</i>					
α-Chlordane	0.4	1	1.4	0	0
β-Chlordane	1.0	1	1.4	2	3.3
Oxychlordane	1.0	16	22.5	3	5.0
<i>Endosulfan-I</i>	1.0	5	7.0	3	5.0
<i>Mirex</i>	0.4	47	66.2	13	21.7

Note: Q%, the percentage of quantifiable samples.

Table 3
The distributions of selected organochlorines (ng/g lipid) in the maternal and newborns' cord serum.

Organochlorines	Mothers				Newborns				<i>p</i> ^a
	GM	Median	Min	Max	GM	Median	Min	Max	
DDTs									
p,p'-DDT	14.68	17.01	<LOD	361.52	5.41	<LOD	<LOD	76.68	<0.001
o,p'-DDT	2.51	<LOD	<LOD	26.48	3.39	<LOD	<LOD	34.91	0.270
p,p'-DDE	203.54	231.05	<LOD	3196.54	116.14	148.53	<LOD	2509.02	<0.001
o,p'-DDE	0.62	<LOD	<LOD	12.08	0.85	<LOD	<LOD	4.13	0.007
p,p'-DDD	1.07	1.42	<LOD	24.66	0.66	0.73	<LOD	20.90	0.001
o,p'-DDD	---	---	---	---	<LOD	<LOD	<LOD	13.00	---
DDT	245.82	266.75	1.54	3234.94	146.03	169.94	7.0	2527.08	<0.001
BHCs									
α-BHC	<LOD	<LOD	<LOD	8.83	---	---	---	---	---
β-BHC	67.67	73.96	<LOD	348.03	33.39	35.29	<LOD	261.29	<0.001
γ-BHC	<LOD	<LOD	<LOD	4.24	---	---	---	---	---
δ-BHC	---	---	---	---	---	---	---	---	---
HCB	70.62	74.84	<LOD	642.94	65.16	55.46	<LOD	989.38	0.189
Heptachlors									
Heptachlor	<LOD	<LOD	<LOD	4.30	<LOD	<LOD	<LOD	8.12	---
Heptachlor epoxide B	<LOD	<LOD	<LOD	0.67	<LOD	<LOD	<LOD	4.38	---
Chlordanes									
α-Chlordane	<LOD	<LOD	<LOD	3.14	---	---	---	---	---
β-Chlordane	<LOD	<LOD	<LOD	2.76	<LOD	<LOD	<LOD	1.36	---
Oxychlordane	<LOD	<LOD	<LOD	14.24	<LOD	<LOD	<LOD	17.78	---
Endosulfan-I	<LOD	<LOD	<LOD	1.32	<LOD	<LOD	<LOD	6.08	---
Mirex	0.36	0.23	<LOD	66.36	0.27	<LOD	<LOD	23.94	0.010

Abbreviation: GM, geometric mean

^aWilcoxon matched-pairs signed-ranks test

Linear regression analyses for birth weight in relation to the concentrations of selected organochlorines (ng/g lipid) in the maternal and cord serum.

Table 4

Organochlorines	Mothers			Newborns		
	β	95%CI	P	β	95%CI	P
<i>DDTs</i>						
p,p'-DDT	-0.48	-2.44	1.49	0.630 ^a	-148.6	-363.8 66.6 0.172 ^c
p,p'-DDE	-0.01	-0.17	0.15	0.908 ^a	-0.10	-0.33 0.13 0.397 ^a
p,p'-DDD	6.09	-17.53	29.71	0.608 ^a	-36.8	-149.3 75.8 0.514 ^b
Total DDT	-0.01	-0.17	0.14	0.894 ^a	-0.10	-0.32 0.13 0.389 ^a
β -BHC	-0.17	-1.21	0.87	0.747 ^a	-0.92	-2.55 0.71 0.262 ^a
HCB	0.24	-0.87	1.35	0.663 ^a	-34.7	-155.6 86.2 0.567 ^b
Mirex	-32.9	-138.4	72.6	0.535 ^c	-111.6	-339.3 116.2 0.330 ^c

Abbreviations: CI, confidence interval.

Multivariate linear regression model, adjusted for maternal age, maternal BMI at delivery, infant gender, and gestational week.

^a OCPs with detection rate >80% were used as the continuous variables in the regression models;

^b OCPs with detection rate >50% but <80% were stratified into three groups by using the LOD value and median concentration of the detected samples as the cut points;

^c OCPs with detection rate >20% but <50% were stratified by the LOD value into two groups.

Table 5

Comparison of selected OCPs in maternal and cord blood of different studies in China.

Place	Year of collection	Sample	Sample Number	Unit	p,p'-DDT	p,p'-DDE	p,p'-DDD	Total DDT	β-BHC	HCB	Reference
China	2010.6-8	Maternal	71	Median (range)	17.01 (0~361.52)	231.1 (0~3196.54)	1.4 (0~24.66)	266.8 (1.5~3234.9)	73.96 (0~348.03)	74.84 (0~642.94)	Present study
		Cord	60	pg/ml	<LOD (0~126.2)	180.4 (0~3064.2)	0.9 (0~34.4)	210.9 (8.3~3086.3)	39.4 (0~319.1)	94.6 (0~903.8)	
		Cord	60	ng/g	<LOD (0~76.68)	148.53 (0~2509.02)	0.73 (0~20.90)	169.9 (7.0~2527.1)	35.29 (0~261.29)	55.46 (0~989.38)	
Hongkong	2005.7-9	Maternal	21	Mean±SD	133±23	1801±195	----	1934±197	---	---	(Tsang et
		Cord	21	ng/g	82±18	1473±300	----	1556±305	---	---	
Guangzhou	2004.3	Maternal	30	Mean±SD (range)	119.7±135.9 (26.3~879.2)	1615.9±1863.8 (98.1~5544.4)	51.3±58.4 (0~206.8)	1676.0±2002.2 (283.4 6167.7)	34.5±50.2 (0.3 180.1)	---	(Qu et al., 2010)
		Cord	30	ng/g	101.2±117.2 (12.0~444.9)	1125.14±812.9 (22.1~2625.4)	12.5±15.3 (0~33.8)	1287.8±1506.5 (189.6 3296.0)	13.7±18.2 (0.9 59.1)	---	
Shanghai	2008.9-2009.10	Cord	1438	Median(range) pg/ml	(0-3200)	1850 (0-31660)	40 (0--3840)	----	450 (0-9690)	420 (0-15940)	(Cao et al., 2011)
Zhejiang	2005.3-10	Cord	4	Median (range) ng/g	---	154.16 (29.33-200.26)	---	---	4.99 (3.59-10.45)	---	(Zhao et al., 2007)
			60	ng/g	----	118.53 (0.60-1426.12)	---	---	1.97 (0.05-47.97)	---	
			26		----	249.56 (0.60-12454.02)	---	---	2.58 (0.05-20.55)	---	