Organochlorine residues in maternal milk from inhabitants of the Thohoyandou area, South Africa

T.N. Mutshatshi, J.O. Okonkwo, B. Botha, and N. Agyei

[a]Faculty of Science, Departments of Environmental, Water & Earth Sciences and Chemistry, Tshwane University of Technology, 001Pretoria, South Africa; [b]Faculty of Science, Department of Chemistry, University of Limpopo, Medunsa 0204, South Africa

The presence of organochlorine compounds (OC) such as DDT and their metabolites in the environment have created a significant environmental concern over the years due to adverse effects. Consequently, DDT has been banned in many countries. However, it is still used in some countries including South Africa, particularly for vector-borne disease eradication programmes. Since the presence of DDT and its metabolites may provide an indication of the general exposure and use of these compounds, there was a need for such a study. Human breast milk samples (n ¼ 30) were collected from mothers within the age range of 19–40 years from the Thohoyandou area, South Africa. The liquid–liquid extraction method was used to extract DDT and its metabolites from the samples. The crude extracts were subjected to column chromatography for measurements of OC levels. The concentration ranges of the contaminants were as follows: not detected (ND) to1770 ng g^{-1} (2,4′-DDE); ND to 3977 ng g^{-1} (4,4′-DDE); ND to 3250 ng g^{-1} (2,4′-DDD); ND to 2580 ng g^{-1} (4,4′-DDD) and ND to 2847 ng g^{-1} (4,4′-DDT). The mean :EDDE, :EDDD and :EDDT obtained from the villages were 1180 ng g^{-1}, 830 ng g^{-1} and 690 ng g^{-1}, respectively. The total DDT ranged from 820–7473 ng g^{-1}. The estimated daily intake varied from 260 to 4696 ng g^{-1}, ND-10551 ng g^{-1} and ND-4237 ng g^{-1} for DDE, DDD and DDT, respectively. These values are significantly higher than the FAO/WHO acceptable daily intake (ADI) of 20 ng g^{-1}. The :EDDT was found to decrease with increasing age of the mothers. The observed high levels of DDE compared to DDT indicated chronic exposure of the mothers to DDT, which is metabolized to DDE and retained in the body.

Keywords: DDT; metabolites; human; breast milk; Thohoyandou; South Africa

Introduction

The presence of persistent man-made chemicals in our environment has been a common problem since a large number of these chemicals were identified in many environmental samples. Among all chemical pollutants, the presence of organochlorine compounds (OC) such as DDT (1,1,1trichloro-2,2-bis-(p-chlorophenyl)ethane and its stable metabolite DDE (1,1-dichloro-2,2-bis-(p-cholorophenyl)ethene in the environment has created significant environmental concern over the years due to their high chemical and biological stability and a high degree of lipophilicity.

Prior to the phasing out DDT in many countries, this OC was the best known, least expensive and probably one of the most widely-used insecticides (Staarc and Polder 1990). DDT efficacy against insects was demonstrated experimentally in 1942 and was put into full-scale production in an attempt to combat insect-borne diseases (Burnce 1994). Consequently, it was considered to be a significant contribution to public health. However, DDT and its metabolites were linked to hormonal interference in humans and wildlife (Kelce 1995; Colborn, Dumanoski, and Myers 1996; Cheek et al. 1999; Vos et al. 2000), through exerting endocrine disrupting effects such as blocking of the action of male hormones. Since then several studies have been conducted measuring DDT in various environmental samples (Bouwman et al. 1990, 2006; Okonkwo, Kampira, and Chingakule 1999, Okonkwo and Kampira 2002; Minh et al. 2004). Consequently, DDT and its metabolites were banned in most developed countries as far back as the 1970s and 1980s.

Despite the ban on the use of OC in many developed countries, DDT is still in use in some developing countries, including South Africa, for public health programmes. Earlier use of DDT in South Africa brought about great success in malaria prevention in some parts of the country, including Johannesburg and Pretoria. Ever since then, DDT has been used against mosquitoes in provinces such as Kwazulu Natal, Eastern Cape, Limpopo and Mpumalanga Provinces, although DDT was replaced with pyrethroids insecticides in 1995. However, due to the resistance developed by mosquitoes to pyrethroids and the increase in malaria cases, DDT was reintroduced with permission from WHO, although insecticide-bed treated nets are still very much encouraged.

As DDT and its metabolites are highly stable and lipophilic, chronic exposure to these compounds through the food chain resulted in the accumulation of these compounds in fatty tissues such as human breast milk. Human breast milk is unique as a matrix for bio-monitoring because it also serves as a food source for a segment of the human population (Groer, Humenick, and Wilson 2002). Thus, the analyses of breast milk for environmental chemicals as well as for nutrients are of wide scientific interest (Berlin et al. 2002). One of the earliest reports on the measurement of environmental chemicals in human breast milk was by Lang, Kunze, and Prickett (1951) who found that the breast milk from 32 women in the general population of Washington, DC contained an average concentration of 0.13 ppm DDT.

In South Africa, investigators measured the levels of DDT and its metabolites in human breast milk samples. Bouwman et al. (1990) reported the levels of DDT and other organochlorines from KwaZulu Natal (eastern part of South Africa). Recently, Bouwman et al. (2006) found that mothers from Jozini in KwaZulu Natal had significantly higher levels of DDT (:EDDT 4480 ng g^{-1} milk fat) than women in Kwaliweni (:EDDT 1100 ng g^{-1} milk fat) all in the same province. The DDT levels from Jozini were lower than the previous survey conducted 14 years ago from a comparable town close by, Mseleni, with :EDDT of 15 800 ng g^{-1} milk fat. The reduction was ascribed to the 5-year interval with no DDT application, before DDT application was resumed 1 year before sampling.

To date, there is a paucity of information on the levels of DDT and other OC in any environmental matrix, but particularly on mothers' milk in the Thohoyandou area (northern part of South Africa), despite the fact that large quantities of DDT have been sprayed in the area against mosquitoes in the past. For example, in 1998/99 spraying seasons, the Department of Health, Malaria Control Sector, applied over 24 metric tons of DDT (75% wettable powder) in houses in the Thohoyandou area. A follow-up study on possible DDT contamination in the area was never conducted. Since the presence of DDT and its metabolites may give an indication of the general exposure and use of these compounds and the danger of exposure of DDT to infants, there was a need to conduct a study, especially in those subjects that are highly vulnerable. The re-introduction of DDT in the area in the past few years for public health programmes added to the need to conduct this study.

Materials and methods

Location of study area

The study was undertaken in the Thohoyandou area under the Thulamela Municipality in Limpopo Province, South Africa. For practical reasons, the following villages were selected for the study: Tshilungoma, Mphego, Dumasi, Tshikhudini, Tshisele, Mulenzhe, Mutoti, Gondeni, Ha-Mukoma, Maniini, Makwarela, Thohoyandou, Makhuvha, Dididi, and Lufule. Figure 1 shows a map representing the study area and sampling sites.

Physiographically, the area is a hilly region with rugged terrain divided by some wide valleys. Bushveld savannah is the main type of vegetation on the floors, whereas the hill slopes and other highland areas are covered with a deciduous woodland type of vegetation. The region is generally warm to hot in summers with daytime temperatures in excess of 18^{o}–37^{o}C, and with cool to cold winters with an average temperature range of 14–21^{o}C.

Sample collection

A government clinic (Magwedzha) in Dumasi was identified as an ideal sampling collection point. Breast-feeding mothers between the ages of 19–40 were chosen for the study, and only those who had normal deliveries. Mothers expressed 5–50 mL of breast milk into thoroughly washed and oven dried glass bottles under the supervision of qualified nurses. A total of 30 milk samples were collected and placed in the freezer for preservation. These were later taken to our lab in a cooler box for analysis. Consent forms containing information about the project were given to the participating mothers for their approval. The WHO questionnaires were used to collect the following information: age, diet, number of children, longevity in the area, and frequency of spray, since these are known to influence the levels of DDT and its metabolites in human samples.

All glassware used were of the Pyrex brand. They were all soaked in dilute HNO_3 overnight, thoroughly washed and rinsed properly with distilled water, and finally with acetone. They were then dried in an oven at 80^{o}C for 24 h before use. One hundred milliliter glasses with screwed caps were used for the collection of milk samples and they underwent the same washing procedure as indicated above.

Reagents

DDT, DDE and DDD (Sigma Aldrich) standard solutions were used to establish the calibration curve with pentachloronitrobenze (PCNB) as the internal standard. PCNB was selected as an internal standard due to its high sensitivity, and was also analyzed using GC-ECD. The OC used are shown in Table 1. Analytical grade reagent chemicals, such as diethyl ether (AAR, 99% Set Point Instruments, SA), acetone (HPLC Reagent Grade, ACS, ISO, UV-VIS Spectroscopy 99.99% Sharlan), and n-hexane (GR, ACS, ISO 99%), isopropanol (HOLPRO Analytics PTY Ltd, SA) and methanol (AR of 99.99% purity Bio-zone Chemicals, SA) were used as extracting solvents for liquid–liquid extractions.

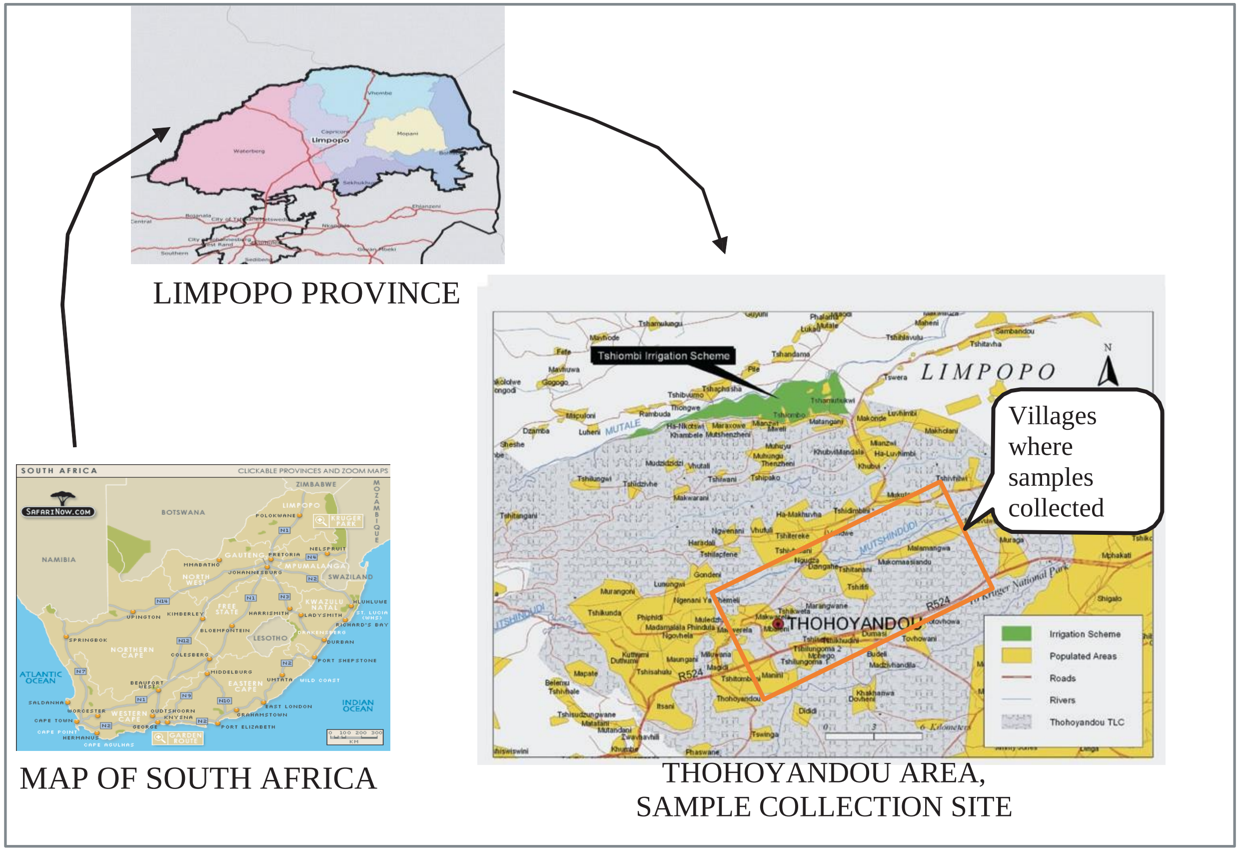

Figure 1. Study area and sampling sites.

Table 1. Standard organochlorine compounds used in the study.

Compounds	Purity (%)
4,4′-DDE	99
2,4′-DDE	99
2,4′-DDD	99.5
4,4′-DDD	97.5
4,4′-DDT	99
Pentachloronitrobenzene (is)	99

Florisil® 60–100 mesh (Aldrich); sodium oxalate (99% Hopkins and Williams USA); anhydrous sodium sulphate (anhydrous powder), and sulfuric acid 98% (Rochelle Chemicals SA) used for column chromatography were all of analytical reagent quality.

Determination of limits of detection (LOD)

The limits of detection of (LOD) for the specific compounds were determined as three times the SD of the blank (Miller 1998). From the stock solution of each standard, several dilutions were made in the preparation of lower concentrations (20–200 $\mu g L^{-1}$). This was done by injecting 1 μL of each concentration three times into the GC-ECD up to the lowest concentration where the instrument was not able to detect a compound. The least concentration that the instrument detected was taken as the lowest instrument detection limit of a particular compound.

Liquid–liquid extraction of human breast milk samples

The extraction method employed in this study was as described by Okonkwo, Kampira, and Chingakule (1999) and modified by Cok et al. (1997) and Burke, Holden, and Shaw (2003). In brief, the frozen milk samples were thawed to room temperature, homogenized, and 5 mL methanol and 0.1 g of sodium oxalate were added to 10–20 mL samples, shaken for 5 min and left for 2 h. Extraction was performed with 15 mL of hexane/diethyl ether (1 : 1 v/v). The organic upper layer was collected and extraction repeated thrice. The solvents from the combined organic extracts were removed under a stream of nitrogen and the fat weight determined gravimetrically. In order to remove the fat and other polar materials, the extracted fat was re-dissolved in 2 mL hexane and 5 mL concentrated sulfuric acid. This was centrifuged for 15 min at 800 g. The acid residues were then extracted twice with an additional 2 mL hexane. The organic phase was collected and dried in a flow of nitrogen. Dried residues were dissolved into 2 mL hexane and then passed through column chromatography for clean up.

Column chromatography

For column chromatography, a glass column was packed with 1–2% (v/m) fluorosil and anhydrous Na_2SO_4 placed at the top to remove any water that may be present in the extracts. The extracts were placed into the column and thereafter eluted with 10 mL hexane followed by 10 mL hexane: methanol: isopropanol (45 : 40 : 15, v/v/v). Both elutes were then collected and dried in a stream of nitrogen. The dry residues were dissolved in 0.5 mL hexane and 0.2 mL of PCNB internal standard was added.

Chromatographic analysis

The chromatographic apparatus used was GC17A (SHIMADZU) coupled with an electron capture detector (ECD). The chromatographic column used was ZB-5, 5% phenol, 95% – dimethylpolysiloxane (30 m x 0.25 idnm, 0.25 film thickness in mm-Separations, SA). The carrier gas flow rate was 1.8 mL min^{-1} and the make-up gas used was nitrogen (AFROX, SA) with a minimum purity of 99% with a total flow of about 42 mL min^{-1}. The carrier gas flow rate was measured using a soap bubble flow meter connected to the detector exit. The injector port and detector temperatures were 250°C and 300°C, respectively. The column initial temperature was 110°C held for two min and programmed to 210°C at a rate of 25°C min^{-1}, held for two min, and then increased to 270°C at a rate of 5°C min^{-1} and held for five min, and then finally to 290°C at 5°C min^{-1}. The final temperature was held for an additional five min. With a 1 mL analytical syringe (Klebur Chemicals) sample volumes of 1 mL were injected into the chromatograph in the splitless mode with the valve closed for about 90 sec. Injections were carried out in triplicate and the peaks were well separated under the above conditions. The analyte species were identified by comparing their retention times with those of the standards.

Quality control

In order to test the performance of the extraction method, five aqueous milk fractions containing up to 50 mL of milk samples were selected for this exercise. This was divided into smaller fractions of 5 mL and then spiked with 1 mL 50–500 mg L^{-1} of standard 2,4-DDE, 2,4-DDD, 4,4-DDE, 4,4-DDD and 4,4-DDT. All the spiked samples were thereafter extracted, subjected to column chromatography, concentrated and analyzed as described earlier. A reagent or extraction blank, consisting of deionized water in an equal amount to the sample, was included in every batch of samples.

Statistical analysis

Correlation ($p \leq 0.05$) were performed using a one-way Spearman test. Standard deviations, mean and median were calculated using Microsoft Excel.

Results and discussion

The results of the recovery tests and the limits of detections are summarized in Table 2. The percentage of recovery ranged from 80 to 130%, and the limit of detection obtained ranged from 5 to 100 mg L^{-1}. The high percentage recovery values obtained validated the method used.

Human breast milk sample analysis (LLE)

The concentrations of OC in human breast milk expressed as lipid weight are summarized in Table 3. The mean concentrations of DDE, DDD and DDT ranged from non-detectable (ND) to 3977, ND-3, 330 and ND-2847 ng g^{-1} lipid wt, respectively. In some villages such as Dumasi (DMS), Gondeni (GNN), and Thohoyandou (THN) and Mutoti (MTT), DDT was not detected in samples obtained. However, only 4,4′-DDE and DDD were detected in Thohoyandou village. Since these compounds are breakdown products of DDT, this may suggest that application of DDT in Thohoyandou may have occurred in the past. 4,4′-DDE and 2,4′-DDD were not detected in the samples from Tshikhudini (TLM); and 2,4′-DDD, and 4,4′-DDD were not detected from Mangondi (MND), Tshikhudini (TKD) and Tshilungoma (TLM) villages. This may suggest recent spray of DDT in these villages. Further examination of DDT composition in Table 3 revealed that DDE was the predominant compound accounting for 90–95% of the total DDT concentrations. DDE was detected in all the villages except Tshilungoma (TLM) and Thohoyandou (THN). This observation was attributed to the breakdown of DDT as a result of prolonged application of DDT within the area. Kanja et al. (1992) suggested that the presence of high levels of DDE in the breast milk was an indication of chronic exposure of the mothers to DDT. The DDT range reported in the present study is significantly higher than that reported by Bouwman et al. (2006) from KwaZulu Natal, South Africa and Burke, Holden, and Shaw (2003) from Indonesia, but significantly less than the levels reported by Bouwman et al. (1990) and Minh et al. (2004) from Hanoi and Hochininh cities in Vietnam. The presence of DDT in the samples analyzed indicated that the mothers who participated in the present study may have been exposed to DDT, which was used extensively in the public health programmes within the study area.

Table 2. Recoveries of OC in spiked milk samples and limits of detection.

Compound	Added amount (ng)	Recovery	Limits of detection ($mg\,L^{-1}$)
2,4′-DDD	50–500	80	20
4,4′-DDD	50–500	130	10
2,4′-DDE	50–500	120	5
4,4′-DDE	50–500	90	20
4,4′-DDT	50–500	94	5

Table 3. Mean concentrations of DDT and its metabolites in human breast milk ($ng\,g^{-1}$ lipid wt) from different villages in the Thohoyandou area, Limpopo Province, South Africa.

Villages	Mean ± SD ($ng\,g^{-1}$)					
	2,4′DDE	4,4′DDE	2,4′DDD	4,4′DDD	4,4′DDT	DDTs
LFL	840[y]	290[y]	340[y]	230[y]	540[y]	2 240[y]
MND	500 ± 0.47	3977 ± 4.47	ND	150 ± 0.14	2847 ± 3.96	7 473 ± 6.78
MNN	340 ± 0.48	85 ± 0.12	1830 ± 2.59	440 ± 0.06	625 ± 0.15	3 320 ± 2.98
DMS	647 ± 0.53	267 ± 0.29	200 ± 0.35	180 ± 0.18	ND	2 730 ± 0.31
BDL	290 ± 0.58	26 ± 0.07	28 ± 0.02	85 ± 0.17	483 ± 0.33	925 ± 0.81
TKD	178 ± 0.40	336 ± 0.18	304 ± 0.70	ND	376 ± 0.36	1 194 ± 0.67
TLM	850 ± 0.42	ND	1 330 ± 1.88	ND	365 ± 0.51	2 545 ± 1.29
GNN	245 ± 0.35	415 ± 0.58	ND	ND	ND	660 ± 0.93
MKV	270 ± 0.38	1015 ± 1.32	3250 ± 4.60	205 ± 0.29	545 ± 0.32	5 285 ± 0.30
THN	ND	560[y]	ND	260[y]	ND	820[y]
MTT	1770 ± 1.06	100 ± 0.14	ND	60 ± 0.08	ND	1930 ± 1.29
MPG	700 ± 0.75	130 ± 0.18	ND	2580 ± 3.00	305 ± 0.43	5 930 ± 3.13

Notes: LFL-Lufule, MND-Mangondi, MNN-Maniini, DMS-Dumasi, BDL-Budeli, TKD-Tshikhudini, TLM-Tshilungoma, GNN-Gondeni, MKV-Makhuvha, THN-Thohoyandou, MTT-Mutoti, MPG-Mphego.
ND ¼ not detected.
[y]Only one sample collected from the villages.

The levels of :EDDE, :EDDD and :EDDT are given in Table 4. :EDDE exhibited the highest mean, median and maximum values of 1180 ng g^{-1}, 850 ng g^{-1}, and 9930 ng g^{-1}, respectively. This was followed by :EDDD with a fall in the median value compared to that of :EDDT. That the lowest value was obtained for :EDDT except the median value may indicate the breakdown process of DDT into its metabolites, and thus reduction in the body burden of such contaminants.

It is known that adult females excrete lipophilic contaminants such as OC via lactation. In order to determine whether there was any correlation between maternal age and fat content of the milk samples, data in Table 5 examined DDT content and maternal age. Mothers were classified arbitrarily according to their age into three groups: 19–22, 23–26, and 27–30, since most of the mothers' ages were within 19–30 except one 40-year-old mother. The table shows that as the percentage of lipid content increased, there was an increase in sum DDT and thereafter a fall in the sum DDT in the older mothers (27–30). The decrease in sum DDT with age is in agreement with the report by Saxena and Siddiqui (1982), although other studies found no correlation between maternal age and DDT levels (Hernandez et al. 1993; Spicer and Kereu 1993; Okonkwo, Kampira, and Chingakule 1999). It is possible that other variables such as diet, number of pregnancies and duration of residence may also contribute to the level of DDT in mothers.

The results of the estimated daily intake (ADI) are shown in Table 6. The results were calculated based on the assumption that the average milk consumption by the infants (3–7 kg) was 700 g/day[21]. The mean values for daily intake of OC were estimated by using Equation (1)

$$\mathrm{DI} \ ¼ \ \frac{C_{\mathrm{milk}} \times 700\,\mathrm{g} \times C_{\mathrm{lipid}}}{3-7\,\mathrm{kg}} \qquad ð1Þ$$

where DI is daily intake (ng g^{-1} body wt day^{-1}); C_{milk} ¼ concentration of the chemical in milk (ng g^{-1} lipid wt); C_{lipid} ¼ lipid content in milk (%).

Table 4. Summarized levels of OC (:EDDE, :EDDD and :EDDT) in human breast milk from the Thohoyandou area, Limpopo Province of South Africa.

Statistical variables	Compounds		
	:EDDE (ng g^{-1})	:EDDD (ng g^{-1})	:EDDT (ng g^{-1})
Mean	1180	830	690
Median	850	170	320
Minimum	80	120	320
Maximum	9930	6910	370

Table 5. Maternal age, percentage lipid content and sum DDT (ng g^{-1} fat wt) of milk samples studied.

Age range	Percentage sum lipid content	Sum DDT
19–22	21.9	10223
23–26	24.8	11805
27–30	35.1	7719

The DI levels obtained differed from one village to another. This is not surprising since the weights of the infants varied from 3–7 kg during sample collection. Furthermore, different levels of OC were obtained from samples collected from the villages, as indicated earlier in Table 3. However, it was recognized that the levels of DI for DDE, DDD and DDT significantly exceeded the FAO/WHO guideline of 20 ng g^{-1}. This finding raises concern on infant health since children are highly susceptible to effects from environmental contaminants. Differences in dietary habits, socio-economic status, and metabolic rates of the donors as well as the frequency of spray of DDT in the area may have contributed to the wide differences in DI levels obtained from the various villages. However, because of the well-recognized advantages of breast-feeding, this practice should not be discouraged (Kacew 1993, 1997). The present study should be applied to introduce better practice in the use of DDT.

A comparison of the average levels of OC obtained in the present study to similar studies conducted in various countries was conducted as shown in Table 7. The upper range mean concentrations for DDE and DDT reported herein are significantly lower than that reported in Vietnam by Schecter et al. (1989) and Minh et al. (2004), except the DDT range for Hochinminh city, but significantly higher than the value for Swaziland (Okonkwo, Kampira, and Chingakule 1999). With respect to total DDT, the upper range reported in the present study is approximately 2-fold lower than that reported by Bouwman et al. (1990) for KwaZulu Natal, South Africa, 17 years ago, and Hong Kong (Ip and Philips 1989). However, the recent report by Bouwman et al. (2006) for the same area is significantly lower than the value obtained in the current study. It is worth noting that the total DDT levels reported by Ramakrishnan et al. (1982) are fairly close to the values reported herein. It can also be observed from Table 7 that the reported total DDT from India (Saddiqui et al. 1981; Jani et al. 1988) are lower than the total DDT reported herein.

Table 6. Estimated daily intake (ng g^{-1} body wt day^{-1}) of OC by infants in Thohoyandou.

Villages	Mean (ng g^{-1})		
	DDT	DDD	DDE
LFL	996	754	714
MND	4237	619	4696
MNN	438	1736	322
DMS	ND	283	1019
BDL	533	248	260
TKD	280	230	506
TLM	357	10551	419
GNN	ND	ND	629
MKV	494	2741	1023
THN	ND	217	468
MTT	ND	41	1465
MPG	242	2668	821

Notes: LFL-Lufule, MND-Mangondi, MNN-Maniini, DMS-Dumasi, BDL-Budeli, TKD-Tshikhudini, TLM-Tshilungoma, GNN-Gondeni, MKV-Makhuvha, THN-Thohoyandou, MTT-Mutoti, MPG-Mphego.
ND ¼ not detected.

Table 7. Mean concentrations of OC residues in women from various countries from 1980s–2007.

Country	Year of study	p,p′.DDE	p,p′.DDT	Reference
Canada	1987	29.22 mg mL^{-1}	2.45 mg mL^{-1}	Dewailly et al. (1996)
Hong Kong	1985		^{z}13800	Ip and Philips et al. (1989)
India	1980		^{z}4800 ng g^{-1}	Saddiqui et al. (1981)
India	1982		^{z}6060 ng g^{-1}	Jani et al. (1988)
India	1984		^{z}1890–8000	Ramakrishnan et al. (1985)
Indonesia	2002	50 ng g^{-1}	110 ng g^{-1}	Burke et al. (2003)
Italy	1985	1400 ng g^{-1}	250 ng g^{-1}	Dommarco et al. (1987)
South Africa	1987		^{z}15830 ng g^{-1}	Bouwman et al. (1990)
South Africa	2006		^{z}4480 ng g^{-1}	Bouwman et al. (2006)
Spain	1991	18.7	0.40	Hernandez et al. (1993)
	2004	509 ng g^{-1}	96 ngg^{-1}	Botella et al. (2004)
Swaziland	1999	20 ng g^{-1}	1130 ng g^{-1}	Okonkwo et al. (1999)
Sweden	1999	145 ng g^{-1}		Aune et al. (1999)
Sweden	1999	5.3 ng g^{-1}	0.2 ng g^{-1}	Atuma et al. (1999)
Turkey	1995/6	20.13 ng^{-1}	1.00	Cok et al. (1997)
UK	1979–80	0.041 mg kg^{-1}	0.003 mg kg^{-1}	Collins et al. (1982)
Vietnam	1989	6700 ng g^{-1}	4700 ng g^{-1}	Schecter et al. (1989)
	2003 (Ho)	340–16000 ng g^{-1}	100–1000 ng g^{-1}	Minh et al. (2004)
	2003 (H)	420–6300 ng g^{-1}	34–6900 ng g^{-1}	Minh et al. (2004)
Zimbabwe	1990	6000 mg kg^{-1}	305–2847 ng g^{-1}	Minh et al. (2004)
Current study	2007	26–3977 ng g^{-1}	^{z}820–7473 ng g^{-1}	

Note: Ho ¼ Hochinminh; H ¼ Hanoi; ^{z} ¼ Total DDT.

Conclusion

The concentrations of OC determined in the current study are significantly higher than the values reported from other countries. The obvious hazard associated with breast feeding is the possible transfer of contaminants in breast milk from mother to child. However, human breast milk is known to contain host resistant factors and offers the infant an immunological protection (Kacew 1993). Suckling also offers emotional bonding between mother and child (Kacew 1994). On the other hand, the levels of OC obtained in the present study are high and, therefore, there are several reasons for anxiety. Based on the well-recognized advantages of breast feeding, this practice should not be discouraged; the results of the present study should be applied to introduce better practice into the use of DDT within the study area.

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