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Levels and Profiles of Organohalogenated Contaminants in Human Blood from Egypt

Mohamed Abou-Elwafa Abdallah[1,2*], Amen Hamdy Zaky[3] and Adrian Covaci[4]

[1]Division of Environmental Health and Risk Management,
School of Geography, Earth, and Environmental Sciences,
University of Birmingham,
Birmingham, B15 2TT,
United Kingdom.

[2]Department of Analytical Chemistry
Faculty of Pharmacy, Assiut University
71526 Assiut,
Egypt

[3] Medical Oncology Department,
South Egypt Cancer Institute, Assiut University,
Assiut, Egypt

[4] Toxicological Center,
University of Antwerp,
Universiteitsplein 1
2610 Wilrijk, Belgium

* Corresponding author
Email mae_abdallah@yahoo.co.uk
Tel. +44121 414 5527
Fax. +44121 414 3078

Abstract

Concentrations of polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs) and some organochlorine pesticides (OCPs) were determined -*for the first time*- in serum of Egyptian colorectal cancer patients (n=35) and compared to a healthy control group (n=32). p,p`-DDE (the major metabolite of DDT) was the most frequently detected contaminant with the highest concentration (median = 131 ng/g lw) in all studied serum samples. BDE-209 was the least frequently detected contaminant with a median concentration <0.3 ng/g lw. The contamination profile in patients and controls was almost identical with p,p`-DDE showing the highest median contribution (77%) and oxychlordane the lowest (1%). The low p,p`-DDT/p,p`-DDE ratio (3.7%) in serum implies bioaccumulation and past exposure to DDT (c.f. recent and ongoing intake) . Statistical analysis revealed no significant differences (P>0.05) between the levels of target contaminants in serum of patients and the control group. Gender, age and body mass index (BMI) were investigated as potential factors influencing serum contaminant levels. ΣDDT, hexachlorobenzene and pentachlorophenol concentrations showed significant positive associations with age and/or BMI of the participants. Comparison with other countries revealed concentrations of PBDEs and PCBs in Egyptian serum among the lowest reported worldwide.

Keywords: Organohalogen contaminants, OCPs, PBDEs, PCBs, Egyptian blood, Colorectal cancer

Introduction

Organohalogen contaminants (OHCs) are a diverse group of chemicals including organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs). Despite their various applications, these compounds are highly lipophilic, persistent in the environment and capable of bioaccumulation and biomagnification along the food chain.[1, 2] Moreover, numerous toxicological studies have associated different OHCs with adverse health effects including endocrine disruption, reproductive, developmental and neurological toxicity, type 2 diabetes and different types of cancer.[3-6] Combined with their ubiquitous distribution in almost all biotic and abiotic environmental compartments, these features have led to global concern over the production and use of OHCs. As a result, most OCPs, PCBS and PBDEs are currently listed as persistent organic pollutants (POPs) under the UNEP Stockholm Convention.[1]

While the regulatory actions have led to levelling off and even slight decline of the environmental concentrations of various OHCs in different regions, human exposure to these contaminants still occurs via direct and indirect pathways.[7] Several authors have documented the association between certain types of food (e.g. fish) and elevated serum levels of OCPs and PCBs,[8, 9] while others established significant positive correlations between PBDEs in indoor dust and their serum levels.[10] Recently, dermal uptake has been highlighted as a potential pathway of human exposure to PCBs and PBDEs. [11]

Due to their relevance for public health and associations with various diseases, several countries have collected extensive data on the occurrence and levels of OHCs in their population.[12-15] However, very little is known about the concentrations of OHCs in the blood of the Egyptian population. Furthermore, epidemiological studies have raised concerns over the increased incidence of colorectal cancer among the Egyptian

population, especially that patients under age 40 constitute 35.6% of all colorectal cancer cases in Egypt.[16, 17] Few authors have investigated genetic, dietary and life-style factors as potential determinants for the increased incidence of colorectal cancer in Egypt. Abdel-Rahman et al. reported an association between polymorphisms in the gene for the DNA repair enzyme XRCC1 with increased risk of colorectal cancer among Egyptians. Interestingly, an association between the studied polymorphisms and early age of disease onset was observed.[18] An epidemiological study of cancer of all organ sites in Gharbiah Province of Egypt from 1999 to 2002 revealed higher urban than rural incidences among both men and women for colorectal cancer.[19] This was linked to dietary preferences of the urban population with higher contribution of meat and fat as opposed to vegetables. Dietary risk factors were further highlighted by the results of another study from Minia governorate, where the most significant dietary and lifestyle colorectal cancer risk factors were higher consumption of red meat, preserved food, artificial sweeteners and fast foods.[20] However, the relationship between exposure to chemical environmental contaminants and colorectal cancer in Egypt is yet to be fully explored. This may be partly attributed to the lack of information on the levels of different OHCs in the Egyptian population. Therefore, the aims of the current study are: (a) to provide first insights into the occurrence and levels of PBDEs, PCBs in addition to some OCPs in serum of Egyptian colorectal cancer patients, (b) to compare the levels of target OHCs in serum of patients to an age- and sex- matched control group, (c) to investigate possible correlations between the levels of OHCs in patients and their age, sex or body mass index (BMI) and finally (d) to compare the levels of target OHCs in the Egyptian serum with those reported from other countries.

Materials and Methods

Target Compounds

The OHCs investigated in this study include:

(a) Polychlorinated biphenyls (PCBs) no. 118, 138, 153, 170, 180.

(b) Polybrominated diphenyl ethers (PBDEs) no. 47, 99, 100, 153, 154, 183, 209

(c) Organochlorine pesticides, namely: pentachlorophenol (PCP), hexachlorobenzene (HCB), oxyhchlordane (OxC), 4,4`-dichlorodiphenyldichloroethylene (p,p′-DDE) and 4,4`-dichlorodiphenyltrichloroethane (p,p′-DDT).

Reagents and chemicals

Solvents and chemicals used for analysis were of HPLC grade (Sigma-Aldrich, St. Louis, MO 63103 USA). Oasis® HLB SPE cartridges (6 mL/500 mg, 30 μm) were obtained from Waters (Milford, MA 01757 USA), while empty polypropylene cartridges (3 mL) and corresponding frits were purchased from Supelco (Bellefonte, PA, USA). Individual standards of OCPs and PCBs were obtained from Dr.Ehrenstorfer Laboratories (Augsburg, Germany), while PBDEs standards were purchased from Wellington Laboratories (Guelph, ON, Canada).

Sample collection

Blood samples (5 mL, n=35) were collected from colorectal cancer patients admitted to the South Egypt Cancer Institute (SECI) between October and December 2012, while control samples (n=32) were obtained from the Upper Egypt Blood Bank from healthy donners at the same period. Informed consent was obtained from each participant following approval of the research protocol by the SECI ethics committee. Selection

criteria included Egyptian nationality, living in the Upper Egypt region for the last 8 years and lack of occupational exposure to any of the studied chemicals. Exclusion criteria were family history of colorectal cancer, patients with a primary cancer other than colorectal cancer and severely ill cases. The controls were healthy, unrelated to the patients, from the same geographical area and with no family history of colorectal cancer. Demographic information on the participants' age, sex and BMI are provided in table SI-1.

The serum was separated by centrifugation, transferred to clean tubes and kept frozen at −20°C until analysis. Cholesterol and triglycerides were determined at the collection clinic using routine laboratory analysis then the value for total lipids (TL) was estimated according to the method of Phillips et al. [21]

Sample extraction and clean-up

Sample extraction and clean-up were performed according to a previously reported method.[22] Briefly, thawed and homogenized serum samples (~3 mL) were spiked with internal standards mixture (BDE-77, BDE-128, ^{13}C-BDE-209, PCB 143, Ɛ-HCH), then mixed with 2 mL of milliQ-H_2O and 50 µL of formic acid prior to ultrasonication for 20 min. The equilibriated samples were loaded onto pre-conditioned Oasis HLB cartridges, rinsed with 4 mL of milliQ-H_2O and dried under vacuum. Target analytes were eluted with 10 mL of DCM:MeOH (4:1, v/v) and 2.5 mL of hexane. The eluate was dried under a gentle stream of N_2 and resolubilized in 500 µL of hexane:DCM (9:1, v/v).

The crude extract was cleaned-up over 800 mg of pre-washed silica topped with 100 mg of 10% acid silica packed in 3 mL polypropylene SPE cartridges. PCBs, PBDEs and DDTs were eluted first by 8 mL of hexane, followed by PCP in 10 mL of DCM. The 1st fraction was evaporated and redissolved in 80 µL of isooctane containing 100 pg/µL of PCB129

and ^{13}C-BDE-100 used as recovery determination (syringe) standards (RDS) for quality assurance/quality control (QA/QC) purposes. The 2nd fraction was derivatized by methylation and finally redissolved in 80 µL of iso-octane containing 100 pg/µL of PCB129 used as RDS. Further details are provided in the SI section.

Gas chromatography/mass spectrometry (GC/MS) analysis

Instrumental analysis of target analytes was performed using a FOCUS GC coupled to a DSQII mass spectrometer (Thermo Fisher Scientific, Austin, TX, USA). Separation of target analytes was achieved on an Agilent DB-5 column (15m x 0.25mm; 0.1 µm). The mass spectrometer was run in selected ion monitoring (SIM) with ion source, quadrupole and mass transfer line temperatures set at 230, 150 and 300 °C, respectively. Further details of the GC/MS methods[22] are provided in the SI section.

QA/QC

A multi-stage QA/QC protocol was adopted to investigate the accuracy and precision of the applied analytical method at different stages. Five-point calibration curves were created for all the analytes with a good linearity ($R^2 \geq 0.986$) across the studied concentration range. None of the target compounds was above the detection limit in procedural blanks (n=8) analysed alongside the serum samples. Method accuracy and precision were evaluated via replicate analysis (n=5) of NIST SRM1958 (organic contaminant in human serum). Our results compared favourably with the certified concentrations of all target compounds (Figure SI-1) indicating good accuracy and precision of the applied method. Good recoveries (72-114%) were obtained for all the surrogate standards.

Statistical analysis

Statistical analysis of the data was conducted using Excel (Microsoft Office 2010) and SPSS version 22.0. Statistical distribution within each dataset was evaluated using *Kolmogorov-Smirnov* goodness of fit tests. The results - combined with visual inspection of frequency diagrams - revealed concentrations in all data sets to deviate significantly from the normal distribution. Hence, further statistical analysis was performed using non-parametric tests (e.g. Wilcoxon signed rank test and Spearman rank order correlation). In all instances, where concentrations were ≤ LOQ, (limit of quantification) concentrations were assumed to equal half the LOQ (Table SI-2) and *P* values <0.05 were considered significant.

Results and discussion

Occurrence and levels of OHCs in Egyptian serum

All target PCBs, PBDEs and OCPs were detected in the analysed serum samples. A statistical summary of target OHCs concentrations in the analysed samples is provided in Table 1 (the full dataset is given in Table SI-5). p,p`-DDE was the only target compound to be detected in all the analysed serum samples, with the highest median concentration (131 ng/g lw, n=67). BDE-209 was the least frequently detected contaminant (detection frequency = 36%) with a median concentration below the method LOQ. Interestingly, the OHC contamination profile in patients and control was almost identical. ΣDDT (calculated as p,p`-DDE + p,p`-DDT) showed the highest median contribution to the OHC profile in serum of patients and control (77%), while oxychlordane showed the lowest contribution (1%) (Figure 1). This is not dissimilar to previous reports of OHC profiles in serum of non-occupationally exposed adults from

Romania, Belgium, Pakistan, Saudi Arabia, USA and Canada.[12, 22-24] Predominance of p,p`-DDE as the major OHC in serum has been attributed to a combination of factors including continuous exposure via diet or breast milk, high bioaccumulation potential and biomagnification along the food chain, in addition to long elimination half-life (median $t_{0.5}$ of p,p`-DDE in human serum was more than 8 years).[25] Moreover, while DDT is listed under the Stockholm Convention on POPs, several countries in Africa, Asia and Latin America still use DDT for vector control. This can halter the international efforts to reduce the global contamination levels with this chlorinated pesticide, due to its environmental persistence and potential for long-range atmospheric transport. In Egypt, DDT was used as a pesticide for cotton fields (1952-1971) with reported stockpiles of 600 tons. [26] It has been officially prohibited from agricultural use since 1980, and in 1996 a Ministerial Decree prohibited the import and use of multiple pesticides including DDT in Egypt.[26] While the higher levels of p,p`-DDE (the main metabolite of DDT) compared to p,p`-DDT in Egyptian serum (Table 1) is expected given its longer half-life and bioaccumulation potential, the ratio between p,p`-DDT/p,p`-DDE can be used to differentiate between current and historical exposures to this pesticide.[27] The low p,p`-DDT/p,p`-DDE ratio (3.7%) in this study implies high environmental persistence and bioaccumulation (c.f. recent and ongoing intake) as the major sources of DDT exposure.[27]

A literature survey revealed one study reporting levels of p,p`-DDE, p,p`-DDT and HCB in Egyptian colorectal cancer patients (n=31) and control (n=17) serum samples collected in 1996.[28] Notwithstanding the caveats related to the analytical methodology applied at this time, the median concentrations of p,p`-DDE, p,p`-DDT and HCB in the current study are approximately half of those reported in 1996.[28] Similarly, Tawfic et al. reported mean ΣPCBs concentrations of 54 ± 17, 59 ± 23 and 61 ± 21 ng/g whole weight

in serum samples of Egyptian females diagnosed with invasive adenocarcinoma of the breast (n=43), suffering benign breast disease (n=21) and normal healthy females (n=11), respectively.[29] These levels reported in the year 2000 are substantially higher than mean ΣPCBs in serum of colorectal cancer patients and control group in the present study (Table 1). This is generally in agreement with the globally observed decrease in the levels of these legacy POPs in the environment and humans as a result of various legislations that ban their production and use.[30]

To the authors' knowledge, this is the first study to provide levels of PCP, OxC, and PBDEs in Egyptian serum or any other human matrices, which precludes any discussion of the temporal trends of these contaminants in the Egyptian population.

Comparison of OHC levels in serum of patients and control group

Due to the non-parametric distribution of the generated datasets, Wilcoxon signed rank test was used to compare the differences in median and distribution between the concentrations of target OHCs in colorectal cancer patients and the control group. No statistically significant differences ($P>0.05$) were observed between the levels of individual target OHCs, ΣPCBs, ΣOCPs, ΣPBDEs and ΣOHCs in serum of colorectal cancer patients and the control group (Table SI-4). The median percent contribution of the studied OHCs to the overall contamination profile in serum of patients and control group was almost identical (Figure 1). Interestingly, the mono-ortho-PCB 118 was the only investigated contaminant showing border line significant difference ($P=0.053$) between its concentrations in serum of patients (median = 2.9 ng/g lw) and control group (median = 0.5 ng/g lw). This is in line with the findings of Howsam et al. who reported an elevated risk of colorectal cancer in Catalan population (n= 137, controls = 76) associated with higher serum concentrations of mono-ortho PCB congeners 28 and

118, while HCB and p,p'-DDE produced no significant increases in colorectal cancer risk.[31] Similarly, a previous study from Egypt reported no significant differences in levels of p,p'-DDE, p,p'-DDT and HCB, in serum of colorectal cancer patients (n= 31) compared to a healthy control group (n = 17).[28] However, other studies from Tunisia (n = 69, controls = 56 females) and Singapore (n = 60, controls = 60 males) have indicated positive associations between concentrations of p,p'-DDE and various PCBs in serum and the risk of breast and prostate cancers, respectively.[32, 33] Therefore, bearing in mind the relatively small sample number; the lack of significant differences between serum levels of OHCs in colorectal cancer patients and the control group in the current study should be interpreted with caution. More research is required on a larger sample size to confirm these findings.

Factors affecting the levels of OHCs in Egyptian serum

Gender, age and BMI were investigated as potential factors influencing the levels of target OHCs in the studied serum samples. The use of other socio-economic factors (e.g. profession, location, diet, income and education) was not allowed by the Ethics Committee to maintain the anonymity of the study participants.

No statistically significant differences (Wilcoxon signed rank test, $P>0.05$) were observed between the concentrations of OHCs in the serum of males and females among the colorectal cancer patients and the control group. Therefore, we pooled the results from both males and females to study possible associations between contaminant levels in serum, age and BMI of the study participants in the patients and control group (Table 2). Results revealed a significant positive correlation between the levels of ΣDDT and the age of the blood donners (Table 2). Previous studies from France (n = 386, aged 18-74 years, randomly selected among the participants in the French Nutrition and Health

Survey),[34] Spain (n= 1259 pregnant women, aged >16 to 40 years),[35] USA (n=192 healthy females, aged 45 to 85 years)[36] and UK (n=153 healthy volunteers, aged 22-80 years)[15] have also reported significant increase of serum DDT concentrations with age. This can be explained by the long half-life and high bioaccumulation potential of DDT, combined with decreased metabolism and elimination of OCPs with increasing age[27]. Despite its lipophilic nature, published results differ with regard to the association between DDT serum levels and BMI.[12] While ΣDDT was significantly correlated with BMI in the present study, no significant association was observed in French adults (despite half the population with BMI > 25 including 15% with BMI >30).[34] This may be attributable to differences in exposure (e.g. diet) and socioeconomic (e.g. profession) factors influencing the serum levels of OHCs in different populations.[34] It's worth mentioning that the concentrations of p,p`-DDE in the present study contributed 96 ± 23% and 83 ± 34% to ΣDDT and ΣOCPs, respectively. Therefore, it's reasonable to conclude that the significant positive associations of serum ΣDDT and ΣOCPs with participants age and BMI (Table 2) are driven mainly by the concentrations of p,p`-DDE.

Interestingly, PCP levels, the second largest contributor to serum ΣOCPs, showed a significant positive correlation with ΣDDT concentrations in both the patients and control groups (Table 2). There is no clear explanation for this strong correlation. In addition to direct exposure via diet, it has been suggested that PCP in serum can result from HCB metabolism.[23] Since no significant correlation was observed between the levels of ΣDDT and HCB or PCP and HCB in serum (Table 2), it is likely that the correlation between ΣDDT and PCP concentrations originate from common exposure sources to these two contaminants (e.g. diet).

PCP levels were significantly correlated to BMI in the serum of the control group. A possible explanation for this association is that BMI could alter PCP toxicokinetics and

accumulation of the compound in body fat resulting in increased internal concentration in obese individuals.[37] HCB levels showed a significant correlation with patients' age (Table 2), which may be attributable to bioaccumulation resulting in increased serum concentrations with age.[12, 34]

Comparison with other countries

The concentrations of target OHCs in the analysed Egyptian serum samples (n=67, patients + control group) were compared to those reported previously from other countries (Figure 2 and Table SI-6). While we are aware that studies from different countries have targeted various populations (e.g. pregnant women, males, diabetic patients and general population) of different age groups with different lifestyles and habits, we believe that such comparison is beneficial to provide a general perspective of the measured concentrations of target OHCs in human blood from Egypt compared to other parts of the world. This is of particular interest given the global distribution of the studied contaminants and the synchronised international efforts required to minimize exposure and reduce human body burdens of these OHCs.

Median HCB level (5.9 ng/g lw) in Egyptian serum was at the lower end of this contaminant concentrations reported globally. This is consistent with low serum HCB concentrations in other developing countries like Saudi Arabia (*n=60, 40 diabetic patients and 20 healthy controls*),[24] Pakistan (*n=85, 34 mothers, 34 children (3-10 years) and 17 general population*)[22] and Bangladesh (*n=24 males*) .[38] Higher serum HCB concentrations were reported from China (n=26, median = 39 ng/g lw)[39], Spain (n=2433, median = 34 ng/g lw)[40] and USA (n = 341 males, 15 ng/g lw).[41] This may reflect less historical use of HCB in the developing countries. In Egypt, HCB was detected at concentrations of 4 - 93 ng/L in water samples collected at different locations along

the river Nile in 1995. It was also detected at low levels in Egyptian fish (2.5-20 ng/g wet weight) and vegetables (3-9 ng/g wet weight)[42], indicating dietary intake as the predominant source of human exposure to HCB.

PCBs in Egyptian serum showed a similar profile to that reported from other countries with PCB 138 as the predominant congener (median = 4.93 ng/g lw) followed by PCB 153 (median = 2.83 ng/g lw). However, median serum ΣPCBs in this study (10.36 ng/g lw) was lower than those reported elsewhere (Figure 2). This is generally in line with low PCB residues found in the Egyptian terrestrial and aquatic environment, which was attributed to the low industrial profile of the country until the 1970s.[43]

Unlike PCBs, the median serum concentration of p,p`-DDE in the current study (131 ng/g lw) was higher than those reported in blood samples from the general population of UK (n=153, 100 ng/g lw)[15], Belgium (n=204, 64 ng/g lw) [12] and Canada (n= 5000, 63 ng/g lw). [12] DDT was never used for Malaria control in Egypt. However, it was widely applied to treat cotton fields from 1952 to 1971. In the 1970s, DDT usage decreased gradually due to the resistance developed by the cotton leafworm, *Spodoptera littoralis* , until it was officially prohibited from all agricultural applications in 1980.[26] DDTs (dominated by p,p`-DDE) were detected in Egyptian fresh water (3-1048 ng/L), vegetables (1.78-2.82 ng/g), meat (67 ng/g fat) and fish (8-91 ng/g wet weight) products, indicating widespread contamination of the Egyptian environment with DDT.[42]

Fewer studies have reported on the levels of PCP and oxychlordane in serum from different countries. The median serum level of PCP in the current study (229 pg/mL) was lower than those reported in serum samples of pregnant women from the Netherlands (n=69, median = 970 pg/mL) and Sweden (n=15, 2830 pg/mL)[44] as well as

Norwegian women (n=281, 771 pg/mL)[9], but higher than the concentrations reported from Japan (n = 20 males, 140 pg/mL)[45] and Pakistan (130 pg/mL).[22]

OxC is the oxidised, relatively more polar metabolite of the pesticide Chlordane, which is more likely to be detected in serum. Median level of OxC in Egyptian serum was below LOQ, (<1.5 ng/g lw) with a detection frequency of 39%. This is consistent with the very low detection frequency of Chlordane in the Egyptian environment.[42]

To the authors' knowledge, this is the first study to report PBDE levels in Egyptian serum. BDE-47 was the most frequently detected congener (87%) with the highest median level (0.97 ng/g lw), followed by BDE-99 (77%, 0.61 ng/g lw). This is consistent with previous studies from other countries, indicating exposure to the penta-BDE commercial formulation.[46] Median penta-BDE level (1.9 ng/g lw, sum of congeners 47, 99, 100, 153 and 154) in Egyptian serum was at the lower end of those reported from other countries (Figure 2). A recent study reported low concentrations of PBDEs in dust samples collected from Egyptian homes (n=17, median penta-BDE = 5.2 ng/g), workplaces (n=9, 11.6 ng/g) and cars (n=5, 35.6 ng/g).[47] Indoor dust was highlighted as the major pathway of human exposure to PBDEs via ingestion and dermal contact.[48] Therefore, the low levels of PBDEs in Egyptian serum samples can be explained by the low concentrations of these flame retardants in Egyptian indoor dust.

BDE-209 (the major congener of the deca-BDE mixture) and BDE-183 (the indicator congener for octa-BDE mixture) were detected in Egyptian serum at lower frequency and concentrations than the penta-BDE congeners (Table 1). This may be attributed to the high lipophilicity and molecular weight of these congeners, which is likely to reduce their bioavailability to humans following exposure via indoor dust or diet. Moreover, the short serum half-life of BDE-209 (7-14 days) indicates that the detected levels in serum likely reflect recent exposure of the participants, rather than prolonged chronic

exposure.[49] Overall, the concentrations of PBDEs detected in Egyptian serum in this study are among the lowest reported worldwide.

Limitations and strengths

The current study doesn't aim and can't qualify to be an epidemiological case-control study. This is mainly due to the ethical restrictions which limited the public disclosure of risk factors to age, gender, and BMI; excluding other known important factors to ensure participant anonymity. In addition, the relatively small sample size combined with the 3 risk factors studied can only detect odds ratios of 4 ~5 (or higher) with sufficient statistical power. Uncertainties in the study also include the degree of representability of the studied samples to the general population given the overall small number of participants and the relatively high average BMI observed for both the patients and control group (Table 1).

However, this work provides the first human biomonitoring data of various OHCs in the Egyptian population, which significantly augments the current knowledge about the global distribution of these contaminants. Furthermore, due to the general lack of statistically significant differences between the patients and control group, the current paper focuses on characterising the levels and profiles of a broad suite of OHCs in Egyptian blood in comparison to previous reports from other countries and regions. This provides novel insights into the internal human exposure to contaminants like PBDEs and other OCPs in Egypt, which may trigger further regulatory and/or socioeconomic actions to reduce human exposure to these hazardous chemicals in the developing countries.

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Supplementary data

Further details of the analytical methodology, quality assurance/quality control parameters and concentrations of all target compounds in individual serum samples are available as supplementary data.

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Tables

Table 1: Statistical summary of the concentrations (ng/g lipid weight) of target OHCs in Egyptian serum samples.

	Patients (n=35, 19 males and 16 females)						Control (n=32, 17 males and 15 females)					
	DF* (%)	Median	Average	SD	Min	Max	DF (%)	Median	Average	SD	Min	Max
Age		47	48	9	34	62		43	44	9	31	61
BMI		29	31	6	23	43		32	33	7	19	48
PCB-118	70	1.34	1.91	1.92	<LOQ	6.88	69	0.50	1.52	1.82	<LOQ	6.10
PCB-138	91	4.93	5.41	3.30	<LOQ	12.45	94	5.00	4.92	3.03	<LOQ	12.86
PCB-153	80	2.66	3.01	2.50	<LOQ	10.17	66	3.03	3.11	2.59	<LOQ	8.03
PCB-170	60	0.48	0.78	0.99	<LOQ	4.66	63	0.52	0.65	0.80	<LOQ	4.36
PCB-180	57	0.27	0.57	0.76	<LOQ	3.14	56	0.33	0.58	0.69	<LOQ	3.35
ΣPCBs		**10.17**	**11.67**	**6.22**	**<LOQ**	**28.63**		**10.76**	**10.78**	**5.45**	**<LOQ**	**21.94**
pp-DDE	100	126.26	230.95	275.21	8.44	1061.65	100	139.75	184.98	205.39	12.18	930.40
pp-DDT	34	<LOQ	8.49	10.35	<LOQ	47.65	53	4.58	8.31	7.17	3.14	33.56
ΣDDT		**133.97**	**239.44**	**281.40**	**12.44**	**1109.29**		**145.24**	**193.29**	**212.21**	**16.18**	**960.11**
HCB	86	5.87	6.37	3.85	<LOQ	14.04	81	6.41	6.60	4.81	<LOQ	18.34
OxC	46	1.50	2.10	0.93	<LOQ	5.28	31	1.50	1.87	0.89	<LOQ	5.12
PCP	89	17.99	33.26	45.87	<LOQ	192.51	94	15.97	28.73	35.48	<LOQ	142.54
ΣOCPs		**155.85**	**281.17**	**314.65**	**25.01**	**1279.01**		**168.40**	**230.48**	**244.42**	**28.88**	**1114.83**
BDE-47	86	0.88	1.65	1.95	<LOQ	7.33	88	1.13	1.89	2.19	<LOQ	8.31
BDE-100	57	<LOQ	0.56	0.85	<LOQ	3.29	66	0.19	0.52	0.68	<LOQ	2.43
BDE-99	80	0.50	1.30	1.63	<LOQ	6.11	75	0.71	1.40	1.66	<LOQ	6.81
BDE-154	34	<LOQ	0.38	0.72	<LOQ	3.02	50	0.04	0.25	0.44	<LOQ	2.23

BDE-153	54	0.11	0.53	0.89	<LOQ	3.78	69	0.20	0.44	0.61	<LOQ	2.80
BDE-183	57	0.29	0.52	0.64	<LOQ	2.22	56	0.31	0.57	0.67	<LOQ	2.08
BDE-209	34	<LOQ	4.03	6.39	<LOQ	21.39	41	<LOQ	4.62	7.05	<LOQ	25.40
ΣPBDEs		**5.95**	**8.96**	**7.98**	**<LOQ**	**25.99**		**7.84**	**9.69**	**8.78**	**<LOQ**	**41.17**

* Detection frequency.

Table 2: Spearman rank order correlations among serum concentrations of OHCs, age and BMI of the study participants.

Patients (n=35)		**Age**	**BMI**	**ΣPCBs****	**ΣDDT[#]**	**HCB**	**OxC**	**PCP**	**ΣOCPs[$]**
BMI	*R*	0.223							
	P	0.197							
ΣPCBs	*R*	0.025	-0.029						
	P	0.889	0.868						
ΣDDT	*R*	**0.349***	**0.343***	0.089					
	P	**0.04**	**0.044**	0.613					
HCB	*R*	**0.386***	-0.015	0.157	0.089				
	P	**0.022**	0.931	0.367	0.611				
OxC	*R*	-0.04	-0.246	-0.071	0.129	-0.027			
	P	0.818	0.154	0.687	0.461	0.877			
PCP	*R*	0.038	0.265	0.007	**0.463***	-0.198	0.278		
	P	0.83	0.124	0.966	**0.005**	0.254	0.107		
ΣOCPs	*R*	0.323	**0.348***	0.085	**0.989***	0.098	0.16	**0.549***	
	P	0.058	**0.04**	0.626	**0.001**	0.576	0.357	**0.001**	
ΣPBDEs[+]	*R*	0.054	0.062	-0.206	-0.084	0.191	-0.143	-0.149	-0.141
	P	0.759	0.723	0.236	0.63	0.272	0.418	0.421	0.419
Control (n=32)		**Age**	**BMI**	**ΣPCBs**	**ΣDDT**	**HCB**	**OxC**	**PCP**	**ΣOCPs**
BMI	R	0.321							
	P	0.073							
ΣPCBs	R	0.058	0.175						
	P	0.751	0.339						
ΣDDT	R	**0.399***	**0.437***	0.023					
	P	**0.024**	**0.012**	0.901					
HCB	R	0.233	0.163	0.146	-0.031				
	P	0.199	0.373	0.425	0.865				
OxC	R	0.198	-0.068	0.275	0.214	-0.211			
	P	0.276	0.712	0.127	0.239	0.247			
PCP	R	0.177	**0.370***	0.021	**0.694***	0.038	0.174		
	P	0.331	**0.037**	0.909	**0.001**	0.836	0.342		
ΣOCPs	R	**0.407***	**0.480***	0.042	**0.991***	0.018	0.173	**0.736***	
	P	**0.021**	**0.005**	0.820	**0.001**	0.923	0.344	**0.001**	
ΣPBDEs	R	-0.341	-0.124	-0.254	-0.115	-0.291	-0.058	0.124	-0.123
	P	0.056	0.499	0.160	0.530	0.106	0.753	0.500	0.503

***** Statistically significant at the 0.05 level.
** Sum of PCB congeners 118, 138, 153, 170 and 180.
[#] Sum of p,p`-DDE and p,p`-DDT.
[$] Sum of p,p`-DDE, p,p`-DDT, HCB, OxC and PCP.
[+] Sum of PBDE congeners 47, 99, 100, 153, 154, 183 and 209.

Figures

Figure 1: Median profile of the studied OHCs in serum samples of (a) colorectal cancer patients (n=35) and (b) control group (n=32).

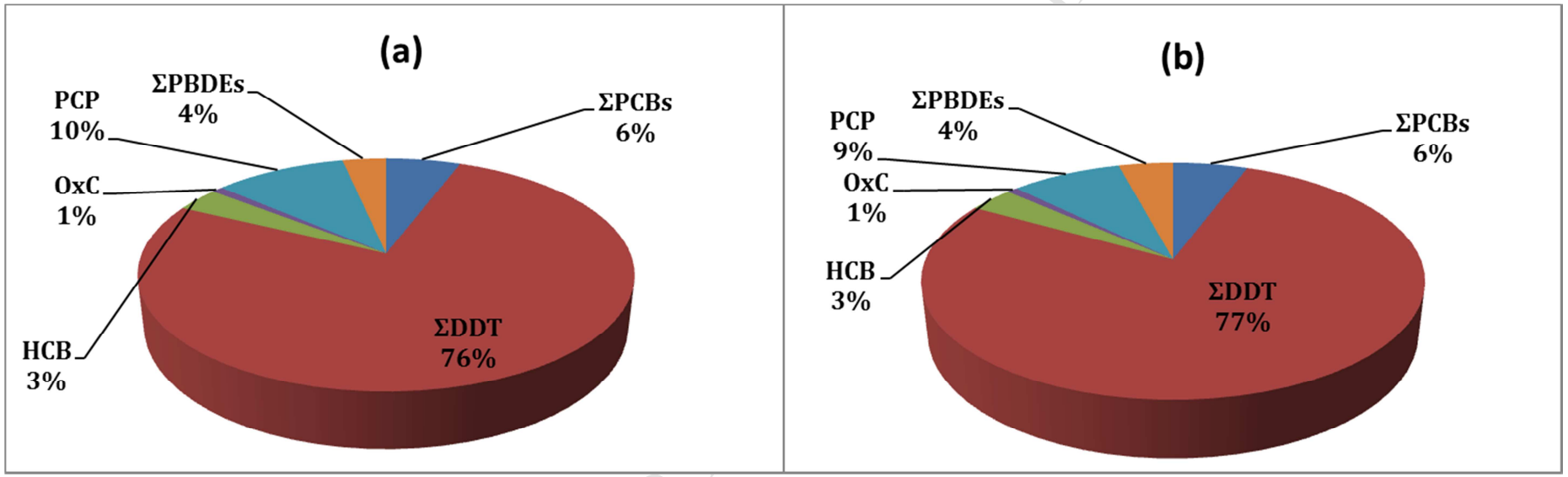
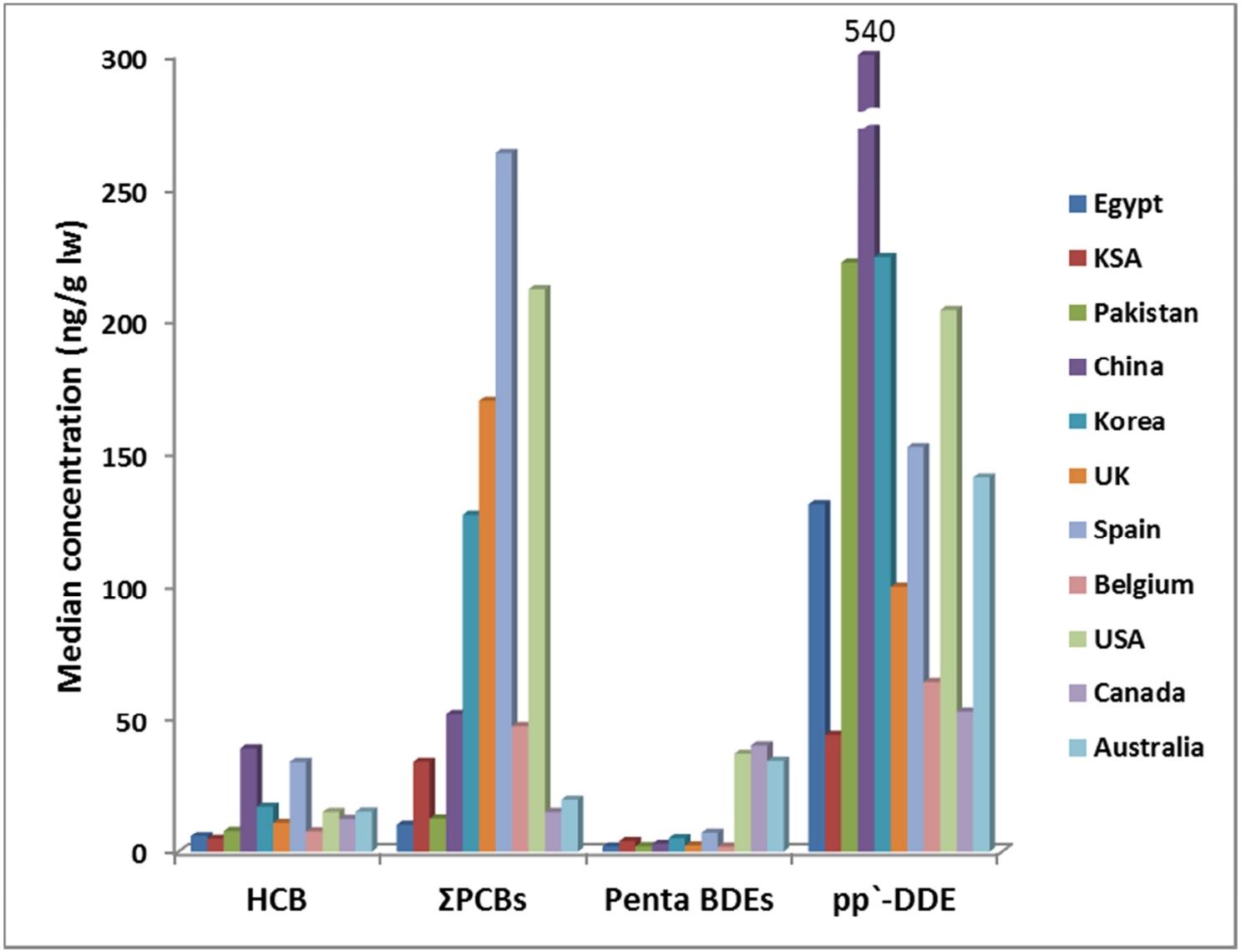


Figure 2: Median concentrations (ng/g lw) of HCB, ΣPCBs, Prnta-BDEs and p,p`-DDE in human serum samples from different countries.



Research Highlights

- PBDEs, PCBs and OCPs were determined in 67 human blood samples from Egypt
- No significant differences between colorectal cancer patients and control group
- ΣDDT and ΣOCPs increased significantly with age and BMI
- PBDEs and PCBs in serum of Egyptians are among the lowest worldwide