Int Arch Occup Environ Health (1997) 69:399–406

ORIGINAL ARTICLE

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Internal exposure to hazardous substances of persons from various continents: investigations on exposure to different organochlorine compounds

Received: 11 July 1996 / Accepted: 16 September 1996

Abstract The aim of the study was to investigate the concentration of organochlorine compounds of environmental-medical relevance in biological materials from refugees with regard to their countries of origin and to compare these concentrations with the internal exposure of the German general population. *Methods*: During medical examination after entry to Germany specimens could be taken from the refugees to determine the following parameters of biological monitoring: 1,1-dichloro-2,2-bis(-chlorophenyl)-ethylene (DDE-P), polychlorinated biphenyls (PCB-P), pentachlorophenol (PCP-P) and the beta- and gamma-hexachlorocyclohexanes (β-HCH-P, γ-HCH-P) in plasma and the excretion of chlorophenols (4-MCP-U, 2,4-DCP-U, 2,5-DCP-U, 2,4,5-TCP-U, 2,4,6-TCP-U, 2,3,4,5-TeCP-U, 2,3,5,6-TeCP-U) in urine. One hundred and three men (13 from former Yugoslavia, 29 from the former USSR, 33 Africans and 28 Asians) ranging from 16 to 53 years of age (median 27 years) were investigated. Thirty four male Germans without occupational exposure to these substances and a similar age structure (age 25–36 years; median 26 years) served as a control group. *Results*: A much higher level of internal exposure was found for the DDT metabolite, DDE, for those persons from Asia, the former USSR and Africa compared with the German controls (medians: 16.9 μg/l, 11.9 μg/l, 10.9 μg/l and 1.1 μg/l). The levels of PCB in plasma were below the detection limit in the majority of refugees. In the control group, however, the PCB levels were higher (ΣPCB: median: 2.1 μg/l, maximum: 13.3 μg/l). The highest β-HCH concentrations, up to a maximum of 15.5 μg/l, were detected in the persons from the former USSR and Asia. The five groups do not differ with regard to internal exposure to PCP and γ-HCH. Renal excretion of 4-MCP, 2,4-DCP and TeCP did not differ between the five groups. The concentrations of 2,5-DCP in urine, however, were significantly lower in the Germans than the refugees from the four regions investigated. The median for the Germans was 3.0 μg/l and for the refugees between 10.8 and 14.7 μg/l. Also the levels of 2,4,5-TCP and 2,4,6-TCP in urine were lower in the German controls than in the men from the former USSR, Africa and Asia. *Conclusions*: Organochlorine compounds exist worldwide due to their extensive use. There are, however, regional differences for the various substance groups, which during biological monitoring are seen in the different background exposures of the general population. Particularly characteristic are markedly higher levels of DDE in plasma from the refugees compared with the German population.

Key words Organochlorine compounds · Biological monitoring · Environmental exposure · German population · Refugees

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Introduction

Organochlorine compounds are found worldwide due to their extensive technical use and also as insecticides and pesticides. Some of these substances can be detected ubiquitously in the biosphere. Humans therefore absorb organochlorine compounds with food, via inhalation and skin; accumulation of these substances in the food chain is of particular relevance. In addition to DDT, this also applies to other organochlorine compounds such as polychlorinated biphenyls. Biological monitoring is the preferred method for detecting such exposure. Investigation of specific groups using biological monitoring is of great importance in environmental-toxicological studies when trying to assess internal exposure related to specific life-styles and conditions. While toxicological threshold limit values have proved effective in occupational medicine [12, 16], it is very difficult to evaluate scientifically based threshold limit values, in the sense of a dose-response relationship, for the environmental range. As a rule it can only be said whether the value measured is within the level of background exposure of the general population.

The aim of our pilot study was to carry out biological monitoring in refugees as soon as possible after their entry to Germany to determine levels of organochlorine compounds of environmental-medical relevance, such as dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls, hexachlorocyclohexane and chlorophenols. The internal exposure of the refugees was investigated with regard to the geographical regions they came from. By comparing these values with the German population, it was hoped to gain additional insights into the problem of reference values in the environmental, toxicological range.

Methods and groups

In the period from November 1994 to April 1995, hazardous substances or their metabolites were investigated in the urine and blood of refugees during the medical examination immediately after their entry to Germany. Subjects were included in the study, if they fulfilled the following criteria: male, between 16 and 60 years of age, maximum period since leaving their country of origin: 20 days [18]. A random sample of 103 male refugees who arrived in Bavaria took part in the study (13 from former Yugoslavia, 29 from the former USSR, 33 Africans, and 28 Asians) ranging from 16 to 53 years of age (median: 27 years old). Since leaving their country of origin 3–20 days had elapsed (median: 8 days). Their age, height, weight, and smoking habits were documented. Data were collected on occupation, living area (industrial region/urban area/rural area) and any previous employment in agriculture. The investigation was carried out with the agreement of the refugees. The data collected were made anonymous in accordance with legal requirements regarding data protection and medical confidentiality. In particular, it was made impossible to reassign the data to the particular individual.

Thirty-four German males without occupational exposure and a similar age structure (age: 25–36 years old, median: 26 years old) served as controls. The data from the individual groups are presented in Table 1.

Table 1 Basic data of the different groups

	Former Yugoslavia	Former USSR	Asia	Africa	Control group
Number of cases (*n*)	13	29	28	33	34
Country of origin	Kosovo-Albania (10), Bosnia (2), Serbia (1)	Georgia (8), White Russia (6), Armenia (6), Russia (3), Moldavia (3), Georgia (1), Azerbaijan (1), Latvia (1)	Iran (12), Pakistan (9), India (4), Sudan (1), Vietnam (1), Burma (1)	Sudan (14), Ethiopia (10), Zaire (4), Algeria (2), Somalia (1), Eritrea (1), Gambia (1)	
Age (years) [median(minimum – maximum)]	27 (16–46)	26 (17–53)	28 (22–42)	27 (20–49)	26 (25–36)
BMI (kg/m^2) [median(minimum – maximum)]	22.5 (19–28)	22.2 (19.1–30.1)	22.5 (17.9–29.8)	22.4 (18.7–29.0)	23.9 (20.2–29.8)
Percentage of smokers	61.5 %	55.2 %	57.1 %	48.5 %	23.5 %
Time since leaving the country of origin (days) [median (minimum – maximum)]	5 (3–8)	8 (3–14)	10 (3–20)	7 (4–14)	
Percentage of people who had worked in agriculture	7.7 %	20.7 %	14.3 %	36.4%	0
Percentage of people from an industrial region	15.4 %	51.7 %	7.1 %	6.1%	0
Percentage of people from an urban region	23.1 %	27.6 %	78.6 %	51.5%	100%
Percentage of people from a rural region	61.5 %	20.7 %	14.3 %	42.4%	0

During the medical examination specimens were taken from the refugees to determine the following biological monitoring parameters: 1,1-dichloro-2,2-bis (-chlorophenyl)-ethylene (DDE) as the main metabolite of dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCB, congeners 28, 52, 101, 138, 153, 180[1]), pentachlorophenol (PCP), β-hexachlorocyclohexane (β-HCH), γ-hexachlorocyclohexane (γ-HCH) in plasma; 4-monochlorophenol (4-MCP), 2,4-dichlorophenol (2,4-DCP), 2,5-dichlorophenol (2,5-DCP), 2,4,5-trichlorophenol (2,4,5-TCP), 2,4,6-trichlorophenol (2,4,6-TCP), tetrachlorophenol (2,3,4,5-TeCP + 2,3,5,6-TeCP) in urine. The volume of specimens was, however, not sufficient to be able to carry out the whole spectrum of analysis with each individual. Therefore, for each parameter, the number of cases is always given, which was also taken into consideration in the statistical evaluation.

The level of the hazardous substances in blood and urine samples was determined with tested, reliable methods [2] under the conditions of statistical quality control [17]. Statistical evaluation was carried out using non-parametric test procedures (H test according to Kruskal and Wallis) and in some cases after transformation using variance analysis with subsequent Scheffé test.

Results

DDE

DDE, the main metabolite of DDT, was detected in the plasma samples of refugees from the former USSR, Asia and Africa in relatively high concentrations (Fig. 1). The maximum value was determined in one Asian refugee at 93.0 µg/l. The median was also highest in the Asians at 16.9 µg/l, followed by refugees from the former USSR with 11.9 µg/l and the Africans with 10.9 µg/l. The refugees from former Yugoslavia had a markedly lower level of exposure; the median was 2.3 µg/l and the maximum 12.2 µg/l. The lowest values were found in the Germans with a median of 1.1 µg/l and a maximum of 5.0 µg/l (Table 2). Statistical evaluation revealed that the values in the control group were significantly lower than for refugees from the former USSR, Asia and Africa. Also the results of analysis from the men from former Yugoslavia were significantly lower than those of the other three groups of refugees. The anamnestic data regarding former employment in agriculture and living area had no influence on the results of biological monitoring. The level of DDE in refugees who came from rural

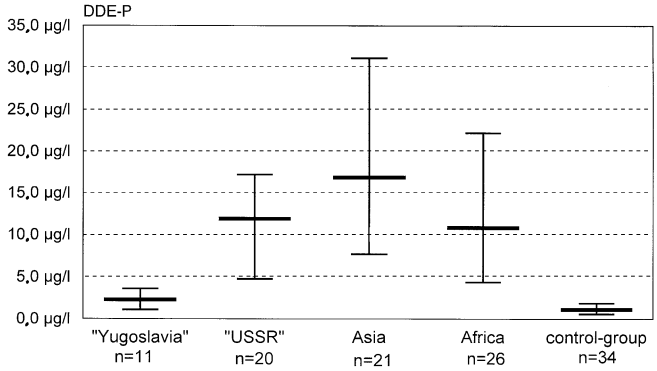

Fig. 1 Description of the concentrations of 1,1-dichloro-2, 2-bis (-chlorophenyl)-ethylene (*DDE*) in plasma (µg/l) of the different groups (median, 25th percentile, 75th percentile)

areas or were formerly employed in agriculture was not higher.

PCBs

Internal exposure to PCBs can be estimated by determining indicator congeners 28, 52, 101, 138, 153 and 180. In our groups congeners 52 and 101 were not detected in any of the men, congener 28 occurred in three men at a concentration of 0.3 µg/l. Two of these men came from the former USSR, and one from Asia.

The results of analysis of congeners 138, 153 and 180 were above the detection limit of 0.1 µg/l in all the German controls. Comparison of the groups showed that the highest values were to be found in the Germans, both for the maxima and the medians. For the majority of refugees, however, we were not able to determine any exposure to these congeners. The maximums reached, depending on the congener, were 0.6 to 1.0 µg/l, while in the German controls maximum values between 3.4 and 5.6 µg/l were found (Table 2). The lowest internal exposure for the sum of the three compounds was found in the Asians, followed by the Africans, the refugees from former Yugoslavia and those from the former USSR (Fig. 2). In the controls all PCB plasma levels of these three congeners were above the detection limit, while these congeners could be detected in only 38% of the Asians, 57% of the Africans, 83% of the refugees from former Yugoslavia and 86% of those from the former USSR. The internal exposure in the control group was higher than the exposure of the Asians and Africans on average by a factor of seven; the maximum value reached was 13.3 µg/l. In the statistical evaluation the Germans differed significantly from all other groups. The values for the refugees from the former USSR were also significantly higher than those of the Asians and Africans. Multifactorial variance analysis showed that the factors of employment in agriculture and living area had no influence on the results of analysis. The data on occupation revealed

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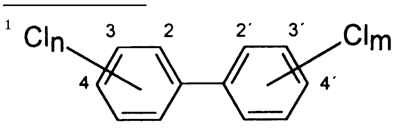

PCB 28	2, 4, 4′-Trichlorobiphenyl
PCB 52	2, 2′, 5, 5′-Tetrachlorobiphenyl
PCB 101	2, 2′, 4, 5, 5′-Pentachlorobiphenyl
PCB 138	2, 2′, 3, 4, 4′, 5′-Hexachlorobiphenyl
PCB 153	2, 2′, 4, 4′, 5, 5′-Hexachlorobiphenyl
PCB 180	2, 2′, 3, 4, 4′, 5, 5′-Heptachlorobiphenyl

Table 2 Plasma levels of the various organochlorines (median, range, 25th, 75th, and 95th percentile) for the different groups. For the men seeking asylum from former Yugoslavia the 95th percentile could not be calculated due to the small number of cases. *< d.l.* Result below the detection limit.Detection limits: 1,1-dichloro-2,2-bis(-chlorophenyl)-ethylene in plasma (*DDE-P*) 0.1 µg/l; Polychlorinated biphenyls in plasma (*PCB-P*) 0.1–0.2 µg/l; β-hexachlorocyclohexane in plasma (*β-HCH-P*) 0.5 µg/l; γ-hexachlorocyclohexane in plasma (*γ-HCH-P*) 0.1 µg/l; pentachlorophenol in plasma (*PCP-P*) 3.0 µg/l

	n	Minimum	25th Percentile	Median	75th Percentile	95th Percentile	Maximum
Concentrations of DDE-P (µg/l)							
"Yugoslavia"	11	0.70	1.10	2.30	3.60	–	12.20
"USSR"	20	1.80	4.78	11.90	17.23	53.85	54.20
Asia	21	2.90	7.70	16.90	31.15	91.25	93.00
Africa	26	1.80	4.40	10.85	22.23	42.47	45.20
Control group	34	0.30	0.60	1.14	1.89	3.76	4.97
Concentrations of PCB-138 in plasma (µg/l)							
"Yugoslavia"	12	< d.l.	< d.l.	0.20	0.30	–	0.50
"USSR"	22	< d.l.	0.20	0.40	0.60	0.79	0.80
Asia	21	< d.l.	< d.l.	< d.l.	0.20	0.30	0.30
Africa	28	< d.l.	< d.l.	< d.l.	0.20	0.40	0.40
Control group	34	0.28	0.40	0.53	0.81	3.03	4.22
Concentrations of PCB-153 in plasma (µg/l)							
"Yugoslavia"	12	< d.l.	< d.l.	0.25	0.30	–	0.80
"USSR"	22	< d.l.	0.28	0.40	0.70	0.99	1.00
Asia	21	< d.l.	< d.l.	< d.l.	0.25	0.39	0.40
Africa	28	< d.l.	< d.l.	0.20	0.30	0.50	0.50
Control group	34	0.40	0.61	0.83	1.27	4.21	5.63
Concentrations of PCB-180 in plasma (µg/l)							
"Yugoslavia"	12	< d.l.	< d.l.	0.13	0.20	–	0.60
"USSR"	22	< d.l.	< d.l.	< d.l.	0.30	0.50	0.50
Asia	21	< d.l.	< d.l.	< d.l.	< d.l.	0.20	0.20
Africa	28	< d.l.	< d.l.	< d.l.	< d.l.	0.47	0.60
Control group	34	0.20	0.49	0.70	0.93	2.96	3.43
Concentrations of β-HCH in plasma (µg/l)							
"Yugoslavia"	11	< d.l.	< d.l.	< d.l.	< d.l.	–	< d.l.
"USSR"	27	< d.l.	0.60	1.60	2.60	5.75	7.30
Asia	27	< d.l.	< d.l.	0.99	3.23	13.24	15.45
Africa	32	< d.l.	< d.l.	< d.l.	< d.l.	1.76	2.60
Control group	34	< d.l.	< d.l.	< d.l.	< d.l.	1.50	1.50
Concentrations of γ-HCH in plasma (µg/l)							
"Yugoslavia"	11	< d.l.	< d.l.	< d.l.	< d.l.	–	0.40
"USSR"	27	< d.l.	< d.l.	< d.l.	< d.l.	0.29	0.42
Asia	27	< d.l.	< d.l.	< d.l.	< d.l.	0.16	0.20
Africa	32	< d.l.	< d.l.	< d.l.	< d.l.	0.49	1.02
Control group	34	< d.l.	< d.l.	< d.l.	< d.l.	0.25	0.25
Concentrations of PCP in plasma (µg/l)							
"Yugoslavia"	12	< d.l.	< d.l.	< d.l.	3.93	–	10.40
"USSR"	26	< d.l.	< d.l.	< d.l.	4.25	26.24	36.70
Asia	25	< d.l.	< d.l.	< d.l.	4.38	48.54	51.90
Africa	28	< d.l.	< d.l.	< d.l.	4.63	10.83	12.00
Control group	34	< d.l.	< d.l.	4.06	5.80	12.43	15.50

that refugees with "office jobs" (in particular, students, teachers, and salesmen) had significantly lower internal exposure to PCB than refugees with manual or industrial jobs.

β-HCH

Only the refugees from the former USSR and Asia revealed any relevant internal exposure to β-HCH. Of the Asians, 67% and 78% of the refugees from the former USSR had detectable plasma concentrations; the medians were 1.0 µg/l and 1.6 µg/l, respectively. The maximum value of 15.5 µg/l was found in an Asian refugee. In all other groups in 87% to 100% of cases no β-HCH was detectable in plasma (Table 2). The groups from Asia and the former USSR differed significantly from the other three groups.

γ-HCH

γ-HCH was only detectable in the plasma of a few men; in all groups 91%–96% of the men had values below

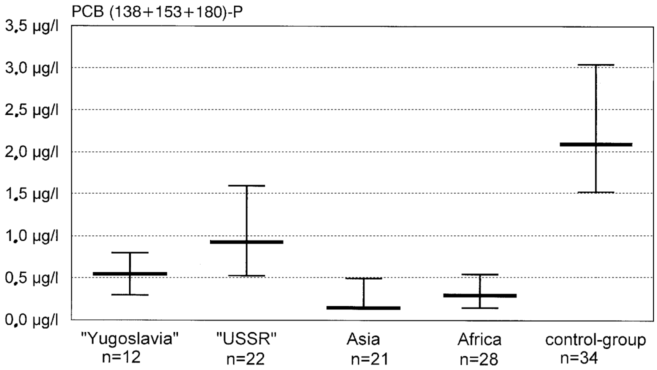

Fig. 2 Description of the concentrations of polychlorinated biphenyls 138 + 153 + 180 in plasma (*PCB-P*) (µg/l) of the different groups (median, 25th percentile, 75th percentile)

the detection limit. The maximum value of 1.0 µg/l was determined in an African refugee (Table 2). Significant differences between the groups were not observed.

PCP

Internal exposure to PCP in plasma in the German controls was on average slightly above that of the refugees. The median was 4.1 µg/l, while PCP was not detectable in the plasma of more than 50% of the refugees. The highest individual value of 51.9 µg/l was found in an Asian refugee (Table 2). Significant differences between the five groups did not occur.

Chlorophenols

Different results were found for the chlorophenols in urine depending on the substance analysed (Table 3). The average excretion of 4-MCP in urine was highest in the refugees from former Yugoslavia (8.0 µg/l), followed by refugees from the former USSR (5.3 µg/l), from Asia (5.1 µg/l) and Africa (4.3 µg/l). The German controls

Table 3 Chlorophenol levels in urine (median, range, 25th, 75th, and 95th percentile) for the different groups. For the men seeking asylum from former Yugoslavia the 95th percentile could not be calculated due to the small number of cases. *< d.l.* result below the detection limit. Detection limits: *MCP*: 0.1 µg/l; *DCP*: 0.2 µg/l; *TCP*: 0.3 µg/l, *TeCP*: 0.5 µg/l.

	n	Minimum	25th Percentile	Median	75th Percentile	95th Percentile	Maximum
Concentrations of 4-MCP in urine; (µg/l)							
"Yugoslavia"	10	2.30	3.44	7.96	11.35	–	13.10
"USSR"	22	< d.l.	3.17	5.25	11.13	18.25	18.40
Asia	18	< d.l.	3.81	5.10	9.79	–	14.39
Africa	24	< d.l.	1.78	4.34	9.35	32.98	34.80
Control group	33	1.29	2.42	3.38	5.40	14.08	14.86
Concentrations of 2,4-DCP in urine; (µg/l)							
"Yugoslavia"	11	0.80	0.90	1.48	1.90	–	9.70
"USSR"	24	0.30	1.00	1.40	1.88	19.32	24.63
Asia	21	< d.l.	0.90	1.35	1.74	4.82	4.94
Africa	24	0.50	1.02	1.70	2.60	5.34	6.12
Control group	33	< d.l.	0.61	0.71	1.11	2.61	2.96
Concentrations of 2,5 DCP in urine; (µg/l)							
"Yugoslavia"	11	1.90	9.00	10.84	14.40	–	26.20
"USSR"	24	2.60	6.59	14.47	19.93	51.53	55.40
Asia	21	1.12	4.95	11.80	19.40	52.25	55.20
Africa	24	3.10	6.35	14.65	33.33	173.90	206.80
Control group	33	0.45	1.55	3.01	6.68	14.74	18.93
Concentrations of 2,4,5-TCP in urine; (µg/l)							
"Yugoslavia"	11	0.51	0.80	1.10	1.90	–	3.00
"USSR"	24	0.50	1.30	1.80	2.50	12.05	14.40
Asia	21	0.34	1.01	2.00	3.35	8.48	8.89
Africa	24	0.70	1.07	1.85	2.53	34.77	42.50
Control group	33	< d.l.	0.49	0.85	1.35	2.73	3.00
Concentrations of 2,4,6-TCP in urine; (µg/l)							
"Yugoslavia"	11	< d.l.	0.72	1.10	1.70	–	4.00
"USSR"	24	0.50	1.30	1.71	3.38	16.32	19.32
Asia	21	< d.l.	1.01	1.90	2.95	33.05	35.78
Africa	24	0.40	1.18	1.70	2.44	9.63	11.70
Control group	33	< d.l.	0.48	0.60	1.07	2.37	3.80
Concentrations of 2,3,4,5/2,3,5,6-TeCP in urine; (µg/l)							
"Yugoslavia"	11	< d.l.	< d.l.	< d.l.	0.80	–	1.70
"USSR"	24	< d.l.	< d.l.	0.60	1.00	5.25	5.40
Asia	21	< d.l.	< d.l.	< d.l.	1.00	4.49	4.73
Africa	24	< d.l.	< d.l.	0.60	1.00	12.69	16.30
Control group	33	< d.l.	< d.l.	< d.l.	< d.l.	6.94	15.49

excreted the lowest level of 4-MCP in urine at 3.4 μg/l on average. Significant differences between the groups were not observed. There were also no significant differences between the groups for the excretion of 2,4-DCP in urine. The German controls also had the lowest values here with 0.7 μg/l on average; the median for the refugees was between 1.4 and 1.7 μg/l. The highest individual value was determined in a refugee from the former USSR at 24.6 μg/l. Renal excretion of 2,5-DCP was significantly lower in the German controls than the refugees from the four regions investigated. The median was 3.0 μg/l and for the refugees between 10.8 and 14.7 μg/l. It was conspicuous that for this parameter in some cases there were very high values; in one African 206.8 μg/l. For 2,4,5-TCP and 2,4,6-TCP the German controls excreted significantly lower levels than the refugees from the former USSR, Africa and Asia. The medians differed by a factor of three. No significant differences were detectable, however, between the control group and refugees from former Yugoslavia. Also for this parameter high individual values were detected with a maximum of 42.5 μg 2,4,5-TCP/l in one African refugee and 35.8 μg 2,4,6-TCP/l in one Asian refugee. No significant differences were detected between the five groups for the excretion of tetrachlorophenol in urine (2,3,4,5-TeCP + 2,3,5,6-TeCP). The values tended to be low; the maximum value was 16.3 μg/l.

Other possible influences such as living area, last occupation, employment in agriculture and smoking habits neither influenced excretion of chlorophenol in urine, nor the concentrations of PCP and HCH in plasma.

Discussion

DDT was first synthesized in 1874 and as from 1939 was used in great quantities worldwide due to its insecticidal effect [21]. In the refugees investigated from Asia and Africa, and even from the former USSR – regardless of living area and occupation – increased internal exposure to DDE was found relative to the control group. Only in the refugees from former Yugoslavia were the plasma levels significantly lower, but nevertheless higher than in the German controls. The level of DDE found in refugees who formerly worked in agriculture or lived in rural areas was not higher. Their plasma concentrations were of the same order of magnitude as their compatriots without occupational exposure. We suspect that particularly in Asian and African countries due to the wide use of DDT there is relevant exposure through the food chain, which is reflected in high DDE levels in all inhabitants [4, 9, 10, 15]. DDE, the main metabolite of DDT which has been banned in Germany since 1972, was detected in each of the German controls, but only in very low concentrations. There was no occupational exposure, so the values measured represent background exposure caused by accumulation of DDT in the food chain. The 95th percentile was 3.8 μg/l, the maximum value found was 5.0 μg/l.

The use of PCBs as technical additives, for example in the electronics, hydraulic and plastics industry, has led, due to the high persistency and lipophilic properties of these compounds, to their accumulation in the food chain and therefore wide occurrence [6, 11, 25]. Congeners 28, 52 and 101 are rarely detected in plasma samples, which is due to the low biological half-life and low accumulation of these congeners in the course of the food chain. Congeners 138, 153 and 180 can, however, be measured in the plasma of the German population in some cases in relatively high concentrations [13]. People are also affected who have no relevant exposure at the workplace. Our control group consisted mainly of students with no occupational exposure. Although the use of PCBs has been banned in Germany since 1989, concentrations of PCBs were detectable in the plasma of our control group. This is probably due to the wide occurrence of these substances, which were used among other things in many buildings as sealing agents or as flame-proof paints [8]. They can be released from these materials over long periods of time and in addition to oral uptake via the food chain can also lead to inhalation exposure. For Germany a significant correlation was described between internal exposure to PCBs and the age of the persons investigated [13]. The groups investigated were well matched with regard to age. The age of the German controls ranged from 25 to 36 years old, the median was 26 years old. For this age group we determined with a larger group a reference value of 5.8 μg/l for the sum of PCBs 138 + 153 + 180 [13]. The 95th percentile for the German controls investigated here was 10.2 μg/l, higher than the reference value by a factor of almost two. This is caused, however, almost exclusively by two extreme values (13.3 μg/l and 9.1 μg/l), which due to the relatively low number of cases ($n = 34$) influence the 95th percentile.

The results of analysis for the refugees, however, were much lower. Often no PCBs could be detected in plasma. This is probably due to the fact that products containing PCBs are only rarely used in the refugees' countries of origin due to a lack of technical progress. Internal exposure was extremely low in the Africans and Asians and mainly limited to those persons who absorbed PCBs as a result of their occupation. This shows that these substances are not yet ubiquitously present and that in particular in Asia and Africa no relevant accumulation in the food chain has taken place, which leads to measurable exposure of the general population. Former Yugoslavia and the former USSR represent a mid-stage, where PCBs were detected in plasma in over 75% of the test subjects from these regions.

γ-HCH (lindane) is one of eight stereo-isomers of hexachlorocyclohexane. For a long time lindane was a component of wood preservatives in Germany and outside Europe it is used in particular against parasites and pests [9, 15, 23]. It is also used in antiparasitic topical preparations for humans [19]. In 1974–1978 the use of technical-grade HCH was banned in Germany in agriculture, in veterinary medicine, in forestry and in wood preservatives. In the case of γ-HCH it must be remembered that in over 90% of all test subjects the concentration in plasma was below the analytical detection limit. The γ-HCH levels detectable in a few cases, up to a maximum of 1.0 μg/l, are probably the result of the wide use of lindane as an insecticide. With a half-life of about 10 days in blood, relevant exposure from the different regions would have been detected in the investigations, which took place on average 8 days after leaving the country of origin. For the German control group the 95th percentile and maximum were 0.25 μg/l. The groups from Asia and the former USSR produced conspicuous results in the evaluation of exposure to β-HCH. In the majority of subjects a measurable concentration was found in plasma; the maximum value was 15.5 μg/l. β-HCH has a longer biological half-life and occurs in technical-grade HCH or as a contaminant of lindane [24]. The relatively high β-HCH values may indicate, due to the longer biological half-life, former exposure to β-HCH in the countries of origin. For the German control group the 95th percentile and the maximum were 1.5 μg/l.

The large amounts produced and worldwide use led to global distribution of PCP. Since the ban on PCP in 1989, its commercial production, distribution or use has been forbidden in Germany. There were no significant differences between the five groups in internal exposure to PCP. With a half-life in serum of about 17 days, specific exposure in refugees from the different regions would also have been detected for this parameter. However, almost identical exposure was found for all groups, which is probably the result of the wide use of PCP not only as a fungicide and herbicide, but also as a preservative and impregnant [14]. For the German control group the 95th percentile was 12.0 μg/l, the maximum 15.5 μg/l. These values are below the current upper limit of the reference range [5, 7]. The reason for the much lower values is probably reduced environmental exposure as a result of the limitations on the use of PCP. With a low accumulation rate in the human body and only low persistence in the environment, the average concentration in serum can be expected to decrease further in the future [7, 20].

Chlorophenols in urine can be used as important parameters for determining exposure to various ubiquitous organochlorine compounds [1, 3]. Particularly suitable are HCH isomers, chlorobenzenes, chlorophenols and chlorophenoxycarbonic acids, which are used in industry, commerce, agriculture and private households for a variety of reasons [22]. Significantly increased values relative to the controls were found for 2,5-DCP in the refugees from all four regions. The exposure may be due to *p*-dichlorobenzene, a substance used as an insecticide but also found in pigments and dyes. The refugees from Asia, Africa and the former USSR also excreted significantly higher amounts of trichlorophenols than the control group, which was not true of the refugees from former Yugoslavia. Exposure to insecticides and herbicides can also be assumed here, but it must also be borne in mind that exposure to hexachlorocyclohexane leads to increased excretion of trichlorophenol in urine [1]. In particular for the regions Asia and Africa, and to a lesser extent also the former USSR and former Yugoslavia, higher exposure to organochlorine compounds, which are used above all in insecticides, fungicides and herbicides, is generally to be expected. If the values of the 95th percentile for the controls are compared with the currently available reference values [3], it can be seen that renal elimination of 4-MCP is higher in the controls (14.1 vs 7.5 μg/l) while the concentrations of 2,4-DCP + 2,5-DCP (17.4 vs 33.6 μg/l), 2,4,5-TCP (2.7 vs 4.5 μg/l), 2,4,6-TCP (2.4 vs 4.7 μg/l), and 2,3,4,6-TeCP + 2,3,5,6-TeCP (6.9 vs 22.2 μg/l) in urine are lower.

Organochlorine compounds exist worldwide due to their extensive use, although there are great regional differences depending on the substance group, which in biological monitoring are reflected in the different background exposures of the general population. High exposure to organochlorine compounds, which are used as pesticides, are generally to be expected in Asian and African countries. In industrialized countries on the other hand, exposure is mainly through industrial use of organochlorine compounds. This must be taken into account when evaluating so-called reference ranges. The 95th percentile, as the upper limit of the reference range, can only be regarded as an orientation aid when classifying the exposure to hazardous substances of an individual compared to other persons from the same environment.

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