Polychlorinated Biphenyls (PCB) in the Ambient Environment and Reproductive Disorders in the Town of Serpukhov (Russia)

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Abstract

Data presented in this article demonstrate environmental pollution in the town of Serpukhov in Moscow region which was caused by PCB emissions from a capacitor producing plant. High concentrations of PCB were detected in environmental samples, locally produced food products, blood serum of workers, and breast milk of local women. Elevated rates of miscarriages, congenital malformations and low birth weight were observed in the town.

Introduction

More than 1.2 million tons of PCB have been produced all over the world. From 300 to 500 thousand tons of that amount have been produced in Russia. According to expert assessments, there are more than 100,000 tons of PCB containing industrial wastes in Russia. Capacitor producing factory, which is located in the town of Serpukhov in Moscow region, used to be one of major PCB consumers. The factory had been using PCB for 25 years until the year 1988, and during that period 1,400 tons of ascarels had been used. The factory consumed both soviet (Sovol) and imported (Pyralene, Clophene) chemicals. Imperfect technology, leakage from storage tanks and from other facilities located on factory's territory led to intensive PCB pollution of the town's territory. During the period from 1986 to 1988, when the factory was working at full capacity, studies on PCB pollution were conducted in the city [1, 2]. The studies revealed high PCB concentrations in soil and ambient air as well as accumulation of PCB in workers' blood and in breast milk of local women. In 1988 usage of PCB at the factory was banned and technological process was changed.

Methods of analysis

Samples of soil, breast milk, blood, locally grown vegetables, and eggs were analyzed for PCB content by gas-liquid chromatography according to methodology described in [3,4]. After extraction of PCB with organic solvents, the extract was treated with concentrated H2SO4.

Chlororganic pesticides were separated by dehydrochlorination in alkaline solution. Tetrachlorbiphenyl 2, 2', 5, 6' (IUPAK-53) was used as an internal standard. Analyzed PCB mixture contained mainly low chlorinated compounds, therefore Aroclor 1232 and Aroclor 1254 were used as standard solutions. Concentrations of PCBs were determined using following devices: Gasochrom-1109 equipped by packed column, Carlo-Ebra series Mega with electron-capture detector, and Hewlett-Packard HP-68890 with mass selective detector MSD HP 5890. Vegetables were usually analyzed immediately after sampling. Samples of breast milk were collected during first week after each child birth. The samples were stored in a freezer at -20° C. Eggs from clean and polluted yards were also stored in a freezer. Egg yolks were analyzed for PCB content.

Results

Ambient environment. Soils. Maximal concentration of PCB and TCD in soil samples equal to 35,700 mg/kg was detected at 300 m distance from the plant. Pollution was also detected at 40 to 60 centimeters depth (50.6 mg/kg). In 1992 – 1995 concentration of PCB in soil ranged from 0.6 to 110 mg/kg, concentrations of TCD ranged from 0 to 0.444 mg/kg. Pollutants migrated in soil and contaminated groundwater. Water from private wells was used by residents of the polluted area for drinking and watering gardens until 1988. Concentration of PCBs in groundwater in 1988 was 1.7 micrograms per liter, in 1991 concentration was 2.65 and in 1992 – 0.03 micrograms per liter. Snow samples were collected before and after change of technological process at the plant. In 1986 concentration of PCB in snow at 2.5 km distance from the plant ranged from 0.84 to 106.0 micrograms per liter. In 1992 PCB concentration was 0.8 micrograms per liter.

Food products. Residents of Serpukhov like residents of many other Russian cities eat locally produced food products - vegetables, fruits, berries, milk, eggs, and poultry. Residents of houses, which are located near the plant, routinely eat contaminated food products. Concentration of PCB in such common food products as potatoes and cabbages ranges from 0.0002 to 0.38 and from 0.0009 to 0.15 mg/kg, respectively. Elevated concentrations of PCB in vegetables and fruits have been detected even after the plant stopped PCB emissions. In the second half of the year 1991 low chlorinated biphenyls were responsible for up to 50 % of total PCB contamination of egg yolks (Table 1).

Breast milk and blood. High concentrations of PCB were found in breast milk samples (Table 2). Data on PCB content in serum samples collected from capacitor plant workers are presented in Table 3.

PCB and reproductive problems. It has been proven with animal experiments that high doses of PCB can cause malfunctioning of reproductive system. Low survival rate of animals' young, fertility problems and other reproductive disorders, which were observed during toxicological experiments, were caused by malfunctioning of endocrine system.

Infertility. There are very few publications on epidemiology of infertility in Russian scientific literature. Usually only data on fertility clinics visits are available. According to different authors, percentage of infertile women among those who visited gynecologists ranged in fifties and sixties from 9 to 29 %. Several epidemiological studies have been conducted later to assess prevalence and types of infertility in urban population. Prevalence rate of infertility in the city of Riazan was 8.4 per 100 couples including 3.1 % of primary female infertility, 5.1 % of secondary female infertility, 2.3 % of primary male infertility and 0.6 % of mutually infertile couples [5]. In the city of Tomsk secondary female infertility rate was significantly higher - 12.9 %, but rate of primary female infertility was approximately the same (3.8 %), which demonstrated that primary infertility rate was comparatively stable [6]. Significant problems with female reproductive health were detected in the town of Chapayevsk even earlier. In this town heavy environmental pollution and high concentration of dioxins in breast milk of local women were caused by a chemical factory which produced chlorine containing fertilizers [7]. Prevalence rate of infertility in this town was proven to be statistically significantly higher than in a control town. Infertility rate in Chapayevsk was 21.2 ± 2.5 per 100 women, and 14 ± 2.1 in control town, $p < 0.05$ [8]. In Serpukhov 105 patients with fertility problems were listed in 1997 in a data base of a women consultation.

Table 1. PCBs Contents in Egg Yolks from the Hens of Serpukhov Region, μg per yolk

Years	*No. of Samples*	*PCBs*		
		Mean	*SD*	*Range*
1987	5	7.3	2.1	3.4–9.1
1990	3	21.3	6.65	12.1–27.6
1991	18	9.5	9.7	1.9–40.1
1994	19	13.7	9.7	1.4–37.7
1995	13	24.9	33.7	0.85–11.3
1996	5	9.6	57.1	2.2–18.2
1997	9	7.6	9.9	1.2–25.5

Table 2. PCB Concentrations in Breast Milk of Women Residing in Serpukhov Town and Other Regions of Russia, μg/l

Region of Study	*Years*	*No. of Samples*	*PCBs*	
			Mean	*S. D.*
Serpukhov	1986	30	244.5	489.4
	1987	30	135.3	313.8
	1991	35	27.9	28.0
	1995	12	31.3	14.9
	1996	5	59.6	37.6
Moscow	1994	105	25.0	4.3
Altay province	1993	170	22.2	2.3
Kaluga province (country inhabitants)	1993	110	17.3	3.5

Table 3. PCB Concentrations in Blood Serum of the Serpukhov Capacitor Plant Workers, μg/l

Years	*No. of Samples*	*PCBs (A-54)*			*TCD (A-30)*		
		Mean	*S. D.*	*Range*	*Mean*	*S. D.*	*Range*
1988	15	2.12	13.1	0.04 – 54	241.3	311.8	0.04– 1080
1989	5	70	65.4	26 – 200	470	278	260-1010

Spontaneous abortions. Collection of statistical data on spontaneous abortions was started in Russia only several years ago. Rate of spontaneous abortion in the town of Serpukhov is 27 per 100 pregnant women [9] (Table 4). Average rate in Russia ranges from 20,6 to 23,3 per 100 pregnant women [10].

Low birth weight. This index reflects the effect of PCB exposure [11,12]. Rate of low birth weight in the town of Serpukhov is 7.1 per 100 births which is slightly higher than average rate in Russia (5.7 - 6.2 per 100) [10] and in other countries [13,14]. In cities with high level of ambient air pollution rate of low birth weight is not higher than 6.5 per 100 alive births.

Table 4. Number of Miscarriage per 100 Pregnant Women, by Cities

City	*Years*	*Total Population, in Thousands*	*Miscarriage No.*	*Pregnant Women No.*	*Per 100*	*Reference*
Serpukhov	1990 – 1992	144	493	1 796	27.4	[8]
Chapavevsk	1991 – 1993	85	730	635	19.6–23.6	[9]
Samara	1991 – 1993	1 236	10 939	9 260	12.6–12.0	[9]
Togliatti	1991 – 1993	676	8 237	7 432	8.8 – 9.6	[9]
Russia, Total Per 100 pregnant women without med. abortions	*1988 – 1994*				*20,6 – 23,3*	[7]

Table 5. Low-Birth Weight Babies

Countries	*Per 100*	*Reference*
Serpukhov (Russia), 1991 – 1995 y.	7.1	Current issue
Russia: 10 cities with the high level of ambient air pollution	> 6,5	[15]
Russia in General	*5,7 – 6,2*	[10]
European Countries	3.8 – 5.6	[13]
USA	6.9	[13]
China	6.0	[14]

Congenital malformations. Registers of congenital malformations are absent in Russia but based on American or European registries studies have been conducted in a number of cities. In 1989-1991 prevalence rate of congenital malformations was 4.5 per 100 new born infants [9]. In most of other Russian cities, where epidemiological studies have been conducted, prevalence rate of congenital malformations was not higher than 2.2 per 100 new born infants (exclusive of infants who were born to exposed to occupational hazards women) (table 6).

Table 6. Frequency of the Congenital Malformations* in Newborns According to the Data Epidemic Surveys

City (Region)	*No. of Newborns*	*No. of Newborns with Congenital Malformations*	*Per 100*	*Reference*
Serpukhov, 1989 – 1991	1193	57	4.5	[9]
Moscow, 1981	51476	1118	2.3	[17]
Klin, Moscow province	14595	214	1.5	[16]
Lyubertsy, Moscow province	21691	359	1.6	[16]
Novomoskovsk, Tula province	17235	299	1.7	[16]
Kaluga province	2800	54	1.9	[18]

* Total Frequency without any Indication of the Nosological Forms

Summary

The capacitor plant had been polluting ambient environment in Serpukhov with PCB for 25 years. Southern part of the town with private households and kitchen-gardens had been polluted more intensively. Vegetables, fruits, berries as well as eggs and dairy products, which are consumed by local people, are still polluted and an adult person can digest up to 5.86 mg of PCB per day. Exposure to polluted food products continues to be a problem even after change of technological process at the capacitor plant. The polluted area is especially hazardous for infants because daily PCB intake with breast milk can reach 500 maximal allowable daily doses. Concentrations of PCB are higher in breast milk of Serpukhov women than in milk of women who reside in other parts of the former USSR, in the USA, and in other western countries and who are not exposed to PCB at work places. Daily PCB intake by infants ranges from to 4.4 to 1722 micrograms per day. Preliminary analysis of reproductive function of Serpukhov women revealed elevated rate of miscarriages, congenital malformations and low birth weight. Serpukhov population is quite stable, ethnically and socially homogenous. There is no significant difference in social and economic status between exposed population and population of comparatively clean areas of the town which makes Serpukhov an interesting object for a special epidemiological project. A pilot project on PCB exposure and infertility will be conducted by the scientists from Harvard Schools of Medicine and Public Health in collaboration with our group. Dr. Susan Korrie (USA) will be a Principal Investigator of this project.

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