POLYCHLORINATED BIPHENYLS IN THE URBAN ENVIRONMENT OF BELARUS: SOURCES, POLLUTION, PROBLEMS OF MONITORING

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Abstract. In the paper environmental problems connected with such dangerous chemicals as polychlorinated biphenyls (PCBs) are discussed. Sources of PCBs in Belarus, location of the main part of PCBs in cities and towns, as well as specificity of PCB discharges into environment are shown. The content of PCBs in urban soil of different functional zones is given. High level of soil pollution by PCBs in places of PCB-containing equipment installation and storage is revealed. The peculiarities of hot spots formation and spreading of PCBs beyond the places of PCB leakage are established. Pollution of bottom sediments of some aquatic ecosystems by PCBs is identified. The problems and perspectives of PCB monitoring in urban environment are discussed.

Keywords: polychlorinated biphenyls; urban environment; soil pollution; bottom sediments; monitoring

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1. Introduction

Eenvironmental pollution by polychlorinated biphenyls (PCBs) is one of the most pertinent global ecological problems. Synthesized in 1930s for industrial purposes, PCBs were not considered dangerous chemicals for many years. Moreover, PCBs and PCB-containing products were produced and utilized with little restrictions or control in many countries. Only decades later evidence of their long-term adverse effect on human health and ecosystems was revealed, which resulted in the process of gradual introduction of restrictions and prohibitions on the use of PCBs. Nevertheless, PCB pollution remains one of the most critical environmental problems, since at present most of the previously produced PCBs are still either used or stored. The primary source of PCB discharges into the environment is PCB-containing electrical equipment (Berdowski et al., 1999; Guidelines for the identification…, 1999; AMAP, 2000; Breivik et al., 2002).

Wide application of PCBs, a variety of PCB discharges into environment (with leakages, emissions, products and waste), and PCBs' properties resulted in the fact that PCBs can be found virtually everywhere, including background territories. As xenobiotics (substances that are foreign to the natural environment), PCBs are present in all natural components including air, precipitation, waters, bottom sediments, soils, plants and animals, and human body (Toxicological profile…, 2000; Regionally-based assessment…, 2002; Ockenden et al., 2003; Dioxins & PCBs…, 2004). Characteristic features of PCBs' behavior in the environment include their very slow decomposition, ability to long distance distribution and bioaccumulation in fatty tissues of exposed animals and humans. Therefore, even with low PCB concentration in the environment there is a danger of PCBs accumulation on the top of the food chain – in human body.

PCBs have been used for over 40 years in Belarus. Yet, similarly to other post-Soviet Union countries, PCB pollution is a poorly studied problem for Belarus. The usage of PCBs is currently unregulated by Belarusian law. Moreover, there is a lack of specially designated storage facilities for the damaged equipment; and a system for PCB collection and disposal in an ecologically sound manner is not established yet. The research of PCB pollution began in Belarus only in the late 1990s. Today a variety of research initiatives in the field are under way, primarily due to Belarus' accession to the Stockholm Convention on Persistent Organic Pollutants. For example, in 2003–2006 several projects on PCB inventory and environmental pollution assessment were implemented (Kukharchyk et al., 2005; Suboch et al., 2005; Kukharchyk, 2006; The National plan…, 2006).

This article discusses peculiarities of the environmental pollution by PCBs in Belarusian cities, and analyses problems and prospects of PCB monitoring.

2. Methods and Objects

Experimental research was conducted in several cities, including Minsk, the capital and largest industrial city, and Lida, where for the last 30 years PCBs were used in the production of paint and varnish. Primary attention was paid to the study of pollution in soils and bottom sediments, because, on the one hand, they are deponents of PCBs, and on the other hand, they are secondary sources of PCBs re-emission and contamination of other environments.

Soil was sampled from different functional city zones as well from places of PCB use and storage of PCB-containing equipment. The total of 250 soil samples and 20 samples of bottom sediments were examined.

The sum of PCBs as well as individual PCB congeners (PCB-28, PCB-52, PCB-101, PCB-118, PCB-153, PCB-138 and PCB-180) was detected by gas chromatography with electron-capture detection and chromatography mass spectrometry (Suboch et al., 2005). Quantitative analysis was performed using five-point calibration with standard solutions.

3. Results and Discussion

3.1. PCB SOURCES

The following factors are determinative of the environmental situation in Belarus: the use of PCB-containing equipment; and the use of PCBs as raw materials in the production of paint and varnish.

3.1.1. The Use of PCB-containing Equipment

According to the results of the inventory (Kukharchyk et al., 2005; National plan, 2006), the total of roughly 1.5 thousand tons of PCBs were revealed in Belarus, 55 per cent of which is concentrated in power transformers, and 44 percent – in power capacitors. It was established that PCB-containing equipment is used at over 760 industrial enterprises which are located in 140 cities (Figure 1).

Most PCBs are concentrated at enterprises of large cities and industrial centers. For example, nearly 90 per cent of the total volume of PCBs in Belarus is concentrated in 23 cities and towns, where 53% of the total population lives. The largest volume of PCBs was revealed in three cities (Bobruisk, Minsk, Novopolotsk) amounting to 44.4 per cent of the total volume of PCBs in the country.

By now a significant share of PCB-containing electrical equipment has been phased out of operation or reserved. According to the inventory, this category of equipment includes 27 per cent of PCB-containing capacitors and 14 per cent of transformers. The uninstalled equipment is frequently stored on unprepared grounds on enterprise territory. The condition of power capacitors and transformers in many cases was evaluated as unsatisfactory, due to the destruction of their frames and PCB leakages as a result.

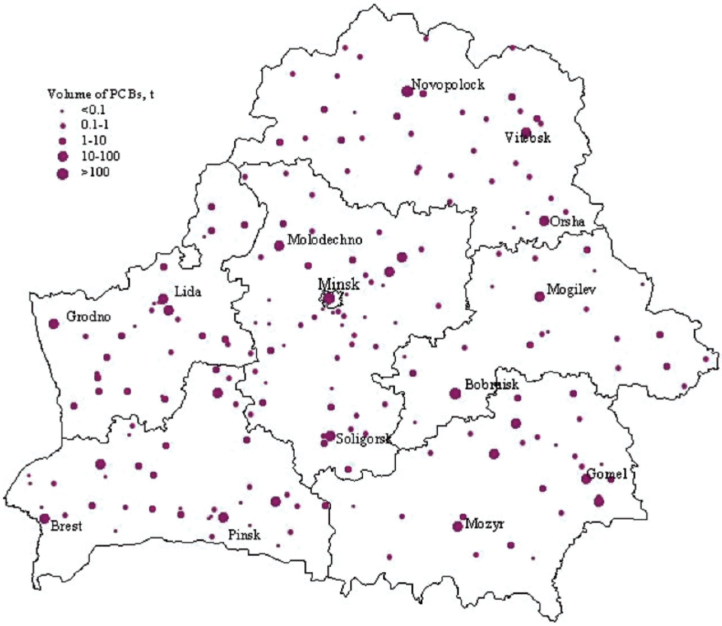

Figure 1. Rating of Belarusian cities by PCB volume

According to calculations, roughly 1.5 tons of PCBs are annually discharged into the environment from leaking power transformers and capacitors (Kukharchyk, Kakareka, 2006). For the purposes of comparison it must be noted that every year only 5 to 10 kg of PCBs are emitted into the atmosphere from thermal sources (fuel and waste combustion; steel production).

It must be emphasized that under the Stockholm Convention, PCB-containing equipment can be used until 2025. Therefore, identification of owners of PCB-containing equipment and regulation of its use and condition, as well as timely prevention of PCB leakage from damaged equipment become extremely important aspects of PCB management.

3.1.2. The Use of PCBs in the Production of Paint and Varnish

During 1968–1998 one of the enterprises in the city of Lida, Grodno region, was using sovol (pentachlorobiphenyl) as plasticizer to produce paint and varnish.

The total of 5 thousand tons of sovol was used (Kakareka et al., 2003). Most of it was transported out of the country with ready products, but some portion has been dispersed in the city through products, sewer waters, atmospheric emissions and wastes. According to the calculations (Kukharchyk, 2006), over the time of its use, nearly 130 tons of sovol leaked into the environment. The most significant discharge of PCBs happened between 1975 and 1985 when the leakages could amount to 3.3–10 tons annually.

3.2. PCB CONTENT IN URBAN SOILS

The results obtained in the process of the study reveal a wide scale of PCB levels in urban soils – ranging from levels below method sensitivity to several milligrams per kilogram of soil (Table 1).

TABLE 1. PCB content in soils of urban landscapes, mg/kg

Compounds	Residential areas (15)*		Green zones (7)		Near industrial enterprises (17)		At industrial site of JSC Lakokraska (13)	
	avg.	max	avg.	max	avg.	max	avg.	max
PCB-28	0.009	0.035	0.068	0.415	0.563	4.9	0.17	0.38
PCB-52	0.008	0.020	0.060	0.162	0.202	1.23	0.95	2.67
PCB-101	0.002	0.007	0.004	0.026	0.074	0.67	2.49	6.78
PCB-118	0.003	0.014	0.004	0.023	0.045	0.50	3.66	10.71
PCB-153	0.002	0.011	0.001	0.004	0.013	0.10	2.25	7.69
PCB-138	0.002	0.012	0.001	0.004	0.031	0.28	3.43	9.58
PCB-180	0.001	0.002	0	0	0	0	0.3	0.96
Sum of 7 congeners	0.032	0.059	0.137	0.635	0.928	7.69	13.25	38.45

*– the number of soil samples is given in the brackets

Higher level of PCB concentration in residential areas and green zones (parks, public gardens) and in the vicinity of industrial enterprises can be primarily explained by the existence of local sources of PCB distribution (discharge into the atmosphere; dispersal of waste, including residual ashes and construction litter). Among individual PCB compounds analyzed in the course of the research, both low-chlorinated and high-chlorinated compounds were identified. This finding proves the multitude of PCB sources. It is well established that the predominant PCB compound in soils of background territories is low-chlorinated (PCB-28). This is the most volatile PCB compound, which is transported through air for long distances.

The level of PCBs in industrial landscapes is determined by the sources of PCB emission. Predictably, high levels of PCBs were revealed on the territory of paint and varnish producing enterprise "Lakokraska", where the sum of 7 isomers reaches 38.45 mg per kg, and the sum of PCBs makes up to 96.6 mg per kg. It was found out, that the enterprise soil is contaminated 30 cm deep.

PCB compounds are dominated by penta- and hexachlorobiphenyls, 53 per cent and 28 per cent respectively, which is clearly indicative of such source of PCB discharge as sovol (Figure 2).

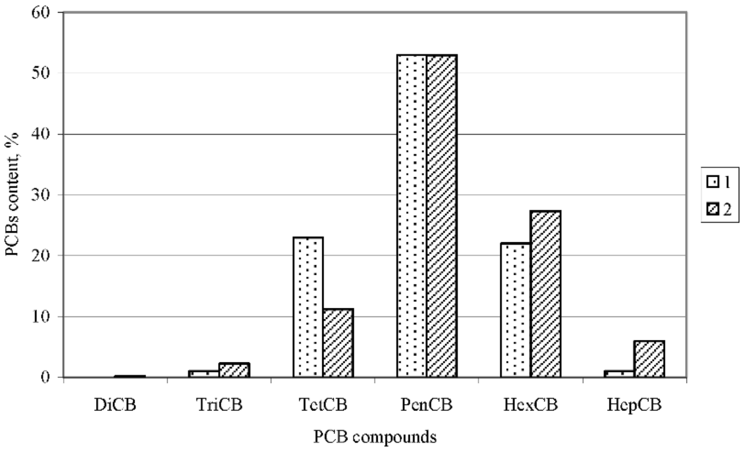

Figure 2. PCB compounds structure: 1 – in sovol, 2 – in soil of industrial site

The research shows that the highest level of soil pollution is found in places of PCB-containing equipment usage and storage (Table 2).

TABLE 2. Content of PCB sum in soils in impact zones of PCB-containing equipment installation or storage, mg/kg

Sampling site, number of samples	Average	Maximum
Places of PCB-containing capacitors installation, 120	12000	82000
Places of PCB-containing capacitors storage (on the ground or on concrete), 16	7130	92000
Places of PCB-containing transformers storage, 4	78000	105000
At distance 1–3 m from PCB-containing capacitors banks, 37	7.03	102
At distance 10–150 m from PCB-containing capacitors banks and storage, 24	0.9	23
Background territories (more than 1 km from sources), 30	0.035	0.165

At the same time, landscapes with extreme levels of PCBs are localized and determined by leakages from damaged equipment. More often that not, the most polluted landscapes are small in size (around 0.05 square meters). Moreover, much wider pollution spots are created in places of emergency leaks (up to 1 square meter and wider). Overall, in roughly 60 per cent of industrial objects assessed during the research, the area of extreme levels of pollution (around 500 mg per kg) was less than 1 square meter; in 20 per cent of the industrial objects the area of extremely polluted soils reached 1 to 5 square meters; and only is single cases did the polluted territory have much larger area.

Basically, those are the so-called “hot spots”, in relation to which cleaning and remediation measures should be taken. Thus, according to the Stockholm Convention, substrates with more than 50 mg per kg are subject to ecologically sound management (Stockholm convention…, 2001). The Environmental Protection Agency of the USA equates 500 mg per kg to PCB-containing materials and makes them subject to utilization (40 CFR…, 2002).

The objects researched differ significantly in the level of soil pollution and the depth of PCB penetration. Extreme levels of pollution are found in the upper soil levels – up to 10 cm. However, in cases of easily identifiable spots of PCB spills, a high level of PCB pollution can be found at the depth of 0.5–1 meters.

The danger of PCB leakages depends upon the spread of PCBs beyond the spots of PCB-containing equipment use or storage. This, in turn, may lead to the contamination of nearby territories and other environmental components, including the contamination of ground and surface waters. Due to leakages of liquid from the equipment, new (secondary) sources of PCB pollution are formed, the impact zone of which is practically unlimited because of PCBs’ ability to mix with aerial and water flows and spread far beyond their locations of production and use by inclusion into the biological circle. This means that, by definition, local application of PCB-containing equipment (several square meters) becomes not only a source of local anomalies, but a source of regional and, in future, global pollution.

3.3. PCB CONTENT IN BOTTOM SEDIMENTS

Bottom sediments are an indicator of the state of aquatic ecosystems, as well as of catchment’s area, from the runoff of which the discharge of pollutants is possible. According to the results of the research, the sum of 7 PCB isomers in bottom sediments of sampled rivers and basins (reservoirs) of Belarus varies from levels below the method detection limit to 23.2 mg per kg. The data in the table 3 confirms pollution of bottom sediments of the majority of basins and rivers examined. Extreme levels of PCBs were detected in bottom sediments of Lidskoe reservoir (city of Lida, Grodno region), which may be explained by the location of an industrial facility of paint and stain producing enterprise "Lakokraska", where sovol was used on the catchment's area.

The level of PCBs in bottom sediments of basins and watercourses, remote from PCB impact sources, does not exceed 0.065 mg per kg of dry matter. Congeners of trichlorobiphenyls (firstly PCB-28) are predominant.

TABLE 3. PCB content in bottom sediments, mg/kg

Sampling site, number of samples	Sum of 7 PCB congeners
River and reservoirs of background territories, 5	nd–0.065
River and reservoirs of urbanized territories	
Minsk city, 7	0.023–0.828
Lida town, 3	0.598–23.2

nd – below the detection limit

4. Problems and Perspectives of PCB Monitoring

Control of PCB levels in the environment is one of the necessary preconditions for minimization of its adverse effect on human health and for the performance of international obligations under the Stockholm Convention on Persistent Organic Pollutants. At this point, the problem of environmental pollution by PCBs in Belarus is acknowledged, but the data collected is still insufficient in order to fully realize the extent of contamination.

Systematic monitoring of PCB levels in the environment requires adequate chemical analysis infrastructure as well as regulatory and methodological frameworks. Currently, there are only two chemical analysis laboratories in Belarus accredited to measure PCB levels in soils, wastes and waters. Both laboratories are located in Minsk, and one of them requires significant modernization of equipment. Moreover, the quality of measurements and method sensitivity need to be improved. For example, the condition of available equipment does not allow for large-scale detection of PCBs in surface and ground waters due to low sensitivity of methods used. Besides, the improvement of water sampling method is necessary. Further advancement of research is also impeded by a lack of qualified professionals in the field of detection of organochlorines compounds. In most cases, the procedures of preparing samples, cleaning the extract and its separation are performed manually, which reduces the productivity of the laboratories (The National plan…, 2006).

At this time, methods of PCB detection in soils belong to the most advanced ones. It is however necessary to continue identification of highly polluted territories, because the soil is an important deponent of PCBs and is the most probable source of PCB supply into waters, animal and human food. It is necessary to implement thorough research at the locations of PCB sources, and to determine a network for systematic monitoring of PCB levels in urban soil. Lida, Minsk, Bobruisk and Novopolotsk are Belarusian cities which require primary attention and assessment. It is also recommended to implement monitoring of surface waters and bottom sediments in these cities.

Overall, the research has shown that in Belarus priority should be given to research (including monitoring), aimed at identification of places, which have critical levels of pollution and are most probable sources of pollution of drinking water and food products.

5. Conclusion

Polychlorinated biphenyls present a serious danger to the health of Belarusian people. Over the last years intensive research has allowed to receive, in short time, fairly accurate data on the sources and quantity of PCBs, and the owners of PCB-containing equipment. The research has also made possible to comprehend possible levels of environmental pollution by dangerous chemicals. However, the ecologically sound management of PCBs and the reduction of adverse effect of PCBs on human health remains a difficult and enduring task, which requires significant financial resources for the creation of the necessary infrastructure, improvement of the legal system, training of staff, development of PCB monitoring equipment as well as increasing public awareness of the PCB problem.

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