PCB-CONTAMINATED SITES IN BELARUS: REVEALING, LEVELS OF POLLUTION, PROBLEMS OF MANAGEMENT

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Introduction

An investigation of the problem of polychlorinated biphenyls (PCBs) in Belarus started in 1999 and was related to a detection and identification of PCB sources, elaboration of emission factors, estimation of PCB emissions and a selective inventory of PCB sources[1,2,3]. In 2004, Belarus acceded to the Stockholm Convention on Persistent Organic Pollutants stimulating many research initiatives. In 2003-2007 several projects on PCB inventories and environmental pollution assessment were implemented[4,5,6,7].

According to the inventories, more than 1.5 thousand tones of PCBs were revealed in power transformers and capacitors. It was established that the main amount of PCB-containing equipment is still in operation because of their long life-time, but much has been taken out of operation. Among PCB-containing equipment, about 10 000 capacitors (which contain approximately 140 tones of PCB) are used at open sites. Right on these sites the probability of PCB leakage is very high. Calculations show, that roughly 1.5 tons of PCBs are annually discharged into the environment from leaking power transformers and capacitors[8].

Another significant source of PCB discharge into environment of Belarus is from paint and varnish production. During 1968-1998, about 5 thousand tons of Sovol was used at the JSC Lakokraska in the city of Lida, Grodno region[3]. Most of it was transported out of the country, but some portion has been dispersed in the city through products, sewer waters, atmospheric emissions and waste. Over the time of its use, nearly 130 tons of Sovol leaked into the environment[5]. The most significant discharge of PCBs happened between 1975 and 1985 when the leakages could amount to 3.3-10 tons annually.

This article discusses the levels and peculiarities of PCB soil pollution, as well as problems and perspectives of PCB-contaminated sites management.

Material and methods

Experimental works were conducted on the territory of sites where PCB-containing electrical equipment was installed or stored as well as on the territory of Lakokraska. About 50 sub-station with capacitors and 2 places with transformers were investigated. Capacitors are installed as capacitor batteries at the height from 0.2 to 2 m. The area of capacitor batteries vary from 30 to 180 m^2. Investigation of soil pollution was done on the base of methodology and guidelines for revealing of polluted sites[9,10] taking into account the following factors: amount of PCB-containing equipment, service or storage condition, visual damaged of equipment and leakages of PCBs, relief and usage of adjacent land.

Soil was collected under destroyed capacitors, under capacitors without damage and at varying distances from capacitors or transformers. Soil was collected primarily from the depth 0-10 cm. In same cases samples were collected from the depth 20-30, 40-50 and 90-100 cm.

More than 200 soil samples were collected and analyzed. 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[4]. Quantitative analysis was performed using five-point calibration with standard resolutions.

Results and discussion:

Soil pollution as a result of PCBs leakage from electrical equipment

PCBs content in the soils of the territories, where electrical equipment is used and stored, makes up to milligrams or sometime grams per kilogram. Maximum concentrations of PCBs (2-105 g/kg) were found in the soil near destroyed capacitors and transformers as a consequence of PCB leakage (Table 1). It exceeds many times not only maximum permissible level, but the level recommended for cleaning and remediation. Thus, according to the Stockholm Convention, substrates with more than 50 mg/kg are subject to ecologically sound management[11]. The United States Environmental Protection Agency equates 50 mg/kg to PCB-containing materials and makes them subject to disposal[12].

Low-chlorinated PCBs dominate in soils at places where capacitors are installed or stored and high-chlorinated PCBs - where transformers are stored (Figure 1).

Generally in most cases PCB content in soils is very heterogeneous; the level of pollution and the structure of anomalies depend on the type of leakage, time of PCB-containing equipment operation or storage and processes of PCBs migration. The size of spots is different; most of them are less than 1 m^2. Moreover, much wider pollution spots are created as a result of capacitors explosion. There are visual features of soil pollution (oily, darker color, burned out vegetation) and specific smell.

The investigated sites 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 was found at the depth of 0.5 m or even 1 m. For example, in the substation Lida PCBs content in soil at the depth 0-0.1 m makes up to 23.5 g/kg, at the depth 0.9-1.0 m – 0.94 g/kg.

Spreading of PCBs beyond the places of PCB-containing equipment usage or storage was revealed. The sum of PCBs in the soil at a distance of 100-150 m from the capacitor battery was between 1.2 to 23 mg/kg. Hot spots are potential sources of secondary ground and surface water, as well as bottom sediments pollution. Due to leakages from the equipment, new (secondary) sources of PCB pollution are formed, the impact zone of which is practically unlimited because of PCBs' ability to spread far beyond their locations and to include 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 also a source of regional and, in future, global pollution.

Soil pollution as a result of Sovol usage

High levels of PCBs were revealed in the territory of JSC Lakokraska, where the sum of 7 isomers in the upper 10 cm reaches 38.45 mg/kg, and the sum of total PCBs makes up to 96.6 mg/kg (Table 1). Maximum values of PCBs in soil were found near the building were Sovol has been used as plasticizer and near the warehouses. Here in depth 20-30 cm the concentration of total PCBs ranged from 23.4 to 57.4 mg/kg.

Penta- and hexachlorobiphenyls are dominant, 53 % and 28 % respectively, which suggests Sovol as a potential source. According to V. Ivanov and E. Sandell[13], the technical mixture of Sovol content 53% of penta- and 22 % of hexachlorobiphenyls.

There was not found the extreme level of PCBs and the spatial distribution of PCBs was homogenous in comparison with the places where PCB-containing equipment installed or stored. However, soil are polluted not only on industrial site (about 80 ha), but at adjacent area. PCB determination in 25 samples collected from agricultural land, residential area and green zones in Lida city show that content of PCBs vary from 0.04 to 4.6 mg/kg.

Problems and perspectives of PCB-contaminated sites management

The problems of PCB-contaminated sites management are the following: dispersion of PCB-containing equipment among enterprises throughout Belarus (more than 760 enterprises) and as a result – lack of a system for reporting and registering of PCB leakages; significant amounts of PCB-containing equipment used or stored at open sites; lack of reclamation and incineration facilities for PCB; absence of PCB monitoring system; lack of special storage places for damaged equipment and no control of ecologically safe management of PCB-containing equipment.

The results of the investigation show that soils are polluted at all sub-stations where PCB-containing equipment was used or stored. In most cases 'hot spots' with high concentration of PCBs are revealed. On the whole, PCBs contamination is extremely heterogeneous. This heterogeneity should be taken into account for the estimation of the areas with a high level of PCBs contamination. For detection of 'hot spots', the pattern of usage and storage of PCBs (current and previous) should be determined. It is very important to have realistic estimates of the extent of PCB contamination from installed and stored equipment for the purpose of remediation. The first measures for soil remediation at the two substations including excavation of most polluted soil and its package into containers for temporary storage confirm the necessity of detailed researches.

To prevent PCB spills and its releases into environment the Recommendation for Prevention of Environment Pollution by Polychlorinated Biphenyls[14] was developed. For these purposes the experience of other countries in PCBs management[11,15,16,17,18] was analyzed. The Recommendation includes: the procedure of PCB-containing equipment identification, labeling and accounting; inspection of PCB-containing equipment; priority activities during damaged equipment revelation and PCB spills; requirements for temporary PCB-containing equipment storage.

Taking into account the results of PCBs investigation and obligation of Belarus on Stockholm Convention on POPs the following measures were proposed and included into the National Implementation Plan[19]: development of a technical regulation document which defines the procedure of POPs contaminated sites clean up; analysis and selection of POPs contaminated soil remediation technologies; excavation of the most contaminated soils from the sites where PCB leakage and spillage are recorded and ensuring their environmentally sound storage; and initiation of a pilot project on clean up of PCB-contaminated sites at substation Lida and OJSC Polimir (Novopolotsk).

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Table 1: 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 (16)	7130	92000
Places of PCB-containing transformers storage (4)	78000	105000
1-3 m from PCB-containing capacitors battery (37)	7.03	102
10-150 m from PCB-containing capacitors battery and storage (24)	0.9	23
Background territories - more than 1 km from sources (30)	0.035	0.165

Figure 1: Average PCBs content in the soils under destroyed capacitors (a) and near destroyed transformers (b)

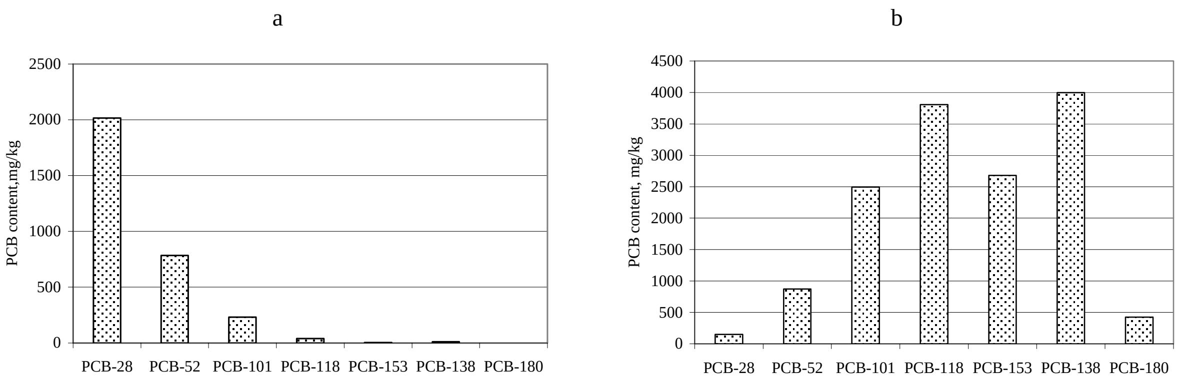

Table 2: PCB content in soils at industrial site of JSC Lakokraska , mg/kg (number of samples = 13)

Compounds	Average	Maximum	The share of compounds, %
PCB-28	0.17	0.38	1.3
PCB-52	0.95	2.67	7.2
PCB-101	2.49	6.78	18.8
PCB-118	3.66	10.71	27.6
PCB-153	2.25	7.69	17.0
PCB-138	3.43	9.58	25.8
PCB-180	0.3	0.96	2.3
Sum of 7 congeners	13.25	38.45	100
Total sum of PCBs	27.2	96.6	