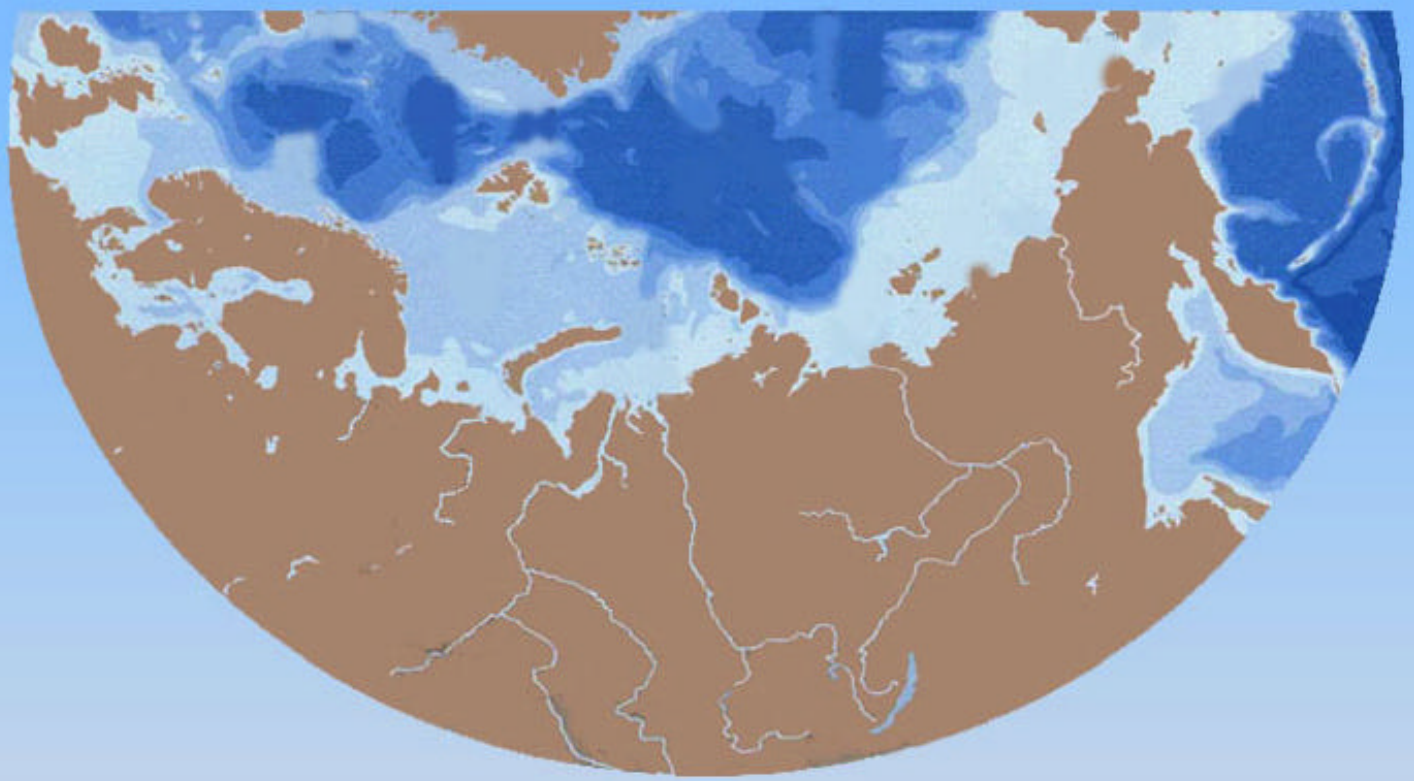
PCB in the Russian Federation: Inventory and Proposals for Priority Remedial Actions

Executive Summary



Center for International Projects

AMAP Arctic Monitoring and Assessment Programme

PCB in the Russian Federation: Inventory and proposals for priority remedial actions

Executive Summary of the report on

Phase I: Evaluation of the Current Status of the Problem with Respect to Environmental Impact and Development of Proposals for Priority Remedial Actions

of the

Multilateral Cooperative Project on Phase-out of PCB Use, and Management of PCB-contaminated Wastes in the Russian Federation

Prepared for the Arctic Council by:

ARCTIC MONITORING AND ASSESSMENT PROGRAMME (AMAP)

STATE COMMITTEE OF THE RUSSIAN FEDERATION FOR ENVIRONMENTAL PROTECTION

CENTER FOR INTERNATIONAL PROJECTS (CIP)

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PCB in the Russian Federation: Inventory and proposals for priority remedial actions

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Contents

Preface

This publication is the Executive Summary of the Report on the First Phase of the *Multilateral Co-operative Project on Phase-out of PCB Use, and Management of PCB-contaminated Wastes in the Russian Federation.* The objectives of this project are to elaborate an inventory of PCB, and develop proposals for priority remedial actions to handle the PCB problem in Russia. Phase 1 of the project was implemented within the period 1May 1999 - 30 June 2000, mainly by the Russian Expert Group and the Centre for International Projects (CIP) operating as the Russian Performing Entity. In this connection, the Steering Group would like to express its appreciation to the members of the Russian Expert group, the staff of CIP and all experts from Russian/former Soviet Union ministries, research institutes and enterprises, who have contributed their time, effort, and data to the success of this work.

The Steering Group would also like to express its appreciation to the western experts for their valuable contributions, and for their constructive joint work with the Russian experts that has helped to provide the comprehensive results obtained during Phase 1.

Special thanks are due to the Danish expert, Frank Stuer-Lauridsen, and his colleagues from COWI for preparing the first draft of this Executive Summary, and to the Moscow COWI Branch that has assisted in the arrangement of effective communication between Moscow and the members of the Steering Group and the AMAP Secretariat.

The Steering Group, the AMAP Secretariat, and the Centre for International Projects is pleased to present this Executive Summary, as well as the full report for Phase 1, for consideration of the Arctic Council and its member states, particularly the Russian Federation.

Finally, it is necessary to emphasise that this work would not have been possible without financial support from all the Arctic countries (Canada - Department of Indian Affairs and Northern Development; Denmark - Danish Environmental Protection Agency; Finland - Ministry of the Environment; Iceland - Ministry for the Environment; Norway - Norwegian Pollution Control Authority; Sweden - Swedish Environmental Protection Agency; and United States - United States Environmental Protection Agency) and the Netherlands - Ministry of Foreign Affairs, and all the project participants would like to express their deep appreciation for this support.

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Introduction

Background

During the period 1997-1998, under the framework of the 1979 Convention on Long-range Transboundary Air Pollution and its related Protocols, the United Nations Economic Commission for Europe (UN/ECE) prepared a protocol on persistent organic pollutants. This protocol was adopted on 24 June 1998 in Aarhus (Denmark) and opened for signature. The goal of the Protocol is to limit, reduce and ultimately eliminate releases and other emissions of certain persistent organic pollutants (POPs) to the atmosphere and other environmental media. Polychlorinated biphenyls (PCBs), a major group of industrial chemicals, constitute one of the 16 POPs listed for restriction and ultimate elimination under the UN ECE POPs Protocol. Although, as part of its obligations to the Helsinki Commission for the Protection of the Baltic Sea (HELCOM), Russia has undertaken not to distribute POPs to the environment, the Russian Federation has not yet signed the UN ECE protocol on POPs.

In November 1997, during an AMAP Working Group meeting in Denmark, preliminary discussions were held concerning assistance to the Russian Federation to solve the problem of elimination of PCB use in Russia. This initiative was supported by all Arctic Countries through agreement reached during the First Arctic Council Meeting in Iqaluit (Canada, September 1998). It was therefore decided to develop and implement the joint "*Multilateral Co-operative Project on phase-out of PCB use and management of PCB-contaminated wastes in the Russian Federation*". This project includes three phases:

1. Evaluation of the current status of the problem with respect to environmental impact and development of proposals for priority remedial actions.
2. Feasibility study.
3. Implementation of demonstration projects.

The combined project phases cover all stages of problem solving, from assessment of the magnitude of the PCB problem, to development of technical-economic proposals for solutions, and their practical realisation.

The report presented in this document covers phase 1 of the project.

Goal, methodology, realisation

Goal

The main goal of phase 1 of the project is the evaluation of the current status of the PCB problem in Russia. The objectives of sub-activities under phase 1 of the project included:

- Assessment of the overall production of PCB in the former USSR and Russian Federation, and the calculation of a mass-balance of the amount produced.
- Estimation of the total volume of PCB still in use, in equipment and in wastes located within the territories of Russian Federation.
- Preparation of an inventory of environmental releases from industrial uses and waste.
- Development of proposals for priority remedial actions.

Methodology

To ensure maximum completeness and reliability in assessing the total amount of PCB, and preparing the inventory of PCB containing equipment and waste in Russia, two independent sources of data collection were employed.

The first were the territorial environmental protection authorities (covering the 89 administrative territories - republics, krai, oblast, autonomous okrug - of Russian Federation) which collected information on a regional basis and submitted this to the State Committee for Environmental Protection.

The second source of information was data collected by relevant ministries from industrial enterprises located throughout Russia in which inventory activities were conducted. These requests for information on production, use and storage of PCB, were sent to the following ministries and organisations connected with various industrial activities: the State Committee for Statistics, Ministry of Economy, Ministry of Fuel and Energy, Ministry of Defence, the electric power network and several other companies. The electric power sector in Russia is divided into a number of enterprises responsible for production of electricity and the distribution networks. These are again divided into both federal and regional levels of subordination. The electric power network consists of the 'Russian joint-stock company of joint electric energy systems' (RAO 'ES of Russia') and 76 regional energy systems, all of whom were sent the request for information on PCBs. For technical reasons, equipment with PCB is not used in electricity production (only transformers filled with mineral transformer oil are used in electricity production). In the distribution network, however, capacitors containing PCB are used.

The following industrial branches (according to the State Committee for Statistics classification) were excluded as not being users of equipment containing significant amounts of PCB:

- Food industry;
- Light industry;
- Production of building materials.

The Ministry of Defence officially replied that it would not take part in the inventory of PCB or PCB containing equipment because PCB containing equipment and materials are not in use anymore. For this reason, the use and disposal of PCB in the military sector was not assessed in the present project.

In the major industrial sectors: chemical and petro-chemical sector, ferrous and non-ferrous metallurgical industries, mechanical engineering, and timber (including pulp and paper) industry, some 300 enterprises, which may utilise high power capacitors and transformers were selected by the Ministry of Economy of the Russian Federation. The same number of enterprises was selected in the electric energy sector. According to the State Committee for Statistics, the number of large enterprises in Russia in 1997 was 265, and the total number of enterprises included in the inventory (600) is approximately twice this number.

As of December 1999, data were submitted by 79 administrative territories of the Russian Federation to the State Committee for Environmental Protection, and information for the inventory was supplied to the ministries by a total of 950 large- and medium-sized enterprises. This, according to expert estimation, covered approximately 80% of the total number of enterprises which may have PCB or PCB containing equipment. The inventory conducted by territorial environmental protection authorities incorporates information concerning presence of capacitors and transformers in all enterprises, also including the food industry, light industry and the building industry.

Realisation

The State Committee of the Russian Federation for Environmental Protection prepared and issued a "*Guide to conduct of the inventory of production, equipment and materials, using and containing PCB, and PCB-contaminated wastes in the territory of the Russian Federation*" for use by the territorial environmental protection authorities and experts in the various industries. This 'Guide' contained information on the basic physico-chemical and toxic properties of PCBs, trademarks of PCB-containing materials manufactured in the former USSR, fields of use of PCB, and also possible items and materials

containing PCB. This information facilitated identification of PCB and PCB-containing equipment for inclusion in the responses to the distributed questionnaire. Official information submitted by governmental and economic organisations at federal and regional levels was used during project implementation.

The complete project was subdivided into 6 tasks covering:

1. Information on production of PCB;
2. Information on production of PCB-containing equipment;
3. Information on use of PCB-containing equipment;
4. Information on PCB-contaminated industrial waste;
5. Information on releases of PCB from industrial waste;
6. Recommendations.

Data were collected by employees of the relevant ministries and territorial environmental protection authorities. Data were then submitted to the State Committee of the Russian Federation for Environmental Protection, for processing by the Russian experts group that was established by order of the State Committee to carry out the project.

The Center for International Projects of the State Committee of the Russian Federation for Environmental Protection (CIP) provided logistical support and prepared the reporting documentation for each task. This documentation was then submitted to the AMAP Secretariat and to the project International Steering Group for review and eventual approval.

PCBs in short

PCBs are a group of some 209 individual chemical compounds, produced in a various industrial mixtures. In common with several other organochlorine compounds, PCBs show a high degree of resistance to biodegradation in the environment and tend to accumulated in the food chain. Consequently, PCBs are included in the large group of substances that are termed persistent organic pollutants (POPs). Many of the individual PCB compounds exhibit toxic properties, with effects associated with long-term chronic exposures. They therefore constitute a hazard to both the environment and the health of exposed populations. Due to their persistence and bioaccumulating characteristics, PCBs can be transported over long distances in various media, with evidence to suggest that they eventually deposit and accumulate in the cold (Arctic) region, a result of the so-called cold condensation or global distillation effect. PCBs can enter the environment in a number of different ways, e.g. direct releases from equipment still in use or in storage, emissions from PCB contaminated waste or from contaminated sites and disposal areas, etc.

PCB was first produced by the Monsanto Co. in the USA in 1929. In the former USSR, PCB was first synthesised in 1934 and industrial production was launched in 1939. Chemically, PCB is composed of two linked benzene rings together with 1-10 chlorine atoms attached to the rings. It is relatively simple to synthesise a product primarily composed of PCB with 3, 4 or 5 chlorine atoms. PCB is chemically stable and heat resistant, and has particularly useful dielectric properties. Consequently, it was used world-wide, especially as a dielectric in electrical components (transformers and capacitors) and as an additive in hydraulic-, cutting- and lubricating oils. Other uses of PCB included ink solvents, plasticisers in paint, and flame retardants.

PCB use was banned or severely restricted in many countries during the 1970s and 1980s, and between 1987 and 1993 production of PCB in Russia was terminated. Prior to the present project, however, no calculation of the total amount of PCB produced and used in the former USSR and Russia has been made. Continuous monitoring of PCB emission sources, or PCB concentrations in environmental media and in foodstuffs are not generally carried out in Russia.

Production of PCB

Locations

PCB was produced at two sites in the former USSR (both in Russia) (Figure 1). The largest facility was the 'Orgsteklo' Ltd. Production Amalgamation (located in Dzerzhinsk in Nizhni Novgorod Oblast, approximately 300 km east of Moscow); and the second was the 'Orgsintez' Ltd. Production Amalgamation (at Novomoskovsk in Tula Oblast, ca. 200 km south of Moscow).

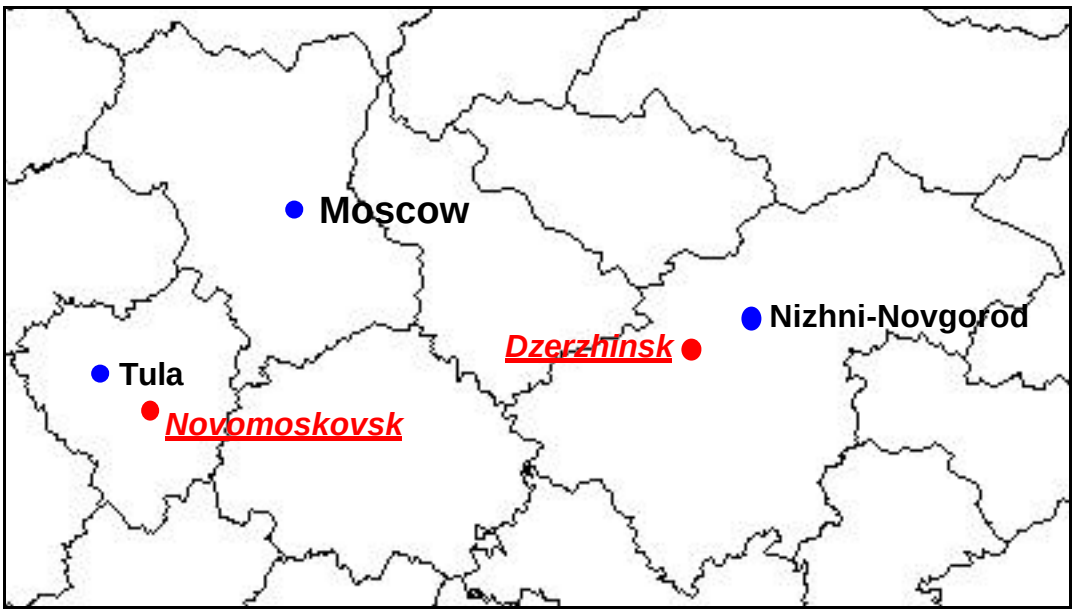


Figure 1. PCB production in Russia.

PCB was produced under three brand-names:

- Sovol: A mixture of tetra- and pentachlorinated PCBs (used as a plasticiser in paints and varnishes);
- Sovtol: Sovol mixed with 1,2,4 trichlorobenzene; especially in the ratio 9:1, named Sovtol-10 (used in transformers);
- Trichlorobiphenyl (TCB): Mixed isomers of trichlorobiphenyl (used in capacitors).

Minor production of special mixtures took place during the early days of PCB production. For example, a mixture of Sovol and α–nitronaphtalene was given the brand-name 'Nitrosovol', and a mixture of PCB with paraffin and cenerezin was used to impregnate paper capacitors. There was also a limited production of Hexol – a mixture of pentachlorobiphenyl with hexachlorobutadiene. These minor productions are not included in the inventories.

Sovol and Sovtol production at the 'Orgsteklo' (Dzerzhinsk) facility began in 1939, and TCB in 1968. Sovtol-10 production was shut-down in 1987, TCB and Sovol in 1990. At the 'Orgsintez' (Novomoskovsk) facility, Sovol and Sovtol production was launched in 1971, and full-size operation started in 1972. 'Orgzintez' Ltd. stopped production of Sovtol in 1990 and production of Sovol in 1993. There was no production of TCB at 'Orgsintez'.

Volume produced

Retrospective analysis of production figures shows that during the period from 1939 to 1993, the factories produced a total of about 180,000 tonnes of the three main PCB brands (see Table 1).

Table 1. Overall PCB production (thousands of tonnes) by 'Orgsteklo' (Dzerzhinsk) and 'Orgsintez' (Novomoskovsk).

	'Orgsteklo'		'Orgsintez'		Total
	Production	Period	Production	Period	
Sovol	43	1939-1990	9.5	1972-1993	52.5
Sovtol	32	1939-1987	25	1972-1990	57
TCB	70	1968-1990	-	-	70
Total	145		34.5		179.5

Between 1990 and 1993, production of PCB at these facilities ceased entirely, equipment has been dismantled and no PCB is stored at the sites.

According to available information, the only exporter of PCB (Sovtol-10) was 'Orgsintez' Ltd. (Novomoskovsk), which during the period 1981-1989 exported 39.5 tonnes to certain countries (Cuba, Vietnam, Pakistan). Import figures are not available. One estimate sets a maximum import of 4,000 tonnes TCB annually for 1980-1983, but this number is based only on a decrease in production capacity at the 'Orgsteklo' plant and not a documented industrial demand for TCB. Overall, the imports and exports of crude PCBs are assumed to cancel each other.

Production of PCB containing equipment

The main users of Sovol, Sovtol and TCB are represented on the maps in Figures 2, 3 and 4, respectively.

PCB use in various industries

Sovol

The plasticiser Sovol was used in a number of industries, especially in those producing paints and varnishes and household products, and in the manufacture of various lubricants. No application in the production of hydraulic oil was identified. A use of approx. 53,000 tonnes from the total production of Sovol was estimated as follows:

- 37,000 tonnes used in the production of varnish and paint;
- 10,000 tonnes used in the production of lubricants;
- ca. 5,500 tonnes used in defence-related industry plants and other industrial enterprises not otherwise included in the inventory.

According to gross estimates, the remaining 127,000 tonnes of PCB were used in the following manner:

- ca. 57,000 tonnes of Sovtol-10 used as a dielectric fluid in transformers.
- ca. 70,000 tonnes of TCB used as a dielectric fluid in capacitors.

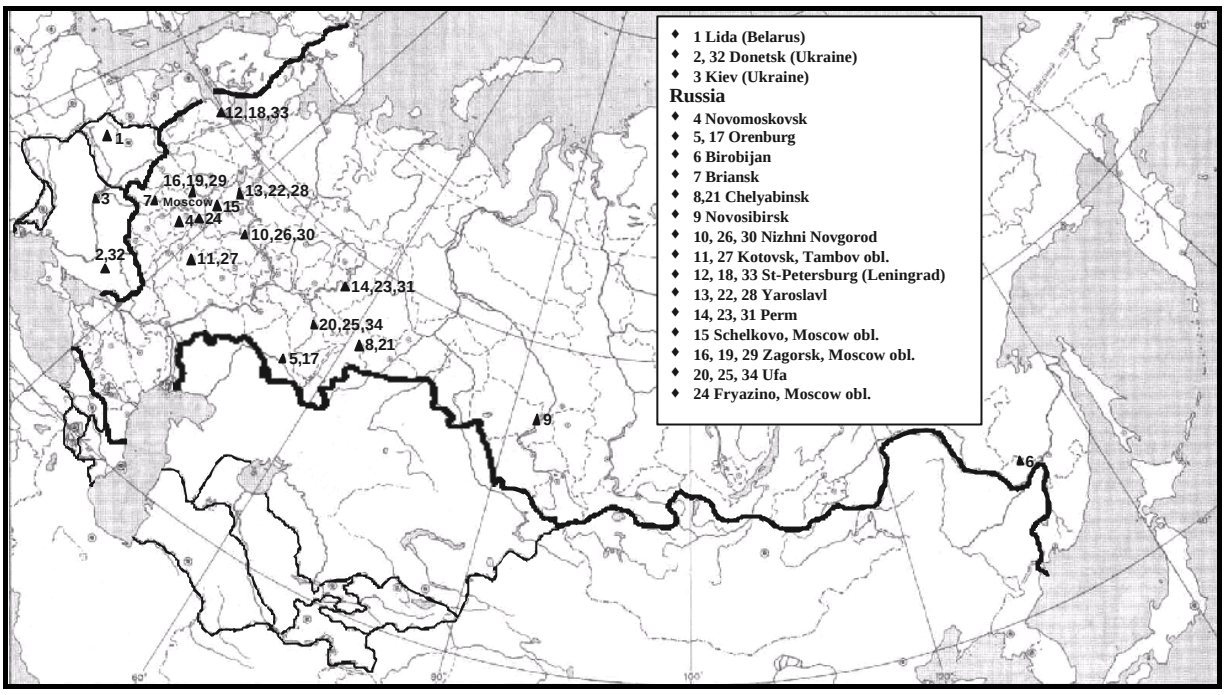


Figure 2. Location of PCB (Sovol) users.

Sovtol-10

The 57,000 tonnes of Sovtol produced were used almost entirely (98%) by the transformer plant at Chirchik (Uzbekistan). The remaining ca. 2% went to other industries, mainly the automobile, steel, and machine construction industries.

According to information from the transformer production enterprises, 35,000 tonnes of Sovtol (60% of the total 57,000 tonnes of Sovtol produced) were used in Russia, and the rest (40%) in the former republics of the USSR. According to expert estimation, only 60% (21,000 tonnes) of the 35,000 tonnes of Sovtol used in Russia are still expected be in Russia today.

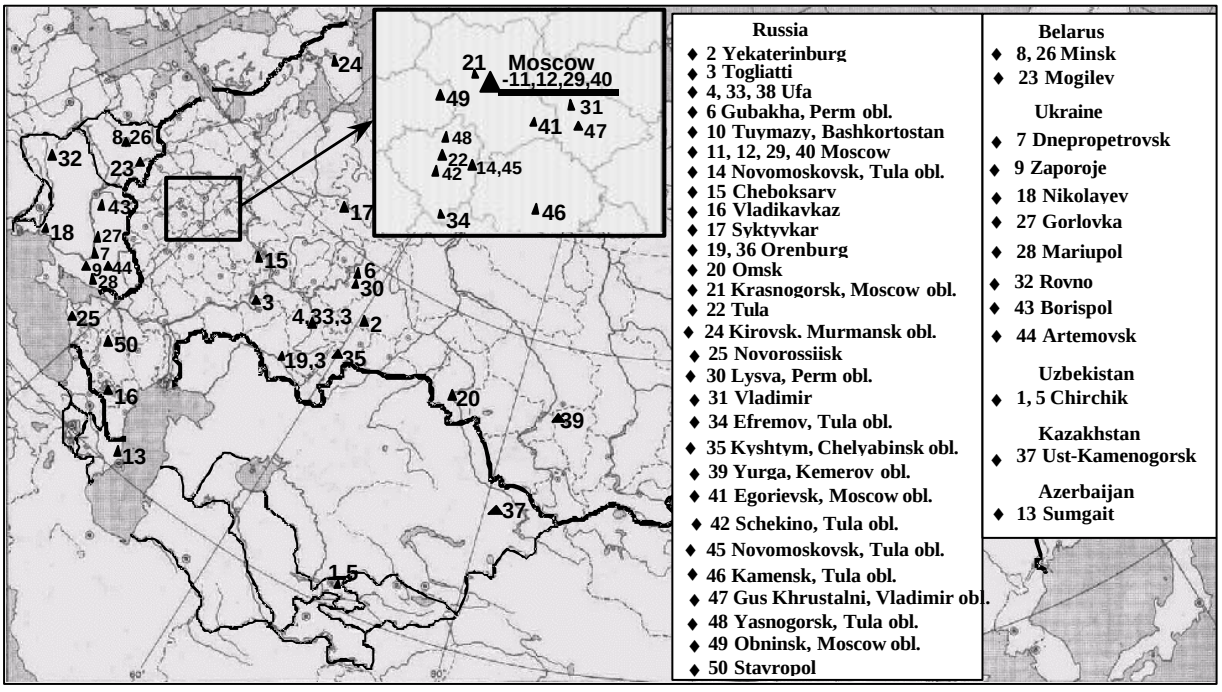


Figure 3. Location of PCB (Sovtol) users.

TCB

TCB was used exclusively for capacitor production. Four enterprises produced capacitors in the former USSR. The amounts used, relative to the total TCB produced at 'Orgsteklo' (70,000 tonnes), were approximately:

- 38% in Ust-Kamenogorsk, Kazakhstan;
- 43% in two factories in Kamairi (Leninakan), Armenia;
- 19% in Serpukhov, Russia.

Of the 70,000 tonnes TCB produced in total, 40,000 tonnes were used for production of industrial capacitors. The remaining 30,000 tonnes were used for production of non-industrial capacitors (for example, for household appliances), which were produced only in Armenia. The non-industrial capacitors have not been traced. According to data from the capacitor production enterprises, 60% (24,000 tonnes) of TCB contained in the industrial capacitors produced in the former USSR was delivered to Russia. Of these 24,000 tonnes, the project group experts estimate that some 14,000 tonnes of TCB are in industrial capacitors still in Russia today, the rest having been discarded.

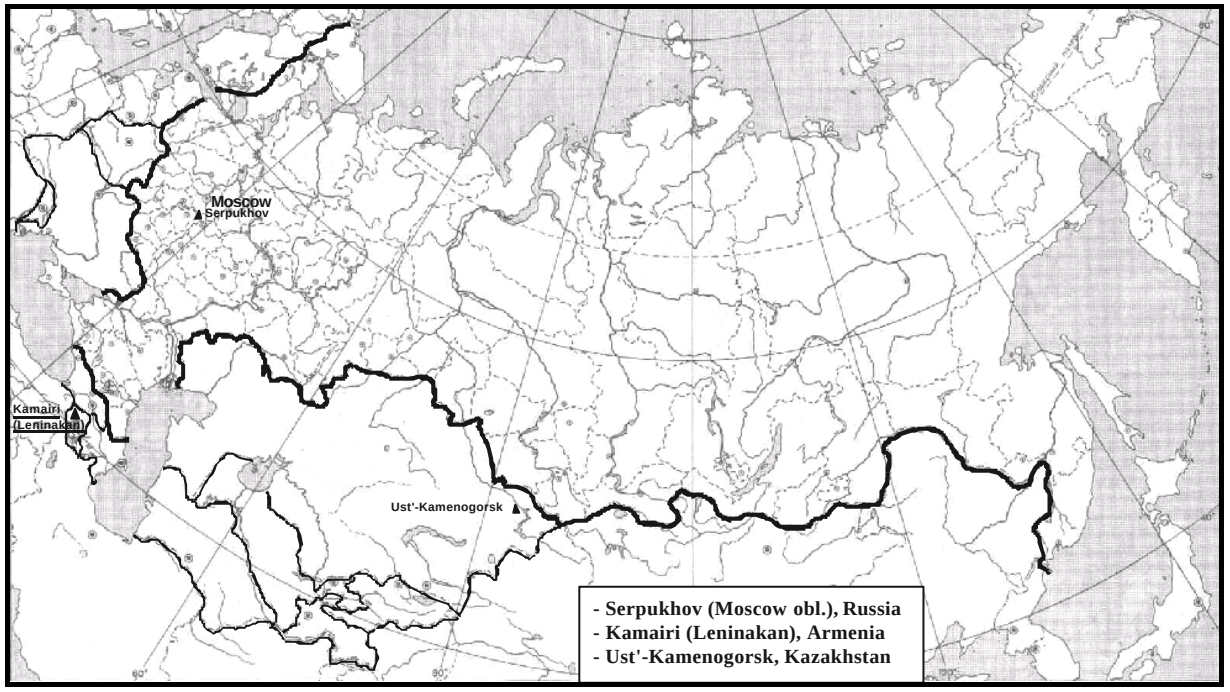


Figure 4. Location of PCB (TCB) users.

Total PCB use

If it is assumed that the paints and varnishes containing PCB were used throughout the former USSR, and similarly that non-industrial uses have led to a ubiquitous distribution of PCB containing equipment, this PCB cannot readily be identified or recovered. On the basis of the data from the PCB production facilities and the enterprises which produced equipment containing PCB, the estimate of the total amount of PCBs in industrial uses that remain within the territory of the Russian Federation is, therefore, 35,000 tonnes.

Use of PCB-containing equipment

The questionnaires returned from industries where equipment containing PCB is used, included information on the numbers of transformers and capacitors (the major PCB sources) in use or held in reserve at the enterprises.

Transformers

The amount of PCB in transformers (if not stated explicitly in the questionnaire response) was estimated from data obtained from the Chirchik transformer plant. Ten types of PCB containing transformers were produced (all marked TNZ plus a letter and/or number code) with a Sovtol content ranging from 160 to 2,980 kg.

The average amount (1,746 kg) was used to estimate PCB contained in transformers.

Capacitors

An average amount of PCB in capacitors was estimated from questionnaire responses where this information was provided.

These capacitors had an average TCB content of 17.2 kg.

This value was used to estimate TCB in capacitors in cases where questionnaire response only included information on the number of capacitors held.

Industries

From industrial enterprises in the chemical and petrochemical industry, metallurgical and non-ferrous metallurgical industry, engineering industry and timber industry sectors, 167 responses were received as of December 1999 (56% return of the distributed questionnaires). According to this information base, the amount of transformer and capacitor PCB fluids totals some 11,700 tonnes.

Fuel and energy sector

The responses from the energy and fuel sectors (168 responses, 56% return) showed that the energy network accounts for the major part of the PCB containing equipment, and the major amount of PCB. The total amount of PCB contained in equipment in use or in reserve in the fuel and electric energy enterprises is approximately 3,140 tonnes, of which only approximately 100 tonnes is in the coal and petroleum industries.

Regions

As of December 1999, data had been submitted from 79 of the 89 territorial environmental protection authorities (ca. 90% response rate). Of these, 19 answered that no PCB containing equipment was used in their regions. This concerned primarily the Siberian regions. The information received from the territorial environmental protection authorities includes additional data from smaller enterprises and non-industrial uses, which are not taken into account in the industrial sector based inventories. These uses add some 6,700 tonnes PCB.

Combined results

According to results of the inventory of PCB in PCB-containing equipment in the territory of Russia, the total amount of PCB was 20,000 tonnes (see Table 2). The identified PCB, in PCB-containing equipment, is equivalent to about 11% of the total PCB production of the former USSR and the Russian Federation that took place between 1939 and 1993 (when production ceased).

When the identified PCB in PCB-containing equipment is grouped according to regional distribution, a non-uniform distribution is observed (Figure 5). The largest amounts of PCB are located in the North-, Central-, Volga- and Ural regions; these regions account for approximately 65% of the total identified amount of PCB in Russia.

Table 2. Amounts of PCB found in PCB-containing equipment according to data from the two major industrial sectors and territorial environmental protection authorities.

Industry	Transformers		Capacitors		Total PCB in PCB containing equipment (tonnes)
	Number	Amount of PCB (tonnes)	Number	Amount of PCB (tonnes)	
Chemical, petro-chemical, ferrous and non-ferrous metallurgy, timber (including pulp and paper) industry, mechanical engineering	3,543	9,028	48,515	879	9,907
Fuel and electric energy industrial sectors	22	40	175,815	3,139	3,179
Additional data of territorial environmental protection authorities	3,599	4,175	133,170	2,745	6,920
Total	7,164	13,243	357,500	6,763	20,006
Total (approximate)		13,200		6,800	20,000

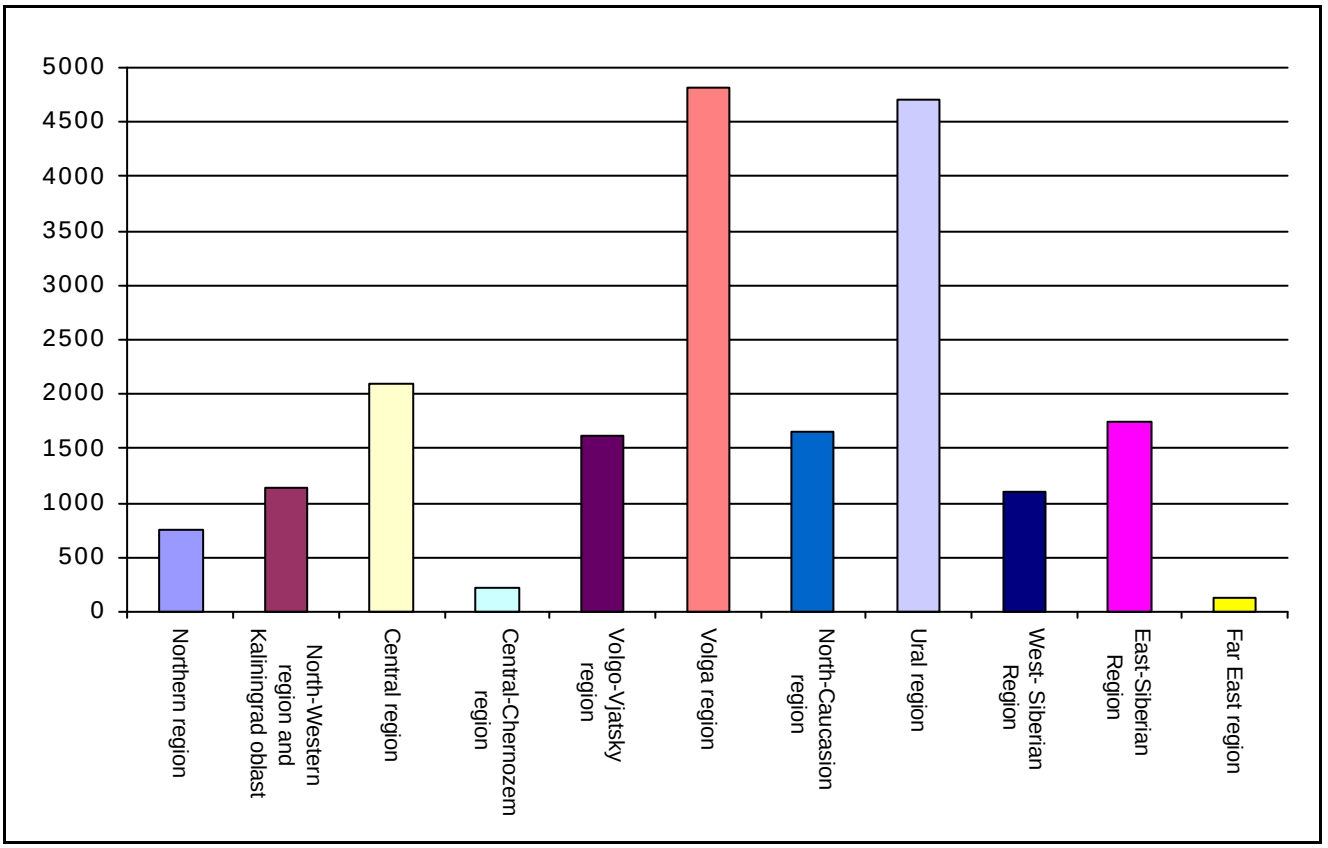


Figure 5. Distribution of PCB (tonnes) in PCB-containing equipment in different regions of Russia.

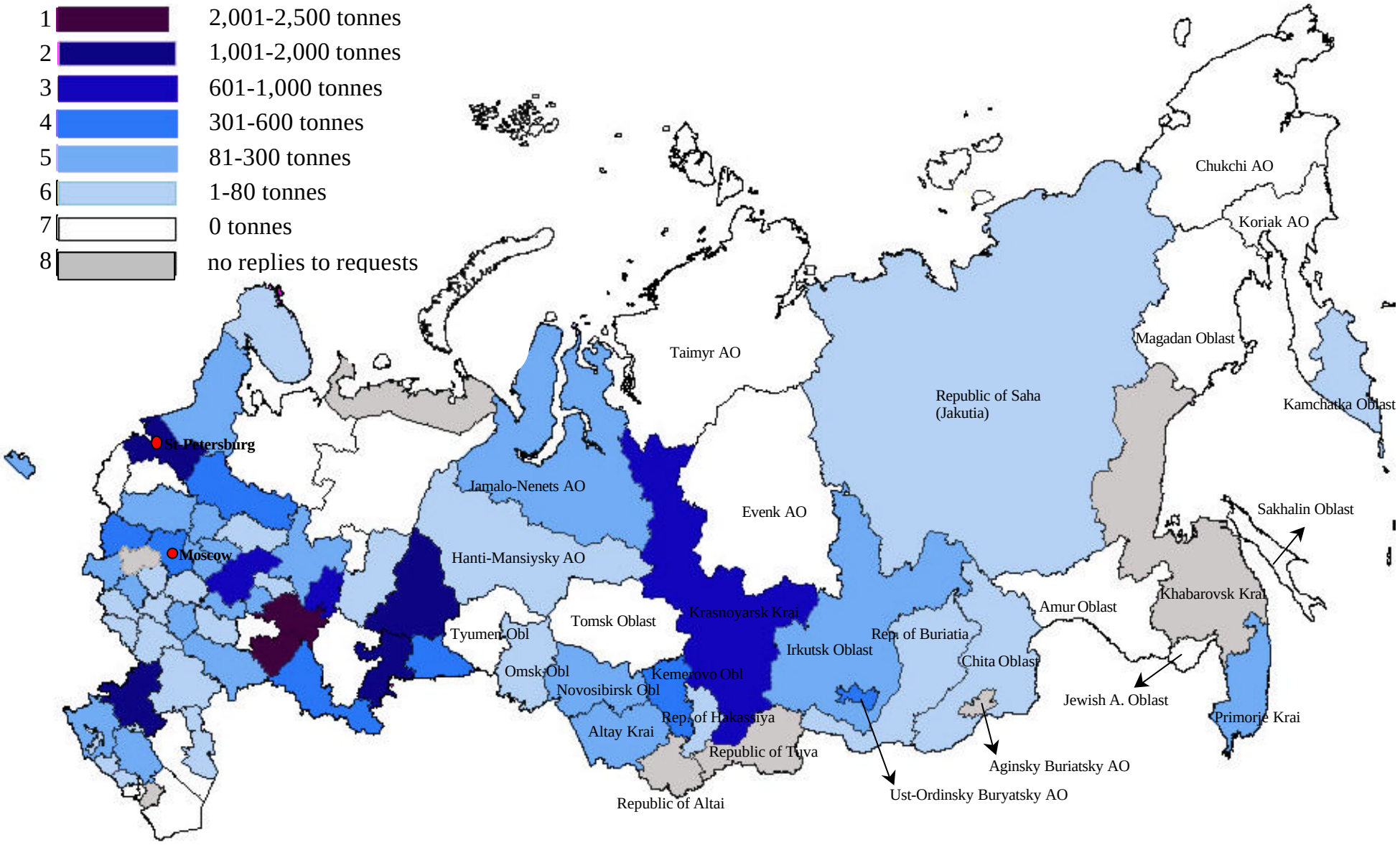


Figure 6. Amount of PCB (tonnes) in PCB containing equipment received during the inventory in administrative territories of the Asian part of the Russian Federation.

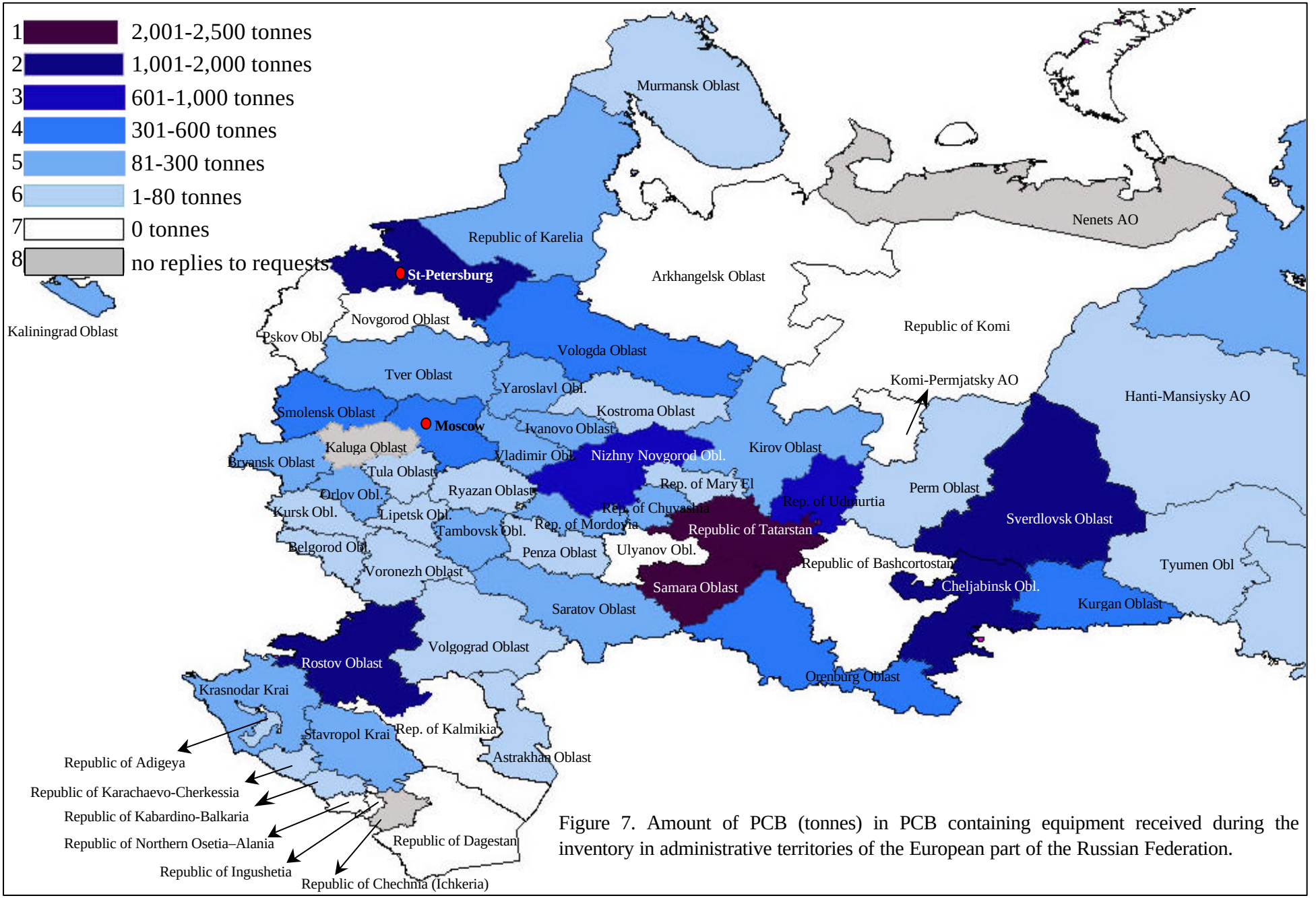


Figure 7. Amount of PCB (tonnes) in PCB containing equipment received during the inventory in administrative territories of the European part of the Russian Federation.

The distribution of PCB amounts in the different industrial branches among the various regions of Russia correlates with the distribution of the industries over the regions. Reflecting the industrial distribution in the former USSR, a considerable amount of information on PCB can therefore be inferred based on the distribution of activities within the industrial sectors. For example, the highest concentrations of chemical and mechanical engineering enterprises are located in Volga region. The inventory results confirm that the greatest amount of PCB in PCB-containing equipment is also located within this region. The largest quantities of PCB in PCB-containing equipment (2,053 ton and 1,940 tonnes, respectively) are located at two enterprises in Samara.

A large number of the ferrous metallurgical enterprises are concentrated in the Ural region. They are located mostly in the Sverdlovsk and Chelyabinsk Oblasts. The amount of PCB is correspondingly high,1,643 and 1,246 tonnes respectively in these areas.

The amount of PCB (tonnes) in PCB-containing equipment in the various administrative territories of the Russian Federation, as identified from the inventory, are shown in Figures 6 and 7.

Tentative mass balance for PCB in Russia

The inventory produced from the information presented above identifies an amount of 20,000 tonnes of PCB in PCB-containing equipment. This amount may be increased as a result of expert estimations to take into account:

1. The seven administrative territories of the Russian Federation that did not provide information about the presence or absence of PCB. Together, these could account for about 160 additional tonnes of PCB in PCB-containing equipment. It is considered likely that about 100 tonnes of PCB are located in the Khabarovsk Krai. In the other six administrative territories of the Russian Federation the amount of PCB is considered very little, estimated at 10 tonnes in each territory.
2. The fact that information received from 82 administrative territories of the Russian Federation was incomplete in that it did not include data from certain industrial enterprises that failed to respond to the questionnaire concerning PCB. Using the industrial sector profile for the regions concerned, it was estimated by the project group experts that this could account for upto 5,800 tonnes of additional PCB.
3. The railway transport system does not use PCB-containing equipment itself. However, from information provided to the expert group, it was estimated that about half of the 12,000 railway stations may have electrical equipment containing PCB. On average, each station may have 2-3 capacitors; yielding a total number of 15,000 capacitors. Using the figure for the average amount of PCB in each capacitor of 17.2 kg, the total amount of PCB in capacitors on the railway network can be estimated as 300 tonnes. The number of large railway stations is about 300, or 5% of the total number of stations. Based on an assumption that each of these large railway stations has one transformer, containing on average 1,746 kg of Sovtol, there exists approx. 500 tonnes of PCB in 300 such transformers. It is estimated, therefore, that equipment at railway stations may contain upto a further 1,000 tonnes of PCB.

Adding an additional amount of 6,960 tonnes of PCB, as determined from expert estimates for equipment not covered in the main inventory, to the identified inventory amount of PCB in PCB-containing equipment of 20,000 tonnes results in a total inventory of ca. 27,000 tonnes PCB (Figure 8). This amount correlates well with the amount of 35,000 tonnes of PCB obtained from the balance of production and use of PCB in the former USSR and Russia.

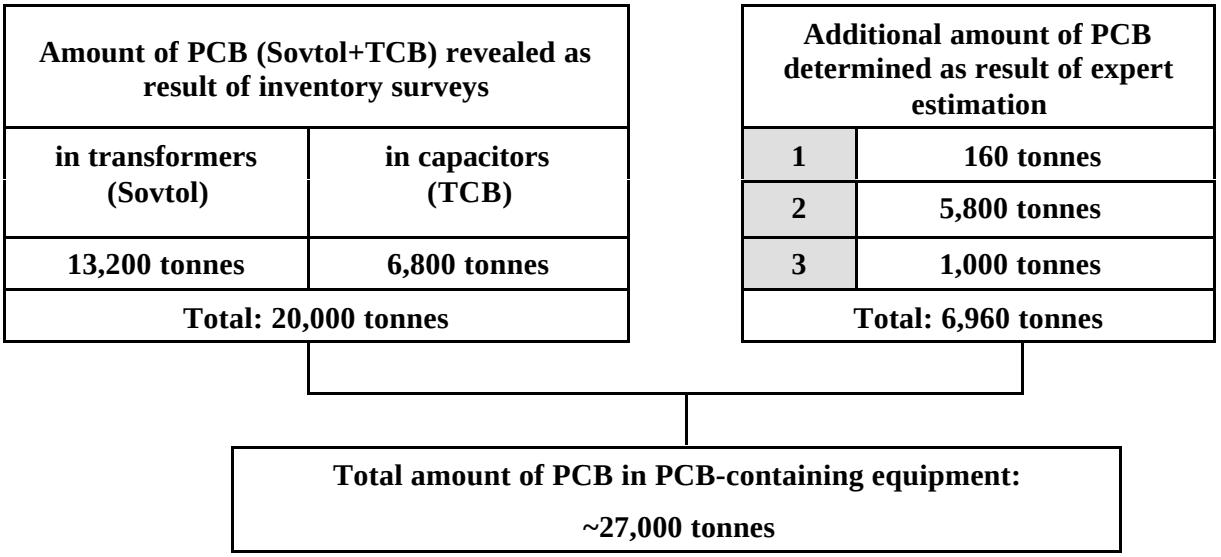


Figure 8. Inventory results and supplementary expert estimations of the amount PCB in PCB-containing equipment in the Russian Federation. (numbers in right hand box correspond to explanatory texts on page 13, above).

Industrial waste containing PCB in the Russian Federation

This part of the project comprises the inventory of PCB-containing equipment taken out of operation or discarded, and PCB-contaminated wastes. It was based on data from the industrial enterprises, enterprises in the fuel and energy production sectors, and the territorial environmental protection authorities. In this context, the term PCB-contaminated wastes is taken to include:

- PCB-containing equipment taken out of operation;
- PCB in PCB-containing equipment taken out of operation;
- PCB emptied from PCB-containing equipment and placed in waste storage containers.

The reported data describe the number of items of equipment taken out of operation (transformers and capacitors), the stored amount of PCB fluids (if relevant), and the storage conditions.

Storage of PCB waste

Within the Russian Federation, there is no collection of PCB waste, and no disposal facilities; PCB-contaminated wastes are usually stored on site. Storage may be in the open air or in storage rooms or warehouses; the PCB is kept in hermetically sealed containers or in the dismantled equipment itself. Access to areas in which PCB-contaminated wastes are stored is normally restricted for unauthorized personnel. PCB-contaminated wastes and equipment taken out of operation are accounted for. In a few instances, disposal at municipal dumps or incineration has been reported. There are no accounts of storage of Sovol (the PCB mixture used as a paint additive).

Amounts recorded by region

About 70% of industrial enterprises and fuel and energy sector enterprises, and 79 of the 89 territorial environmental protection authorities (90%) took part in the inventory. According to the responses obtained, 27 administrative territories of the Russian Federation do not have PCB-contaminated wastes.

Analysis of the data submitted for the inventory reveals that ca. 320 tonnes of PCB in electric equipment (transformers and capacitors) from industry, and ca. 295 tonnes in capacitors and ca. 360 tonnes in various equipment taken out of operation, is distributed among the regions as shown in Table 3.

Table 3. Regional and sectoral distribution of PCB in discarded equipment stored at industrial sites (excluding liquid PCB waste, i.e. PCB fluids emptied from equipment and stored in containers).

Region	PCB in waste in industries (tonnes)		
	Industries	Fuel and energy sector	Territorial environmental protection authorities
Northern	10.6	25.8	5.6
North-western	no data	18.4	no waste
Central	13.8	51.2	84.9
Central-Chernozem	4.2	6.8	4.3
Volga-Viatksky	13.3	50.8	16.5
Volga (Povolzhsky)	83.7	6.2	29.1
North-Caucasian	0.1	55.9	19.8
Ural	144.0	65.8	139.0
West-Siberian	no data	1.9	26.0
East-Siberian	49.2	6.2	21.3
Far Eastern	no data	0.9	7.8
Kaliningrad Oblast	no data	6.4	9.0

Amounts recorded by industrial branch

The amounts of PCB in electrical equipment (transformers and capacitors) taken out of operation within various branches of industry are presented below.

- mechanical engineering - 53.3 tonnes
- timber industry, including pulp and paper industry - 29.7 tonnes
- chemical and petrochemical industry - 23.4 tonnes
- non-ferrous metallurgy - 11.0 tonnes
- ferrous metallurgy - 201.2 tonnes

This distribution shows that more than half of the identified PCB-containing industrial waste (61% of the total amount of PCB) is to be found in the 124 transformers and 5,222 capacitors taken out of operation in the ferrous metallurgical industry. The largest numbers of capacitors in this industrial sector are concentrated in a few regions (the Ural, Volga and Northern regions).

The total amount of PCB-contaminated wastes (Sovtol emptied from transformers or materials impregnated with Sovtol) from the listed industries is 246.5 tonnes of PCB fluid, and is concentrated in two regions: the Ural region - 221.7 tonnes and the Volga region - 24.8 tonnes. In other regions, PCB-contaminated wastes were not discovered in the industrial sectors. In the fuel and energy sector, capacitors are in use but there is no exchange of dielectric fluid, and no stored liquid PCB is reported.

Total amounts

Liquid PCB waste

Liquid PCB wastes are usually represented by Sovtol, emptied from transformers into hermetically sealed containers. The total documented amount of liquid PCB wastes is 246.5 tonnes in the industry and 20.6 tonnes from the regions, yielding a total of 267.1 tonnes.

PCB in decommissioned equipment

The results of the inventory revealed that 35,422 capacitors and 330 transformers have been taken out of operation in industry, the fuel and energy sector and other activities within the regions at the present time. They are estimated to contain some 972.7 tonnes of PCB.

Total amount of PCB waste

The amount of PCB in PCB-contaminated wastes in industrial branches (chemical industry, etc.) is estimated to be 565.1 tonnes, including 318.6 tonnes of PCB in electrical equipment (transformers and capacitors) which has been taken out of operation, and 246.5 tonnes as liquid PCB emptied from transformers. Within the fuel and energy sector, there are some 296.3 tonnes of PCB in PCB-contaminated wastes. According to data of the territorial environmental protection authorities of the Russian Federation, there is a further 378.4 tonnes of PCB in PCB-contaminated wastes.

The total amount of PCB in electrical equipment (transformers and capacitors) taken out of operation, and separately stored as PCB fluids is, therefore, 1,240 tonnes (see Table 4).

The amount of PCB in PCB-contaminated wastes identified by the inventory, distributed between the various administrative territories of the Russian Federation is shown in Figures 9 and 10.

Table 4. PCB in wastes stored in industry.

The source of information	Equipment taken out of operation or discarded			Liquid PCB (tonnes)	Total amount of PCB (tonnes)
	Transformers Number	Capacitors Number	Amount of PCB (tonnes)		
Chemical, petro-chemical, ferrous metallurgy, non-ferrous metallurgy; timber (including pulp and paper) industry, mechanical engineering	186	5,688	318.6	246.5	565.1
Fuel and energy sector	-	19,669	296.3	-	296.3
Data of territorial environmental protection authorities of the Russian Federation.	144	10,065	357.8	20.6	378.4
Total (approximate)	330	35,422	972.7	267.1	1,240

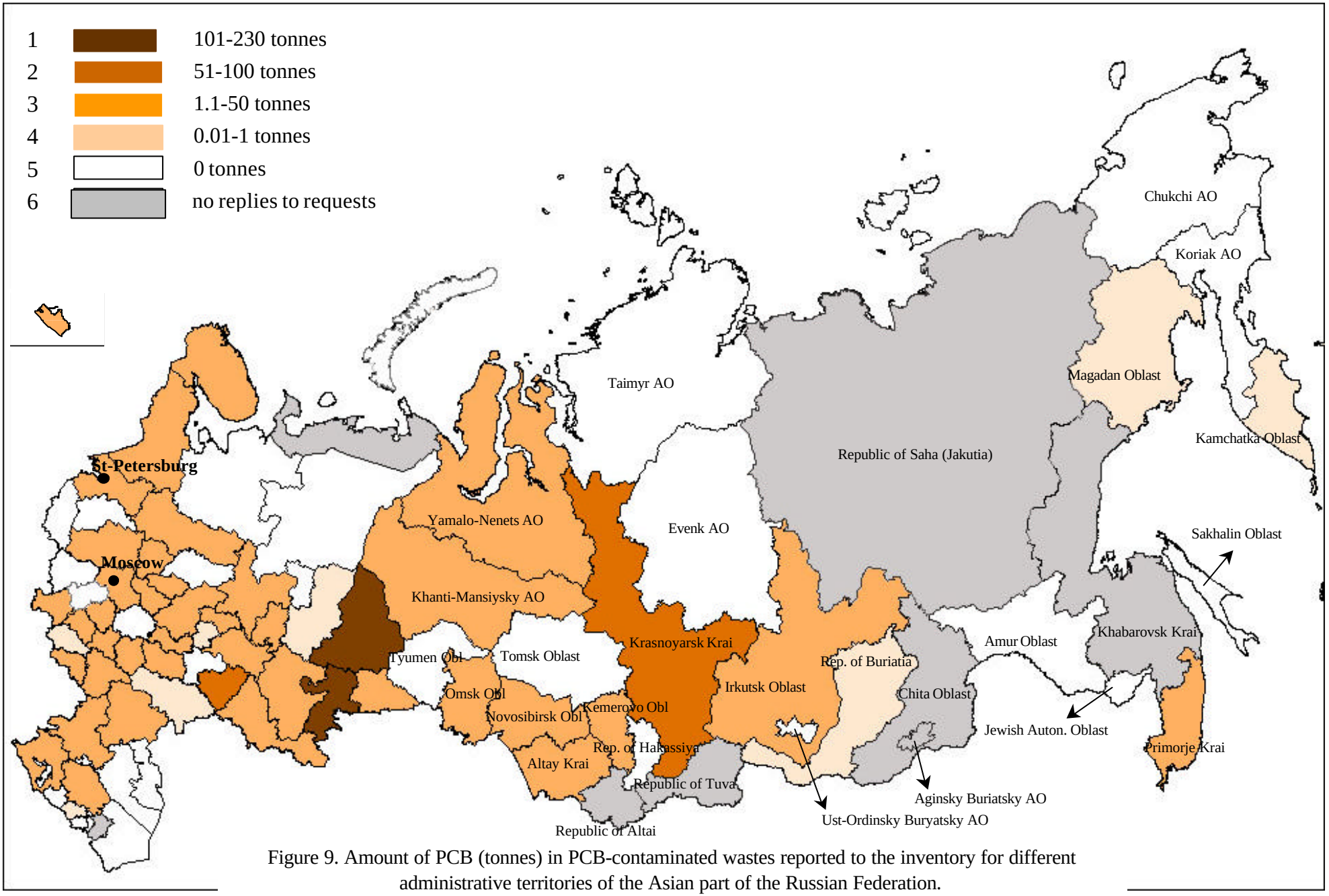


Figure 9. Amount of PCB (tonnes) in PCB-contaminated wastes reported to the inventory for different administrative territories of the Asian part of the Russian Federation.

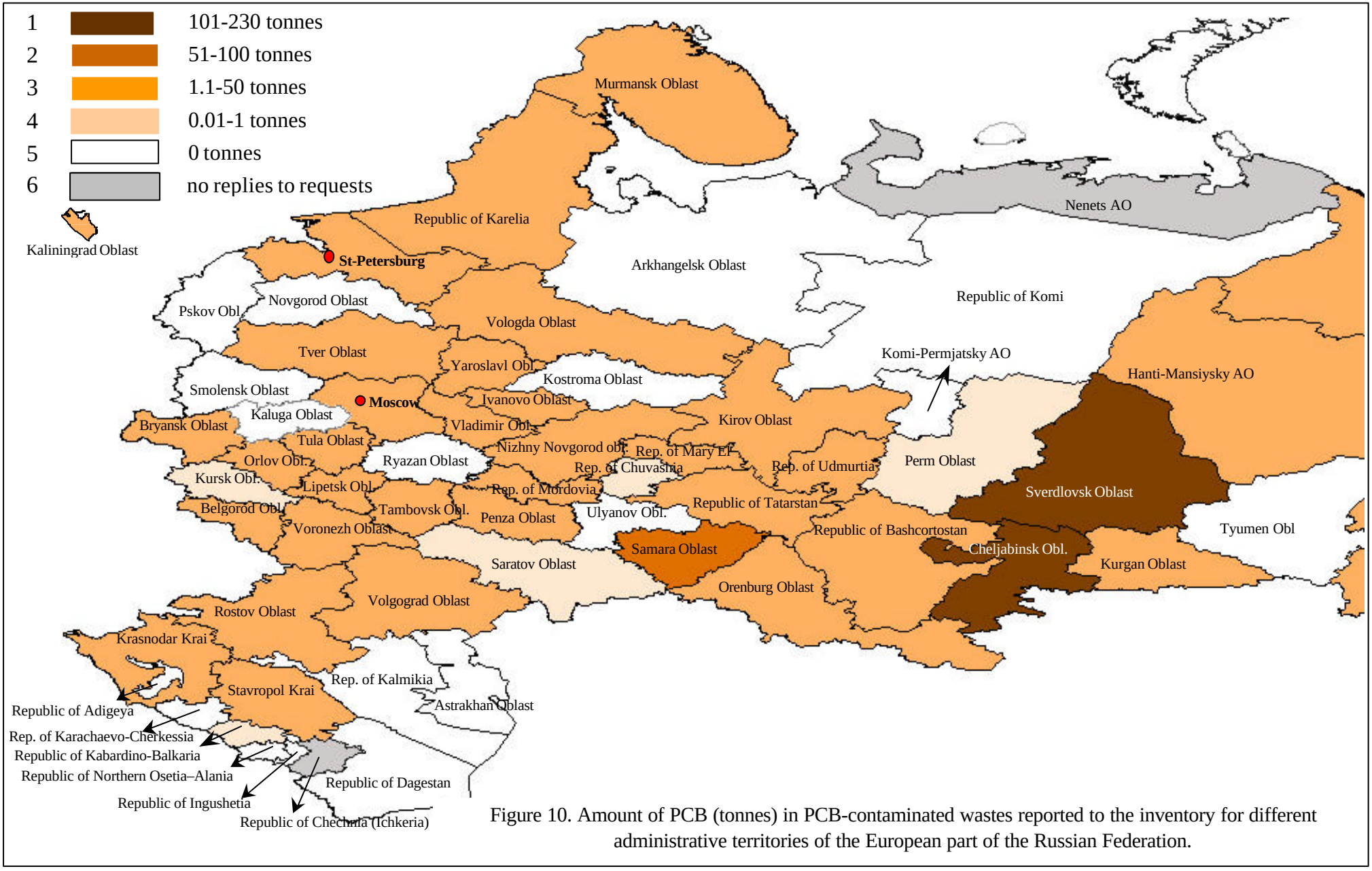


Figure 10. Amount of PCB (tonnes) in PCB-contaminated wastes reported to the inventory for different administrative territories of the European part of the Russian Federation.

Release of PCB from industrial wastes

Release of PCB during production

Since production of PCB has been terminated in the Russian Federation, there are no longer any PCB releases from activities associated with production of PCB. The sites of production are reportedly contaminated, and PCB emissions to the atmosphere can take place from contaminated soil, however, the extent of these emissions cannot be assessed on the basis of the information available to date.

Releases during production of PCB-containing equipment

The facilities for the production of equipment and goods containing PCB (notably transformers, capacitors, and paints and varnishes) were mostly situated in parts of the former USSR now outside of the territory of the Russian Federation. The supply of Sovol for paints ceased in 1992, but at the capacitor factory in Serpukhov (the only major consumer of PCB in Russia) the use of stored TCB continued until 1997, when the production line was completely retrofitted for other use. Consequently, no emissions from the production of PCB-containing equipment are presently expected. Again, the sites of production may be contaminated, with potential for PCB emissions to the atmosphere, but this cannot be assessed from the available data.

Release of PCB from equipment in operation

According to the data received from enterprises, it is possible to calculate that during transformer maintenance and repair work there may be a leakage of Sovtol of, on average, about 10 liters per year from a single transformer. These Sovtol losses (releases) from all operating transformers in Russia are estimated at 3,040 tonnes of PCB during the full time of service, or 120 tonnes per year.

There are no TCB losses from capacitors in operation when in good working order. However, capacitors may fail due to dielectric fluid leakage, and an estimate of the potential spill of PCB of 117 tonnes for the capacitors identified in the inventory during their lifetime can be made on the basis of a study of capacitor failure rates. This corresponds to an annual release of 3.4 tonnes of PCB from leaking capacitors in operation.

The locations of the enterprises with the greatest releases of PCB from operating transformers within the territory of the Russian Federation are shown in Figure11.

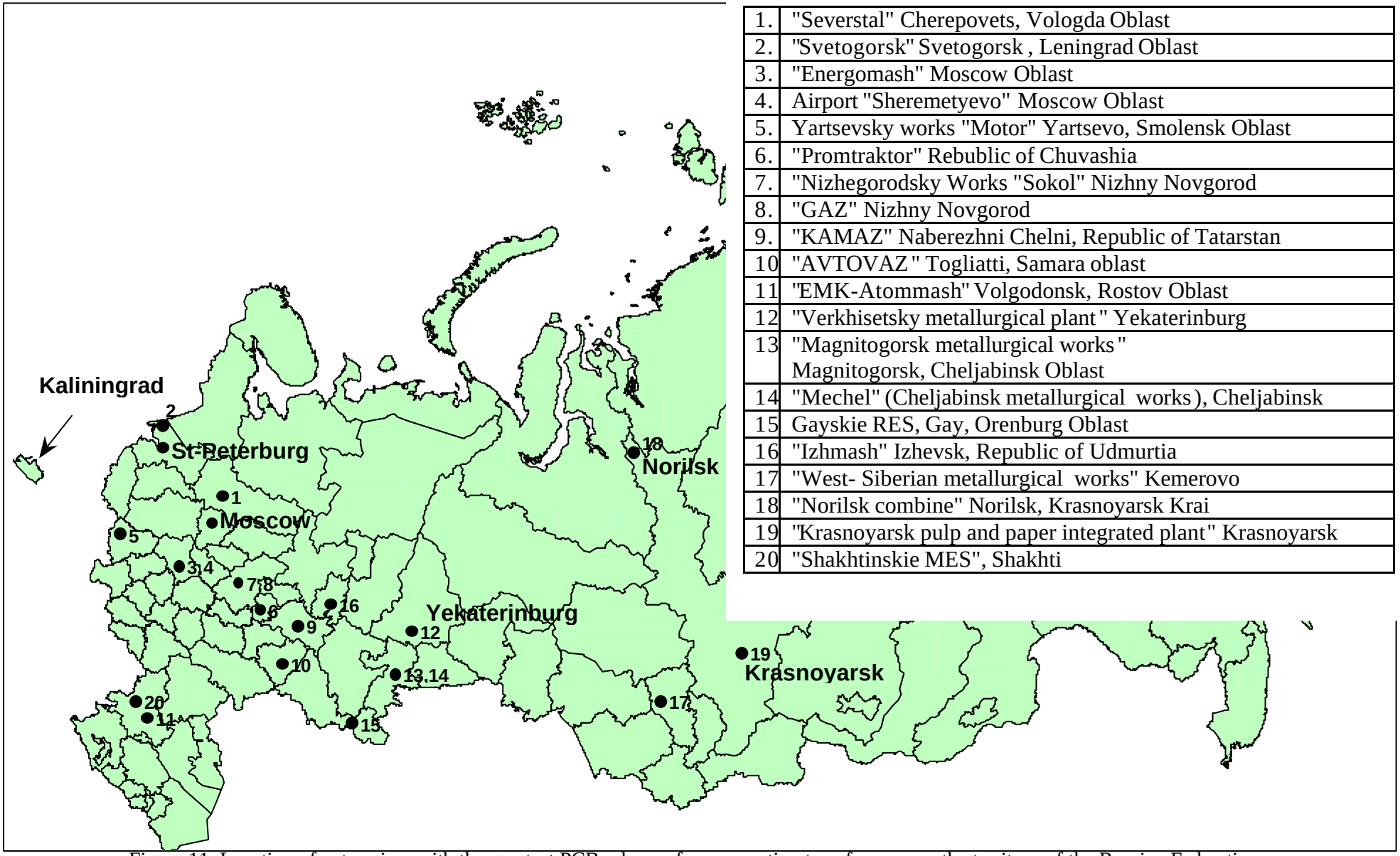
Release from storage or from waste

During failure of transformers and capacitors without leakage, there are no PCB releases to the environment; consequently no releases are expected from stored waste of this type. Obviously, if these items are inappropriately disposed of in the environment or left in the open air, they may eventually disintegrate and release PCB.

Where Sovtol is emptied from transformers following their failure, a discharge of approx. 10-15 liters (the same loss as that during maintenance operations) is assumed. The combined losses are estimated at 4 tonnes from 220 phased-out transformers.

Spills of PCB should, according to Russian guidelines, be collected using sand or sawdust. A small amount of such wastes was discovered in the form of four tonnes of rags and sand containing PCB, from which the release of PCB may be negligible, but this is based on information from only one factory.

The results of the inventory assessment conducted on PCB releases to environment are summarised in Table 5.



1.	"Severstal" Cherepovets, Vologda Oblast
2.	"Svetogorsk" Svetogorsk , Leningrad Oblast
3.	"Energomash" Moscow Oblast
4.	Airport "Sheremetyevo" Moscow Oblast
5.	Yartsevsky works "Motor" Yartsevo, Smolensk Oblast
6.	"Promtraktor" Rebublic of Chuvashia
7.	"Nizhegorodsky Works "Sokol" Nizhny Novgorod
8.	"GAZ" Nizhny Novgorod
9.	"KAMAZ" Naberezhni Chelni, Republic of Tatarstan
10	"AVTOVAZ" Togliatti, Samara oblast
11	"EMK-Atommash" Volgodonsk, Rostov Oblast
12	"Verkhisetsky metallurgical plant" Yekaterinburg
13	"Magnitogorsk metallurgical works" Magnitogorsk, Cheljabinsk Oblast
14	"Mechel" (Cheljabinsk metallurgical works), Cheljabinsk
15	Gayskie RES, Gay, Orenburg Oblast
16	"Izhmash" Izhevsk, Republic of Udmurtia
17	"West- Siberian metallurgical works" Kemerovo
18	"Norilsk combine" Norilsk, Krasnoyarsk Krai
19	"Krasnoyarsk pulp and paper integrated plant" Krasnoyarsk
20	"Shakhtinskie MES", Shakhti

Figure 11. Location of enterprises with the greatest PCB releases from operating transformers on the territory of the Russian Federation.

Table 5. Inventory of PCB releases from equipment and waste.

Sources of PCB releases	Transformers		Capacitors		Total PCB releases in tonnes
	Number	PCB releases in tonnes	Number	PCB releases in tonnes	
Production of PCB and PCB-containing equipment*	-	**0**	-	**0**	**0**
Operating PCB-containing equipment:	**8070**	**3040**			**3040**
- inventory data	5685	2522			2522
- expert assessment of missing data	1385	518			518
Phased out equipment**	**220**	**5**	**7480**	**112**	**117**
- inventory data	170	4	6022	90	94
- expert assessment of missing data	50	1	1458	22	23
Locations of PCB-contaminated wastes storage					*******
- inventory data					
- expert assessment of missing data					*******
Total (approximate), over life-time of equipment:					**3160**

*) No current production; earlier releases during production have not been assessed.
**) Includes phased-out transformers from which Sovtol was discharged, and capacitors phased-out because of seal failure.
***) An amount of 4 tonnes released from PCB-contaminated waste storage was reported, but this information is from one facility only.

Tentative mass balance for wastes and releases

Sovol (paints and varnishes)

If it is assumed that the 32,000 tonnes of Sovol have totally evaporated from paints and varnishes distributed throughout the territory of Russia, then its concentration in air would still be 0.0001 of the maximum permissible concentration (PDK) for air. It is likely that part of Sovol has degraded over the years.

Sovtol (transformers)

Approximately 20,000 transformers were produced using 34,000 tonnes of Sovtol. At present 8,070 transformers are in operation and 430 are phased-out. Assuming the average content of Sovtol in one transformer to be 1.7 tonnes, approximately 11,500 transformers were therefore phased-out in earlier times. Based on the results of the inventory that has been conducted, it can be estimated that during 25 years of maintenance on 11,500 transformers in operation, the releases to the environment constitute 4,300 tonnes PCB (375 kg from each individual transformer). During dismantling, 140 tonnes of Sovtol may have been spilled (23 kg from each transformer).

Tracing the fate of the phased-out transformers, and the Sovtol removed from them, is not feasible after so many years. Account should also be taken of the fact that, at that time of their phase-out, requirements for environmental protection, and in particular requirements in relation to PCBs, were not as strict as they are today.

TCB (capacitors)

Approximately 1,412,000 capacitors may have been produced from 24,000 tonnes of TCB (with an average TCB content of 17 kg per capacitor). The inventory has identified approximately 193,000 capacitors in operation, and 44,000 that have been taken out of service. An estimated 1,175,000 capacitors were therefore phased-out in earlier times (some may be in use in minor industries). Capacitors have a shorter operating lifetime (15-20 years) than transformers (25-30 years). Approximately 17% of capacitors may have been phased-out as a result of leakage, which equates to approximately 200,000 capacitors and 3,400 tonnes of leaked TCB for the entire production volume. There is no documentable trace of the remaining 975,000 capacitors.

Storage and disposal

Information on PCB releases from storage/disposal sites is sparse. During PCB storage in sealed transformers, capacitors and sealed waste containers there are no significant releases. Only isolated instances of PCB incineration on industrial and pilot scales are known. Generally, PCB is under storage pending the development of acceptable disposal techniques and creation of the necessary disposal facilities.

Mass balance - comparison and conclusions

Production and use

The mass balance calculation for production and use of PCB and PCB containing equipment in the former USSR is represented in Figure 12. The total amount of PCB produced was some 180,000 tonnes, comprising 53,000 tonnes of Sovol, 57,000 tonnes of Sovtol and 70,000 tonnes of TCB.

According to data from enterprises manufacturing PCB-containing equipment, approximately 60% of the production was destined for Russia, corresponding to 32,000 tonnes of Sovol in the form of paints, varnishes and lubricants, 34,000 tonnes of Sovtol in transformers, and 24,000 tonnes of TCB in capacitors.

Inventory data

Inventory data collection activities identified 20,000 tonnes of PCB in PCB-containing equipment; an additional amount of 6,960 tonnes was identified on the basis of expert estimation of sources not accounted for in the inventory data. Together, therefore, the total amount of PCB in PCB-containing equipment in the Russian Federation identified by the 1999 inventory was ~27,000 tonnes (Figure 8).

Although household capacitors produced (in Armenia, see Figure 12) using ca. 30,000 tonnes of TCB were hermetically sealed and maintenance-free, over the course of time, a considerable part of this TCB may have been released to the environment due to corrosion and mechanical failures.

From the inventory work, the total balance of PCB can be represented by the following:

- the total quantity of PCB in PCB-containing equipment in circulation, as determined during preparation of the inventory, is ca. 27,000 tonnes;
- the quantity of PCB identified in PCB-contaminated wastes (decommissioned PCB-containing equipment and PCB contained in this equipment, including PCB emptied from PCB-containing equipment and placed in waste storage containers) is ca. 1,250 tonnes.

Thus, the total quantitity of PCB determined by the inventory is ca. 28,250 tonnes.

From the equipment a number of losses can be accounted for:

- the quantity of PCB estimated to be released from equipment and wastes is 3,160 tonnes;
- the quantity of PCB (Sovtol), spilled during dismantling of equipment is 140 tonnes.

Thus the total quantitity of PCB including accounted losses is ca. 31,500 tonnes.

This value agrees well with the estimate of PCB in PCB-containing equipment that resulted from the mass balance calculation of PCB production and use in the former USSR and Russia, i.e. 35,000 tonnes (see Figure 12).

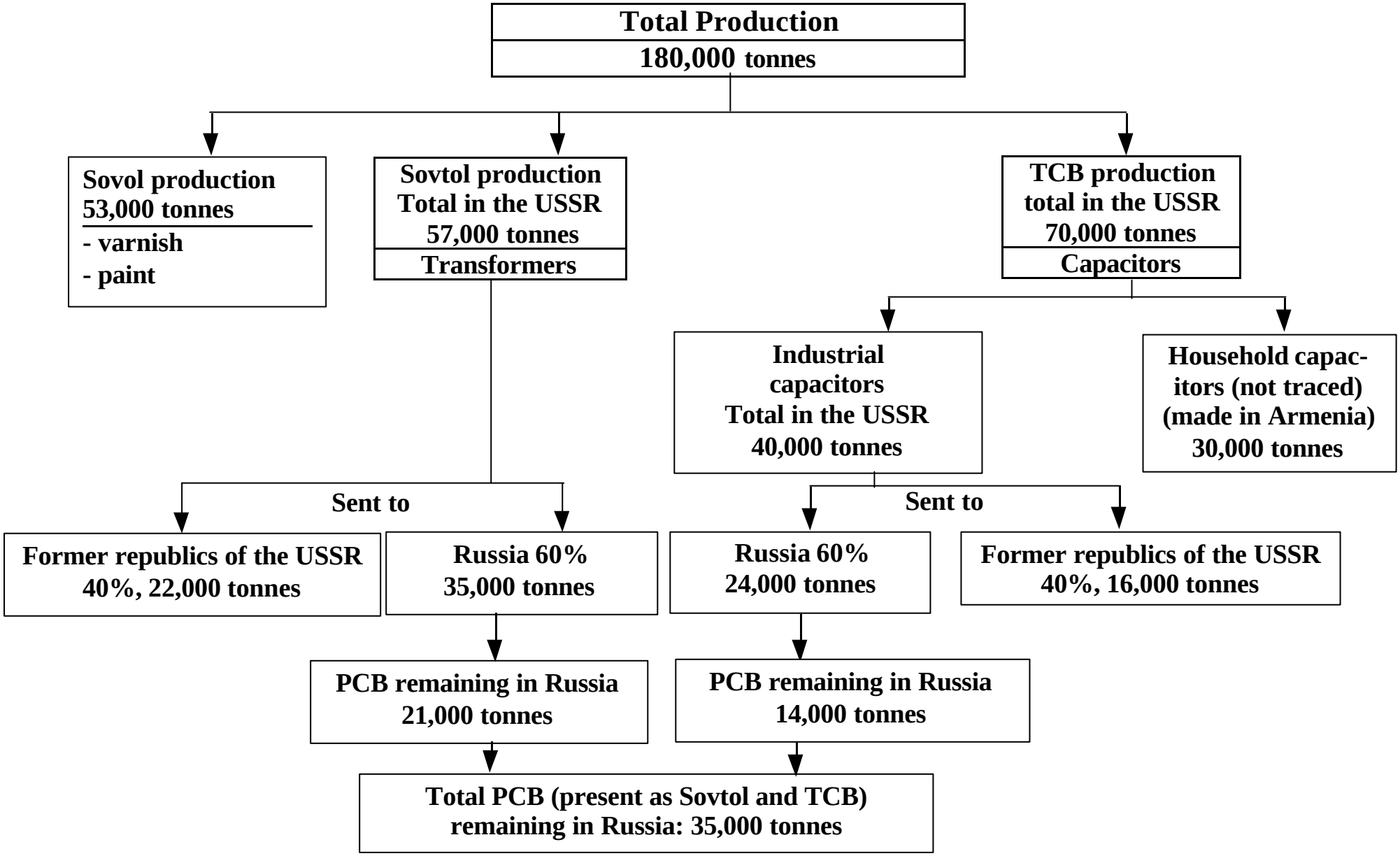


Figure 12. PCB production and use mass balance in the former USSR and Russia.

Recommendations

Phase 1 inventory activities - main observations

Since PCB production was discontinued in 1992, the stocks of PCB are presumably completely used up, and no releases from PCB production or production of PCB-containing equipment are currently anticipated in the Russian Federation. Some emissions from PCB-contaminated production sites ('Orgsteklo' (Dzerzhinsk), 'Orgsintez' (Novomoskovsk), and 'Kondensator' (Serpukhov), or other contaminated areas (e.g. land-fills or illegal disposal sites) may be expected. Such sites will require remediation, and methods for such activities should be addressed. To determine the level of contamination of these sites, special site surveys should be performed.

To allow the gradual replacement of PCB-containing transformers and capacitors, alternative liquids are required to substitute Sovtol and TCB. Such replacement liquids should have the necessary technical, economic and environmental properties. Replacement liquids have already been developed and even tested in the Russian Federation on a pilot scale. However, to bring these developments into full production, considerable financial resources are required. The amount of financing can be determined from feasibility studies.

Possibilities for the import of non-PCB containing equipment as replacement technology should be taken into consideration, however, it is likely that mass volume replacement technology would prove too expensive.

Analysis of PCB destruction methods existing in the Russian Federation shows that the plants (facilities) most prepared for industrial scale use are those for incineration at combustion temperatures >1200°C, and with technologically appropriate schemes for quenching reacting gases. The technique of PCB destruction in cement kilns, as used in some Nordic countries might prove a good alternative, but there is no experience with this type of approach in the Russian Federation.

Destruction/incineration is generally preceded by activities involving labeling, collection and storage of the hazardous materials. Such activities are also envisaged as part of any solution to the phase out of PCBs in the Russian Federation.

Recommendations for phase-out activities

Recommendations for further work are based on the information gathered in Phase 1 of the project, and the gaps in data or knowledge identified during Phase 1.

During the conduct of Phase 1 of the project, it was recognized that certain basic activities are necessary to provide the foundation for other anticipated activities. These activities are not linked to any one site, Oblast or region, but rather constitute part of a coherent project that is capable of demonstrating actions and procedures for local implementation. The recommendations associated with these basic activities are as follows:

1. ***Assessment of relevant regulations and requirements (preparatory activity).*** In order to implement demonstration projects, existing and necessary additional regulations, at both the central and decentralized level, must be identified; suggestions for co-ordination of relevant regulatory structures must be developed.
2. ***Design of PCB collection and storage schemes***. Regardless of the selected destruction technology, there is an identified need for an adequate information system to document procedures and facilities for the identification, labeling, dismantling, collection, transport and storage of PCBs and PCB-containing materials.
3. ***Preparation of a "least cost" overall Russian PCB phase-out strategy.*** Phase-out plans developed at local, regional and central administrative levels should follow a strategy designed to achieve the objective of a cost-beneficial solution for the entire society.

4. ***Selection of alternatives for replacement of PCB, with acceptable environmental characteristics and feasible production.*** For the gradual replacement of PCB-containing transformers and capacitors, the production/use of alternative liquids as substitutes for Sovtol and TCB should be initiated. These substitutes must have acceptable technical, economic and environmental characteristics.
5. ***Construction/retrofit of a prototype facility for production of alternative fluids.***
6. ***Construction/retrofit of a prototype facility for use of non-PCB alternative compounds in a major PCB use sector.***
7. ***Selection/development of environmentally sound technologies for destruction of PCB/containing liquids.*** The available methods for destruction of PCBs (and other hazardous waste), and the choice of stationary and/or mobile facilities must be addressed along with issues of existing facilities and expertise, etc.
8. ***Selection/development of environmentally sound technologies for destruction/ decontamination of PCB-contaminated containers, equipment and their sub-components.*** Several methods for cleaning and emptying PCB fluids from used transformers, and for treating scrap metal, etc., are documented. Since re-use (with or without cleaning) is questionable with respect to prolonging the PCB problem, these technologies should be investigated.
9. ***Selection/development of standard/innovative technologies for rehabilitation of PCB-contaminated areas.*** Existing pollution from PCB contaminated sites may be expected, but the extent of contamination of these sites has not been assessed. ***Special site surveys should be performed to determine the level of contamination of these sites***.

Suggested regions and territories for Phase 2 activities

From the viewpoint of the potential negative impact of PCB releases from the Russian Federation on Arctic ecosystems, the following regions (see Figure 13) can be identified as those warranting priority under Phase 2 of the project:

- North-western region;
- Northern region;
- Ural region;
- Western Siberian region;
- Central region.

Within these main regions, specific areas for priority under Phase 2 are identified in Table 6, selected on the basis of the following criteria :

- location within or proximity to the Arctic/sub-Arctic,
- quantity of PCB in PCB-containing equipment within the area
- quantity of PCB in (stored) waste within the area
- PCB release from PCB-containing equipment

If possible, the regions mentioned in Table 6 should be supplemented with the additional areas where the greatest impacts may be expected to occur.

In relation to remediation, work should focus on sites of production of PCBs and PCB-containing equipment, in particular the Russian cities: Dzerzhinsk, Novomoskovsk and Serpukhov, where potential impacts due to local contamination are to be expected.

Table 6. Areas for priority activity under Phase 2.

Location Arctic and sub-Arctic areas	**Potential impact** as defined by the quantity of PCB or PCB-containing equipment in the area *	**Potential impact** as defined by the quantity of PCB in waste **	**PCB releases** ***	**Situated in catchment area of rivers feeding the Arctic seas** (ranked by quantity of PCB)
Murmansk Oblast	Samara Oblast	Sverdlovsk Oblast	Rostov Oblast	Krasnoyarsk Krai
Viborq, Leningrad Oblast	Viborq, Leningrad Oblast	Viborq, Leningrad Oblast		
Krasnoyarsk Krai	Rep. Tartarstan	Cheljabinsk Oblast	Samara Oblast	Murmansk Oblast
Yamalo-Nenets A.O.	Murmansk Oblast	Samara Oblast	Rep. Tartarstan	Yamalo-Nenets A.O.
	Sverdlovsk Oblast	Krasnoyarsk Krai	Sverdlovsk Oblast	Rep. Karelia
	Rostov Oblast		Murmansk Oblast	Irkutsk Oblast
	Cheljabinsk Oblast		Nizhni-Novgorod Oblast	

*) areas corresponding to the highest 2 categories in Figure 7

**) areas corresponding to the highest 2 categories in Figure 10

***) identified in main project 1 report (Annex 6.1)

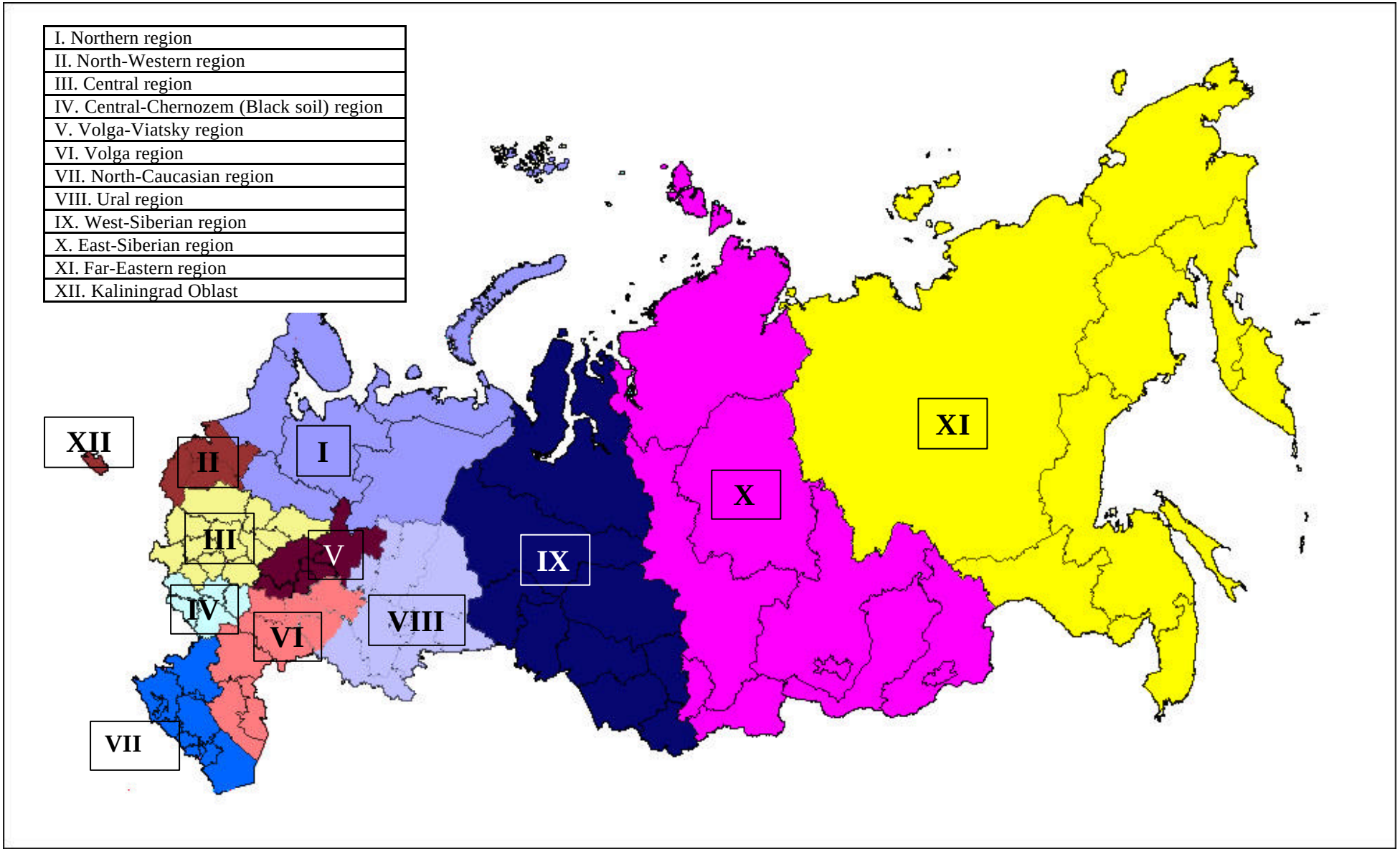


Figure 13. Regions of the Russian Federation.