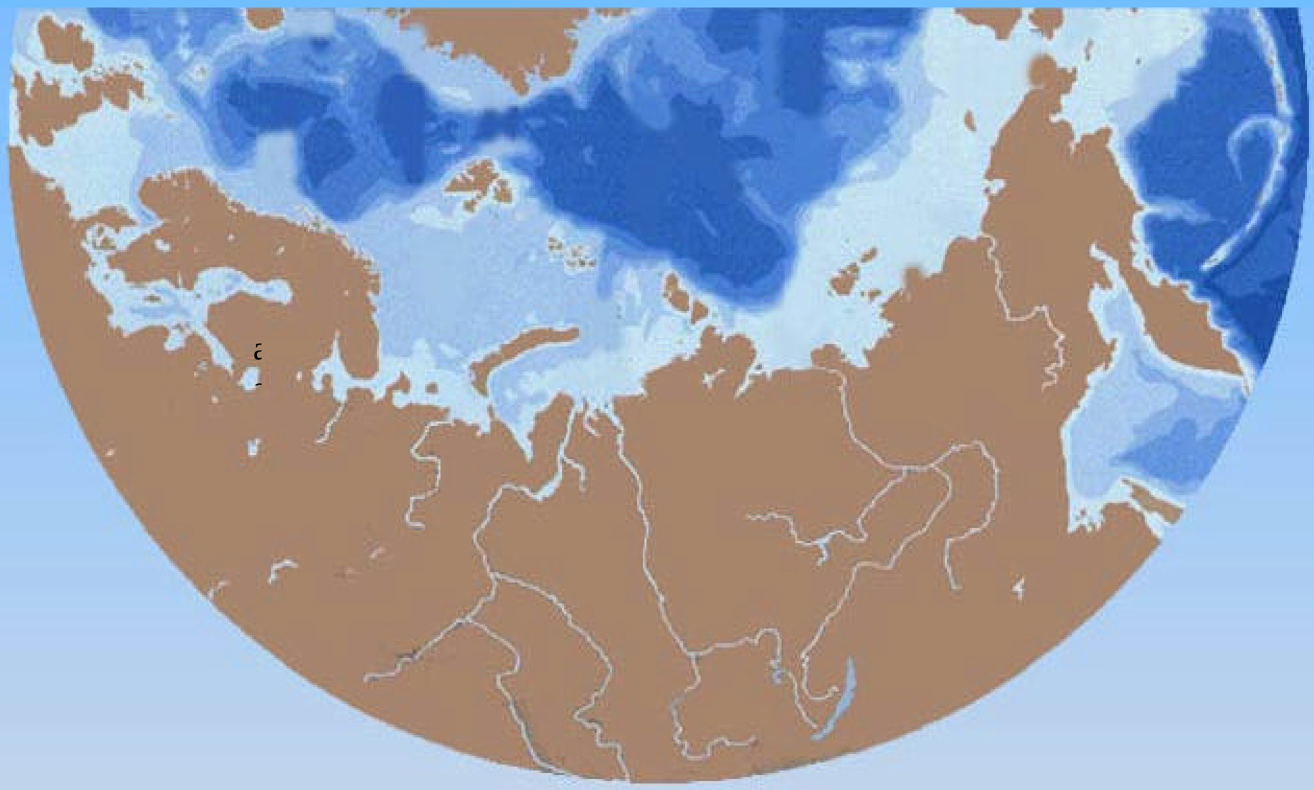
Arctic Council Action Plan (ACAP)

ENVIRONMENTALLY SOUND MANAGEMENT AND ELIMINATION OF PCBs IN RUSSIA

EXECUTIVE SUMMARY



Center for International Projects

AMAP
Arctic Monitoring and Assessment Programme

ARCTIC COUNCIL ACTION PLAN TO ELIMINATE POLLUTION IN THE ARCTIC (ACAP)

Multilateral Co-operative Project on Phase-out of PCB Use, and Management of PCB-Contaminated Wastes in the Russian Federation

PHASE 2: Feasibility Study
Supporting Documentation

EXECUTIVE SUMMARY

ENVIRONMENTALLY SOUND MANAGEMENT AND ELIMINATION OF PCBs IN RUSSIA

SECRETARIAT OF THE ARCTIC MONITORING AND ASSESSMENT PROGRAMME
MINISTRY OF INDUSTRY, SCIENCE AND TECHNOLOGIES OF THE RUSSIAN FEDERATION
MINISTRY OF NATURAL RESOURCES OF THE RUSSIAN FEDERATION
CENTER FOR INTERNATIONAL PROJECTS (CIP)

Multilateral Co-operative Project on Phase-out of PCB Use, and Management of PCB-contaminated Wastes in the Russian Federation	
PHASE I: Evaluation of the Current Status of the Problem with Respect to Environmental Impact and Development of Proposals for Priority Remedial Actions	
Report	EXECUTIVE SUMMARY OF THE REPORT PCB IN THE RUSSIAN FEDERATION: INVENTORY AND PROPOSALS FOR PRIORITY REMEDIAL ACTIONS (ISBN 82-7971-032-9)
PHASE 2: Feasibility Study Supporting documentation	
Arctic Council Action Plan (ACAP)	
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Report of Activity 2:	DESIGN OF PCB COLLECTION AND STORAGE SCHEMES
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Preface

At the 1st Ministerial Meeting of the Arctic Council (Iqaluit, Canada, September 1998), the Ministers welcomed with appreciation and supported "*The Multilateral Cooperative Project on Phase-out of PCB Use, and Management of PCB-contaminated Wastes in the Russian Federation*" as an example of cooperative projects under the Arctic Council Action Plan to Eliminate Pollution in the Arctic (ACAP). This was the first ACAP project and, to a great extent, serves as a pilot for development of other ACAP activities. The project includes the following three phases, covering all stages from assessment of the magnitude of the PCB problem, to development of technical and economic proposals for solutions, and their practical realization:

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 to address the problem.

It should be noted that, from its initial stage, the project was not intended to 'solve' the problem of PCB handling and phase-out in the Russian Federation. To solve this problem, it will be necessary to develop and implement a special Targeted Federal Programme, which would be funded by Russian sources with financial support of international donors and financial institutions. However, the project should present ways of solving a set of issues, which comprise the PCB problem in this country, and might be used as a model for the proposed Targeted Federal Programme. The project is designed to establish prototype demonstration facilities to destroy PCB fluids and to destroy/decontaminate PCB-containing equipment, with special focus on the geographical areas affecting the Arctic region.

On May 22, 2002 the Russian Federation signed the Stockholm Convention on Persistent Organic Pollutants (POPs), a legally binding global instrument for implementing international actions on (initially) 12 POPs, including PCB. According to this Convention, parties shall prohibit and/or take legal and administrative measures necessary to eliminate use of PCB in equipment (e.g. transformers, capacitors or other receptacles containing liquid stocks) by 2025. In the context of signing the Stockholm Convention, the PCB project is of particular importance, since it promotes fulfillment, by the Russian Federation, of its binding commitments to be taken following ratification of this global agreement.

This publication is the **EXECUTIVE SUMMARY** of the Second Phase of the *Multilateral Cooperative project on Phase-out of PCB Use, and Management of PCB-contaminated Wastes in the Russian Federation*. The objective of the Phase 2 set of reports is to provide supporting documentation for the feasibility study on different issues related to phasing out of PCB use and managing PCB-contaminated wastes in Russia. Phase 2 of the project was implemented during 2001-2002, mainly by the Russian Expert Group and the Centre for International Projects (CIP) operating as the Russian Performing Entity, with active involvement of the experts designated by the other Arctic Council members. In this connection, the Steering Group would like to express its appreciation to the members of the Russian Expert Group, the CIP staff, and all experts from Russian ministries, research institutions and enterprises, and to the western experts, who have contributed their time, effort, and knowledge to the success of this work.

Finally, it is important to acknowledge that this work would not have been possible without financial and technical support from all the Arctic Council member states (Canada, Denmark, Finland, Iceland, Norway, Sweden, and the United States of America), the Netherlands, and UNEP Chemicals. All the project participants would like to express their deep appreciation for this support.

The Steering Group of this ACAP project is pleased to present this report to the Arctic Council and its member states for their consideration.

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Introduction

As a result of the inventory which was carried out within the framework of Phase 1 of this Project, it was concluded that in Russia about 10,000 transformers and about 500,000 capacitors are currently either in operation, in reserve, or removed from operation but not destroyed. These transformers contain about 19,000 tons of PCB (Sovtol), and capacitors contain about 10,000 tons of trichlorobiphenyl (TCB).

This report summarizes the results of Activities 1-9 of Phase 2 of the Project. These results include the identification of regulatory documents and requirements for handling PCB and PCB-containing materials in the Russian Federation, development of PCB collection and storage schemes, preparation of the general "least cost" strategy for PCB phase-out, and the identification of the technologies for:

- cleaning of transformers containing PCB;
- PCB destruction;
- destruction of PCB-containing capacitors;
- production of PCB-alternative dielectric fluids (DEF) for transformers and capacitors;
- decontamination of the PCB-contaminated sites.

The selection of technologies was carried out according to the Terms of Reference on the basis of environmental, technological and economic considerations. During this work, priority was given to Russian advanced technologies developed to the extent of their practical application. However, existing foreign technologies were also taken into account, and these considerations may get further development during Phase 3.

The considerations made so far cannot be regarded as the full technical and economic assessments, which should be made in Phase 3 of the Project, but can be characterized as 'supporting or substantiating documentation' .

Recommendations are also given on number and location of installations for transformer cleaning, PCB and capacitor destruction, as well as for production of PCB-alternative dielectric fluids for transformers and capacitors.

The financial issues of construction and operation of installations and equipment will be considered in the Phase 3 of the Project.

1. Assessment of Relevant Regulations and Requirements Related to PCB

The environmental legislation in the Russian Federation forms a multilevel structure, which among other things includes the Constitution and the Government, and the orders of the President and local authorities. The most relevant law is the *Law on Environmental Protection* and the main environmental body is the *Ministry of Natural Resources*. Drawbacks of the legislation are low flexibility, contradictions between laws and the absence of unified implementation mechanisms. In spite of this there are no visible impediments to developing a safe step-by-step PCB phase-out system in Russia, similar to some foreign countries, in a relatively short time.

Background

The environmental legislation in the Russian Federation forms a multilevel structure, which includes the Constitution of the Russian Federation, Laws of the Russian Federation, decrees and orders of the President of the Russian Federation, the orders and the resolutions of the Government of the Russian Federation, acts of the specially authorized state bodies on environmental protection, acts of regional and local authorities, departmental acts, and acts issued by enterprises and institutions.

The Constitution explicitly guarantees the right of each citizen to live in a favourable environment, be provided reliable information on its state, and compensation for damage inflicted upon his or her health or property as a result of violation of environmental legislation. It also declares the supremacy of the international agreements above other Russian legislative and statutory acts.

Evaluation of relevant regulations

The main law is the *Law on Environmental Protection*. The main administrative body engaged in environmental protection in Russia is the corresponding department of the *Ministry of Natural Resources*. The Ministry shares functions with other designated environmental protection bodies:

- Federal Service for Hydrometeorology and Environmental Monitoring responsible for operation of the State Observation System, including environmental monitoring;
- Ministry of Agriculture and Foodstuffs responsible for hunting and fishing inventory and regulation;
- Committee on Land resources and land Use responsible for the State Land Register and other related functions, including control of land use and soil protection.

Ministry of Health and Federal Service for Geodesy and Cartography are also federal executive bodies directly related to environmental protection.

The Russian Federation has detailed regulations concerning hazardous and toxic chemicals and waste, which are relevant and applicable to PCBs. Legislative acts and normative documents related to PCB management include a small number of specific documents and a large number of documents of general character. Most of the legislative acts were enacted in the 1990's. The main technical normative documents were adopted in the 70's and 80's, whereas legal normative documents were stipulated mainly in the 80's and 90's. It is difficult to determine correct legal applicability of a great number of these documents, their relevance to privately-owned enterprises, validity terms, responsibilities of state executive bodies, rules of their revision and abolition and, therefore, whether owners of industrial enterprises must follow requirements of these documents and authorities.

The main features and drawbacks of current environmental legislation relevant to PCB issues are:

- Low flexibility and sometimes contradictions within the multilevel system of Federal Laws, sub-laws, acts and normative documents and standards;
- Existing contradictions between vertical elements of the system (i.e. between Federal, regional, and local levels) and horizontally (between various acts at the same level, particularly issued by different executive authorities). This increases chances for both the enterprises to violate the norms and for state agencies to raise incorrect claims;
- Absence of a unified mechanism of implementation caused by inadequate instructions issued for support of the regulations, which create difficulties in enforcement of regulations;
- Orientation towards environmental protection (waste treatment, disposal etc.) and less frequently to rehabilitation, reclamation and restoration;
- Environmental forecasting is not a regular practice in decisions about future development.

Conclusion and recommendations

In spite of the above drawbacks, analysis of legislative and regulatory and documentation on support of environmental protection in the Russian Federation shows that there are no visible impediments to developing a safe step-by-step PCB phase-out system in Russia, with a similar mechanism to that used by some foreign countries, to solve this problem in a relatively short time. The existing legislative and regulatory basis is sufficient to execute these activities and to reach a final goal, in case of developing an efficient management mechanism for their implementation.

2. Development of PCB Collection and Storage Schemes

Environmentally sound management of PCB wastes will include activities related to collection and storage of PCB and PCB containing equipment. PCB collection and storage schemes have been developed for the Russian Federation on the basis on national and international requirements. The legislative measures to identify, label, transport and store PCB waste under safe conditions have been identified and recommendations given.

Background

At present there are no regulations on the labelling, collection or storage of PCB and PCB-containing equipment, except in general regarding dangerous goods. European transport rules (ADR) have recently been adopted by the Russian Federation. Further development of the Russian regulations regarding collection and storage of PCB waste will focus on European rules for guidance.

Legislation

The Russian legislation which regulates the collection and storage of PCB and PCB-containing equipment has been identified and include the following:

- *law on licensed activities*; the Ministry of Natural Resources grants companies permission to carry out activities, e.g. involving PCB collection and storage;
- *regulation on labour protection* specifies the procedure for labour protection as well as supervision and control on their implementation;
- *industrial safety regulations in hazardous production facilities* sets up the requirements to organisation, and for carrying out of control of the observance of the industrial safety regulations;
- *regulations of production control* specifies the procedures on identification of the main hazards and planning of internal control.

Recommendations on collection and storage

Emergency Plans.

According to the Ministry of Labour, an Action Plan for Emergency Relief (APER) has to be developed for both PCB storage and transportation. The APER shall contain information on actions to be taken in case of accidents. Recommendations have been given concerning training of personnel of transport companies and accident relief teams.

Labelling of Equipment.

In the Russian Federation there are, at present, no regulations on labelling of PCB equipment. Therefore it has been recommended to label the PCB-containing equipment in accordance with the EU Directive 96/59/EC; valid both for PCB-containing equipment in use, in storage facilities and decontaminated PCB equipment.

Collection.

At present there are no regulation on the collection of PCB and PCB-containing equipment except that the carriage has to fulfil the requirements of the *Regulations on the Carriage of Dangerous Goods by Road*. A schematic diagram has been prepared for the suggestion of a collection scheme. Additional it is recommended that carriers shall be equipped with a special license allowing them to carry PCB and PCB-containing equipment.

Safety Passport.

According to the Russian Standard (GOST) a Safety Passport shall be handed over to users of the product at all life stages. This also includes PCB and products containing PCB. A Safety Passport has been prepared for the main PCB groups. The Safety Passport contains information on the human health hazards and the environmental hazards, proposed safety measures in case of injury, fire and accidents, toxicological and ecotoxicological information and transport information. The information has been obtained from different international sources, such as WHO, ILO, UNEP and ISO.

ADR Transport Rules.

The Russian *Regulations on the Carriage of Dangerous Goods by Road* (similar to the ADR) sets up the requirements for the carriage of the PCB and PCB-containing equipment. According to the ADR adequate provision shall be taken to seal the transformers to prevent leakage during transport, and it is prohibited to carry empty contaminated transformers, which have contained PCB.

Storage.

At present there are no regulations on the storage facilities for PCB and PCB-containing equipment. It has been recommended to design storage facilities in accordance with the general Russian requirements for layout of warehouses for organic products, and to the specific requirements for warehouses for highly flammable liquids. The recommendations include:

- creation of embankment systems;
- keeping necessary distances between storage buildings;
- fire protection measures;
- elimination of potential causes of fire;
- storage of PCB fluids in plastic drums.

There is presently a lack of facilities for decontamination or disposal of PCB or PCB-containing equipment the Russia Federation. Therefore, it is recommended to store the PCB and the PCB-containing equipment at a holding location until such facilities have been established.

3. Selection/Development of Environmentally Sound Technologies for Destruction of PCB–containing Fluids

High temperature incineration using a cyclone reactor is the best technology, based on general economic parameters. It is recommended to construct five large stationary installations for PCB destruction, one small installation and two smaller mobile installations. The capacity of the stationary installations should be 1000 t/year to destroy both PCB and accumulated old stocks of pesticides and other organic wastes.

Background

A few enterprises in Russia currently perform, on their own initiative, destruction of PCB drained from transformers in industrial use. Based on available data, two major enterprises have destroyed about 200 tons of PCB. The same enterprises drain and clean obsolete transformers of PCB using in-house technology. These pilot technologies were considered not to meet the existing environmental requirements.

The inventory of PCB in Russia conducted during Phase 1 of the project showed that the majority of enterprises send failed transformers and/or discharged PCB for storage at specially allocated sites on the premises of the enterprises.

Evaluation of technologies for PCB destruction

Ten potential Russian technologies for PCB destruction were considered at the preliminary stage. Screening assessment of these technologies was made using technical, environmental, and economic requirements. Based on the screening, four Russian high-temperature incineration technologies were selected for the subsequent feasibility study:

Technology	Environmental characteristics		Cost	
	PCB destruction, %	PCDD+PCDF ng/m^3	Construction, thousand $US	Processing 1 ton PCB, $US
Cyclone reactor	99.9996	0.1	653	320
Rocket engine for space station orientation	99.9992	45	1041	1070
Plasmatron and chemical reactor	99.9993	55	3430	1000
Liquid-fuel rocket engine	99.9999	<0.1	1680	940

High temperature incineration using a cyclone reactor is considered the best presently available Russian technology. The basic unit in this technology is the cyclone kiln, which is so-called, because of the twisting vertical movement of working gases, which provides high turbulence and effective mixing. The gases then enter a lined gas chamber (afterburner), where the temperature (1250-1400°C), time of contact (~ 2 sec) and excess of oxygen (~ 10 %) destroys PCB. This is achieved within acceptable limits for dioxin formation. Hydrogen chloride formed during PCB incineration is neutralized by an injection of alkali solution directly into the reaction gas.

Evaluation of the necessary PCB destruction capacity

It is recommended to construct five stationary installations for PCB destruction, and one additional small installation at Norilsk, (because of the company 'Norilsk Nickel') according to the table below, and in addition to construct two mobile installations servicing minor non-movable stockpiles.

Region	Possible location	Total number of transformers	Number of PCB destruction facilities
North and North-West	Krasnyi Bor, Kapitolovo (Leningrad Oblast)	500	1
Central, Central Black-soil and Volgo-Vyatka	Moscow Oblast	2500	1
Volga and Northern Caucasus	Tolyatti	2500	1
Urals and West-Siberia	Ekaterinburg	2500	1
East-Siberia and Far East	Irkutsk Oblast	1000	2*

***One installation at the enterprise 'Norilsk Nickel'**

It is expected to finalize the construction and initiate operation of a pilot scale plant in ~ 2005 in the North and North-West. This destruction facility, funded by NEFCO, is to be constructed with the capacity of 500 t/year for destruction of liquid PCB drained from transformers. This installation will include a facility for cleaning of transformers, with a capacity of 250 t PCB per year.

The total amount of liquid PCB for destruction is estimated to be 29,000 tonnes, with an additional 10,000 tonnes contained in capacitors. Since PCB cannot be expected in a continuous supply stream, it was decided to propose stationary installations with the capacity of 1000 t/year and to destroy accumulated old stocks of pesticides and other organic toxic wastes to enhance the economic sustainability of the incinerators.

For the PCB transformers destruction at 'Norilsk Nickel', a stationary installation with high-temperature incineration using the rocket engine technology and with the capacity of 400 t/year is recommended. Low construction cost (350,000 US dollars) was an important consideration, despite the high processing costs (1070 US dollars for 1 ton of PCB).

Taking into account the existence of 10,000 transformers spread all over Russia, construction of mobile installations for PCB destruction is recommended in addition to the proposed stationary installations. Mobile units for PCB destruction will allow reducing transportation costs and risks associated with long-distance PCB transport in containers. For such facilities, the mobile installation based on rocket engine technology developed by "ENEKSINT Ltd." is recommended. Construction cost of an installation with an annual capacity of 80 tons of PCB is 180,000-200,000 $US, and operational cost is 280-320 $US per ton of PCB.

Conclusions and recommendations

Taking into account the technical, environmental and economic characteristics of PCB destruction methods, the stationary installation based on the technology of high-temperature incineration using cyclone reactors, with an annual treatment capacity of 1000 tons PCB is recommended.

For local PCB destruction from the transformers, which are located in inaccessible or remote areas, e.g. Norilsk, the stationary one base module installation of high-temperature incineration with use of rocket engine technology with the capacity of 400 tons of PCB per year is recommended.

In addition to stationary installations, mobile PCB destruction facilities can be constructed. The tentative proposed ratio between mobile and stationary units is 5 - 6 : 2.

4. Selection / Development of Environmentally Sound Technologies for Destruction / Decontamination of PCB-Polluted Containers, Equipment and their Components

4.1. Technologies for Cleaning and Recycling of Transformers after PCB Removal.

It is recommended that transformers emptied of their PCB content are cleaned by washing with methylene chloride. The discharged PCB is sent for destruction and the metal part of the cleaned transformer is scrapped. The transformer cleaning installations should be located close to stationary installations for PCB destruction (section 3). Because of health hazards associated with using methylene chloride, labour safety shall be a primary concern at the installations.

Background

The method for treatment of PCB-containing transformers after PCB removal, by washing with a solvent and scrapping the metal parts of the transformers is recommended. In the evaluation of methods, both the Russian and foreign methods have been considered in relation to the environmental requirement which is (maximum) 50 mg PCB/kg steel/metal in the scrapped metal and 50 ppm in the residual washing solution.

Evaluation of methods for transformer treatment

PCB discharge and washing

Three Russian technologies for transformers cleaning were considered:

- using methylene chloride vapor;
- using liquid toluene;
- using aqueous detergent.

Cleaning with aqueous detergent does not meet the environmental requirements. The use of toluene is a more complex process compared to the use of methylene chloride, and as consequence the installation has higher costs:

Technology	Construction cost, thousand $US	Operational cost, $US
Methylene chloride cost	700	1180
Liquid toluene	820	2020

The method of cleaning using methylene chloride vapor as a solvent was recommended as the basic option for transformers cleaning. By using methylene chloride the cleaning costs for 200 transformers/year is approximately 750 thousand US dollars. One ‘average’ operation of transformer processing takes 72 hours. The cost of the first operation is 1180 US dollars. One 'base module' can carry out 100 operations/year.

After washing down to a PCB-concentration of 50 mg PCB/kg steel/metal, the transformers are dismantled and the metal parts sent for recycling. Re-use of cleaned transformers by refilling with non-PCB-liquid is not cost-effective as the transformers are old and usually need to be repaired.

Nonmetallic parts (paper, wood), which, after washing, usually fail to meet the required PCB concentration limits, should be destroyed.

According to European standards, methylene chloride is considered to cause a health hazard and is possibly carcinogenic to humans. Special attention shall therefore be given to labour protection at installations using methylene chloride. Skin and eye protection is of main concern.

Retro-filling

The retro-filling method is sometimes applied outside Russia. With this method the transformer is filled with new PCB-free dielectric fluid (retro-filling). The method requires proper discharge of PCB and sufficient cleaning of the empty container to avoid PCB-contamination according to environmental requirements consistent with the PCB-concentration in the new dielectric fluid.

The retro-filling method can be applied when it is justified for economic or technical reasons, for example when transformers are too large for transportation or if dismantling turns out to be very complicated. The method is applicable for replacement of dielectric fluid when the transformer can be reused without the need for repair.

Evaluation of the necessary transformers cleaning capacity

The transformer cleaning installations should be located close to stationary installations for PCB destruction (section 3). One transformer cleaning installation, consisting of two units, is recommended at each of five locations of large destruction facilities, and a smaller one-unit cleaning installation at Norilsk. More than 200 transformers are stored at the enterprise 'Norilsk Nickel'.

The capacity of five large transformer cleaning installations is estimated to be 1000 transformers/year. Thus, the 10,000 transformers at Russian enterprises may be cleaned within 10 years. This means that, in a twenty year operation period, a more than double capacity reserve for transformer cleaning can be provided. This will allow for probable variations in the demand for these installations over time/years. This extra capacity could also allow for capacitor cleaning for other substances than PCB before their dismantling and disposal.

Certain objections concerning mobile installations have been raised. The main objections are operational safety, the need for repair after moving along bad roads, and the low technical lifetime of such installations. In addition, labour protection concerns have been raised against these installations In spite of this, mobile installations for transformers cleaning are recommended to supplement the stationary installations, providing they can be moved to safe places for operation where a large number of transformers are located. Mobile installation for transformer cleaning can solve problems with transport of large transformers over long distances. Mobile installations have smaller capacity and differ in technical function from stationary ones.

4.2. Technology for Destruction of Capacitors with PCB

Thermal destruction of capacitors using a molten metal furnaces with systems of after-burning and neutralizing of the waste gases is recommended. A melting furnace with plasma arc, also supplemented with a cyclone reactor, is considered a realistic alternative. The plasma arc system will also have the capacity to destroy other closed PCB - containing equipment as well.

Background

The main issue of this activity is to evaluate Russian and western technologies for the destruction of PCB-containing capacitors. The destruction of other closed PCB-containing containers is also considered here.

Evaluation of destruction technologies

Three Russian technologies (1-3) and one western technology (4) for destruction of PCB-containing capacitors were considered.

1. Chemical neutralization of capacitor PCB with subsequent explosion.

The method was proposed by JSC *'Promtechvzryv'*, and comprise adding PCB waste to industrial explosives. The PCB is destroyed during the use of the explosives.

Test results on environmental indicators were not available from destruction of PCB-containing waste, and it was not possible to evaluate the environmental performance of this technology. Cost of one installation with the capacity of 500 t/year is 2 million US dollars; processing cost of 1 ton of capacitors is 1,350 US dollars.

2. Thermo-chemical waste neutralisation using contact heating and high-temperature combustion fuel

The method was proposed by JSC '*NET*'. It is a prolonged high temperature process based on mixing of waste with metal powder, oxidation and subsequent destruction.

Test results on environmental indicators were not available from destruction of PCB-containing waste, so it is not possible to evaluate the environmental performance of this technology.

Cost of one installation with the capacity of 1000 t/year is 70,000 US dollars (in case of in-kind delivery of the existing equipment); processing cost of 1 ton of hazardous waste varies from 4,000 to 6,000 US dollars.

3. Thermal destruction of capacitors using a molten metal furnace with after-burning and neutralizing of the waste gases.

The system was proposed by JSC '*Techenergochimprom*' and JSC '*Institute-Stalproject*'. A melting furnace is combined with high temperature treatment of flue gasses.

This is a proven technology that meets strict European standards for PCB and dioxin releases in waste gases and in produced lustrous slag. Cost of one installation with the capacity of 4000 t/year is about 1.6 million US dollars; processing cost for 1 ton of capacitors is about 1000 US dollars.

The basic technology is similar to the cyclone reactor used for liquid PCB incineration. It includes preliminary discharge of TCB from capacitors, but destruction of capacitors is also possible without PCB discharge.

4. <u>A furnace with plasma arc supplemented with a cyclone reactor.</u>

This methodology is based on a plasma arc rather than a melting furnace, but is otherwise comparable to method 3.

The technology meets US environmental requirements. The estimated cost of installation construction with the capacity of 4000 t/year will be 1.6 million US dollars, and processing cost for 1 ton of capacitors about 1000 US dollars. An installation with the capacity of 4000 t/year is suggested.

To calculate the installation capacity, an average TCB content in a capacitor of about 20 kg was used. Average TCB concentration in the capacitor is ~ 32% (i.e. the average capacitor weighs ~ 63 kg). Taking into account that it is only possible to drain on average 50% of TCB contained in capacitor, or about 10 kg, the (residual) average capacitor weight will be ~ 50 kg. Thus, a capacity of 4000 t/year allows for destruction of 80,000 capacitors per year, or 1,6 million capacitors over 20 years.

This is approximately threefold the capacity needed, but this overcapacity can be used to buffer possible fluctuations in installation loading over the year(s). Moreover, the reserve capacity will allow destruction of capacitors without prior PCB discharge, and destruction of PCB-polluted containers, various vessels and parts of transformers. Finally, the destruction of other hazardous waste can be considered.

Conclusions and recommendations

Thermal destruction of capacitors using a bubbling smelting furnace with after-burning and neutralizing of the waste gases meets European standards for PCB and dioxin releases in waste gases and in produced lustrous slag. This is considered the best Russian method for capacitor destruction.

Based on the results of technical, environmental and economic estimation of the three Russian technologies for capacitor destruction, the molten metal furnace with the systems of after-burning and neutralizing of the waste gases is recommended.

A melting furnace with plasma arc also supplemented with a cyclone reactor will have the capacity to destroy other closed containers with PCB and is considered a realistic alternative to thermal destruction and can be recommended.

A possible location for the construction of such an installation the is the large industrial enterprise JSC ‘*Khimprom*’ in the city of Novocheboksarsk. This enterprise has experience in handling chlorine-containing products. However, alternative locations will be considered during Phase 3.

5. The Model for Estimation of Removal from Operation of the Transformers and Capacitors filled with PCB

A model showing the possible progress of the process for PCB-transformer and capacitor handling until 2020 was developed. All relationships represented in schematic diagrams. According to the model, about 17,000-21,000 tons of PCB was still in use in transformers and 10,000 t in capacitors in 2000. This corresponds to estimations madde in Phase 1 of the project. The annual amount of PCB in transformers taken out of service will remain nearly constant during the period 2000 to 2010. In 2020 about 1,000-3,000 t PCB will still be in use in transformers, but virtually all PCB-containing capacitors will be taken out of service before 2020. The need for new fluids to replace PCB will, for various reasons, not correspond to the amount of PCB taken out of service.

Background

According to the Stockholm Convention Russian transformers and capacitors containing PCB shall be taken out of service by 2020. To accomplish this, a model showing the possible progress of the process has been developed. The model is based on PCB production and consumption data, the number of transformers and capacitors taken into service in Russia and the expected technical life time of the equipment. The model shows both the change in numbers of transformers and capacitors during time and thus the numbers remaining to be taken out of service during the period upto 2020.

This amount is referred to as 'the consumption' in the following. To simplify the calculations it is assumed that the annual consumption was equal for all years within each decade.

Evaluation of PCB-transformers and capacitors to be handled.

According to the projects Phase 1 report, ~35,000 tons of Sovtol was used in the Former Soviet Union/Russia for manufacturing of ~19,000 transformers. 24,000 tons of trichlorobiphenyl (TCB) was used for manufacturing of 1,200,000 capacitors. The Russian Federation accounted for approximately 60% of the consumption in the former USSR. Decennial breakdown of the estimated amount of PCB in transformers and capacitors installed in the Russian territory is shown in Table 2.

Based on this, numbers of electric equipment to be taken out of service during the period 2000-2020 are estimated. The fact that actual lifetime of electric equipment depends on a number of factors has been taken into account. The typical life of transformers is, for example, around 30 years, but some transformers may be taken out of service before this age, whereas others may by used for 40 or even 50 years. For the results obtained, see Fig. 1.

Evaluation of PCB-transformers and capacitors taken out of service and PCB still in use

Based on data from Phase 1 of the project, the lifetime distribution probabilities for transformers and capacitors, the number of transformers and capacitors removed from operation, and the number of transformers and capacitors remaining in operation over time is calculated. The same relationships were obtained for PCB contained in transformers and capacitors over time.

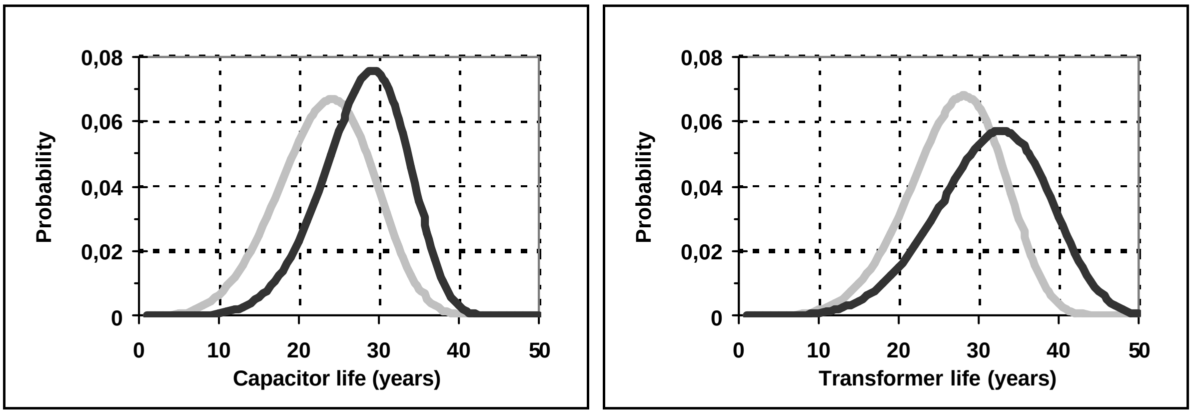
Table 2

PCB in transformers and capacitors taken into service in the Russian territory

Transformers			Capacitors		
Years	Number	Filled PCB, t	Years	Number	Filled PCB, t
1939-1949	1,000	1,800			
1950-1959	2,000	3,600			
1960-1969	2,600	4,800			
1970-1979	7,400	14,000	1968-1979	750,000	14,900
1980-1989	5,200	10,000	1980-1989	450,000	9,100
Total	18,200	34,200		1,200,000	24,000

Figure 1.

Minimum and maximum life distribution for transformers and capacitors



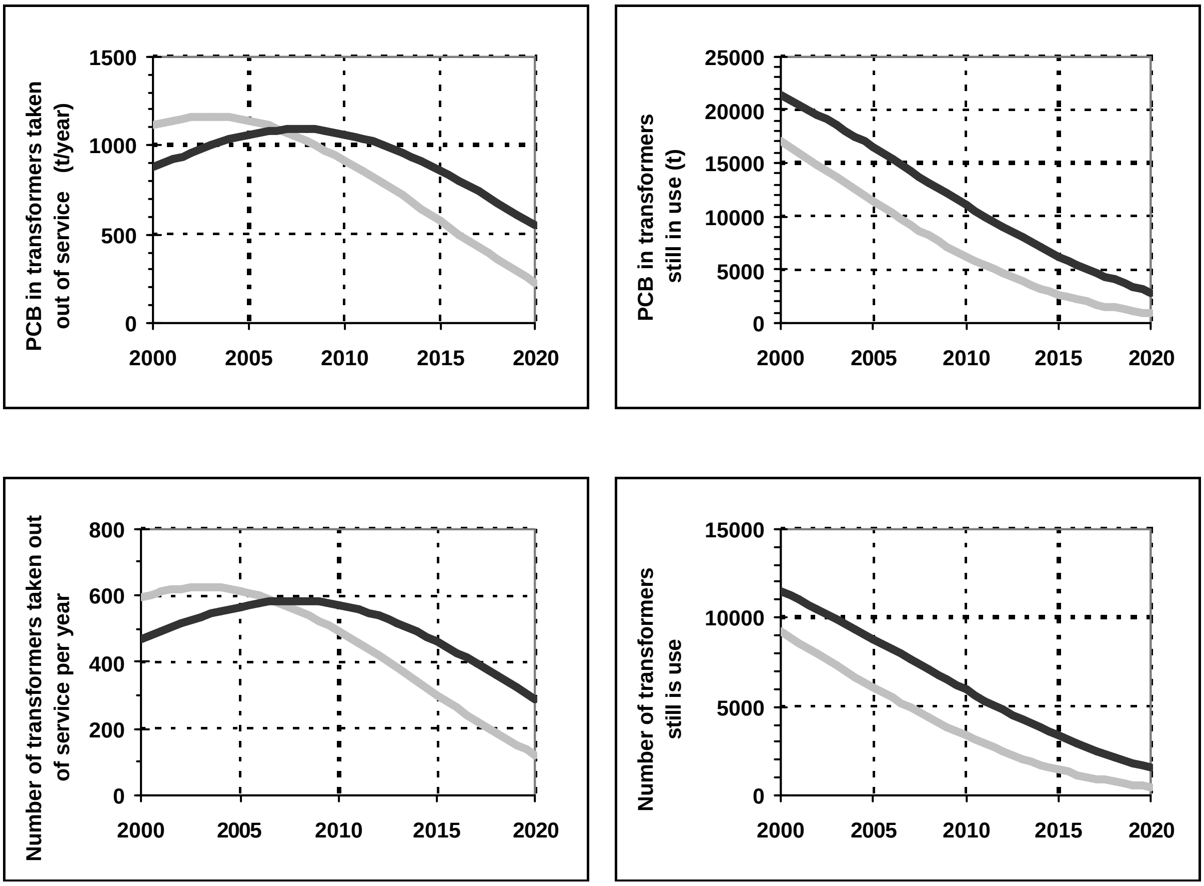
All relationships are presented as diagrams. The Weibull function of probability density was used as a model for lifetime distribution of the electrical equipment.

The amount of PCB in equipment still in use in a given year was calculated by subtracting the total PCB content of equipment taken out of service before that year from the total consumption (taken from Table 2).

The results for transformers in terms of tons PCB and number of units are shown in Figure 2. The grey curve is based on the grey "minimum" life time distribution in **Figure 1**, whereas the black curve is based on the black "maximum" distribution.

Figure 2

PCB in transformers taken out of service and PCB still in use



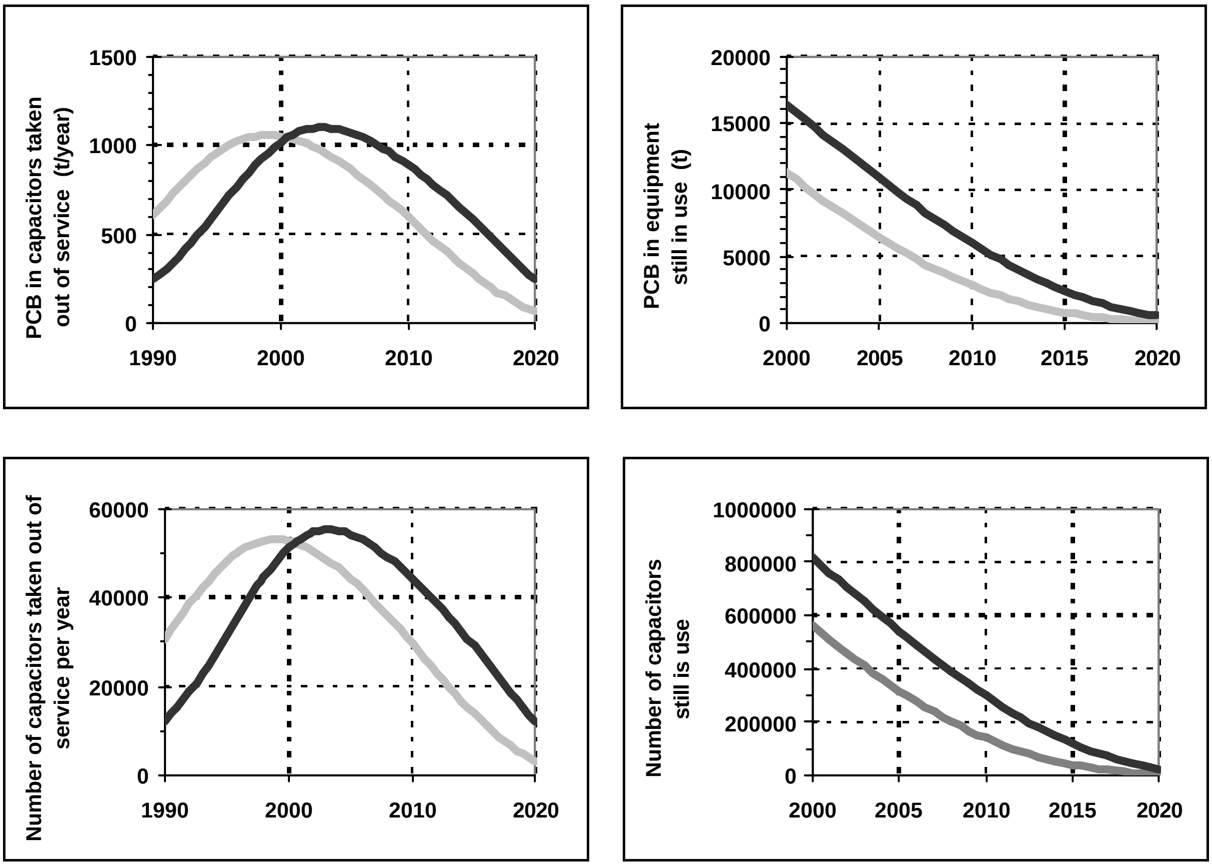
Based on the model it is estimated that some 17,000-21,000 tons of PCB was still in use in transformers in 2000. In the previous section an estimate that 19,000 PCB was still in use in 2000 was presented. That estimate was based on the inventoried equipment and some assumptions regarding the coverage of the inventory. The good agreement between these two estimates indicates that the assumed operational-lifetime distributions used are well in accordance with the actual distributions. The calculations indicate that the annual amount of PCB in equipment taken out of service will remain nearly constant during the period 2000 to 2010. In 2020 still some 1,000-3,000 t will be in use.

This volume of PCB in transformers taken out of service may give an indication of the demand for liquids for transformers to replace PCB contained in transformers, although a one-to-one replacement volume cannot be expected. If the PCB-containing transformers are to be replaced by other transformers with less-flammable liquids, the demand would be about 1000 tons liquid per year for the next ten years.

The capacitors have a shorter life and consequently it is estimated that virtually all PCB-containing capacitors will be taken out of service before 2020 (Figure 3). As for the transformers, the estimated PCB amount remaining in 2000 is in good agreement with the results of Phase 1, where it was estimated that about 10,000 t PCB was still in use in year 2000. Based on the current assumptions the remaining PCB in capacitors is, however, estimated to be between 11,000 and 15,000 t. The annual volume of PCB in capacitors taken out of service is expected to decrease in the coming years.

Figure 3

PCB in capacitors taken out of service and PCB still in use



The need for fluids for replacement of existing capacitors can, for a number of reasons, not be assumed to resemble the amount of PCB in capacitors taken out of service. PCB was used for both high-voltage (>1000 V) and medium-voltage power capacitors (<1000 V). As mentioned above, today fluids are only used for production of high-voltage capacitors. In addition, the capacitor design for high-voltage capacitors has changed, and the fluid content of new capacitors does not resemble the fluid content of old PCB-capacitors.

Furthermore, capacitors produced before 1968 and after 1989, as well as a part of the capacitors produced between 1968 and 1989, were filled with other fluids. The older types, produced before 1968, but to some extent also during the period 1968-1989, were filled with mineral oil. These capacitors will - when taken out of service - be replaced by the same type of capacitors as the PCB-containing capacitors. Consequently, the maximum volume of PCB in capacitors taken out of service around 2000 does not indicate the demand for capacitor fluids, as the other types of capacitors may constitute a larger share before and after that time.

Conclusions

About 17,000-21,000 tons of PCB was still in use in transformers, and 11,000-15,000 t PCB in capacitors, in 2000. This is in good agreement with estimations from Phase 1 of the project. The annual amount of PCB in transformers taken out of service will remain nearly constant during the period 2000 to 2010. In 2020, about 1,000-3,000 t PCB will still be in use in transformers, but virtually all PCB-containing capacitors will have been taken out of service before 2020. The need for new fluids to replace PCB will, for various reasons, not correspond to the amounts of PCB taken out of service.

6. Study of a PCB-contaminated Sites and Evaluation of Rehabilitation Methods

Evaluation of different rehabilitation methodologies for the heavily PCB-contaminated Serpukhov area have been carried out. The total amount of PCB in the (6-7 km^2) area is estimated to be 350 tons. On the basis of a cost-benefit analysis, the recommended methodology for rehabilitation is to use thermal desorption and cyclone kiln PCB destruction. It is possible to reduce PCB content in soil to the levels required by environmental protection guidelines. The methodology is specifically recommended for treatment of PCB-contaminated soil at the Serpukhov site, and remediation of other PCB-polluted sites in Russia must be evaluated on a case-by-case basis. Each case requires a thorough site investigation in order to choose the optimal methodology.

Background

The objective of this study was identification and prioritization of PCB contaminated areas and selection of feasible methodologies for remediation, if possible, with a preference for Russian methodologies.

No data were found for a comprehensive prioritization study on possible contaminated areas in Russia. It was therefore decided to conduct a case study for Serpukhov and its suburbs which have a history of gross pollution by chlorinated biphenyls (PCB) due to the capacitor manufacturing plant '*Kondensator*' with a previous annual use of PCB of up to 1,400 tons per year. Existing health and environmental studies in the region showed increased sickness rates, growth abnormalities, especially among children, and increased PCB content in breast milk.

Eleven foreign and five Russian remediation methodologies were evaluated for the Serpukhov area. Remediation is a site specific task and the evaluation of methodology only applies to the Serpukhov region.

Environmental, technological and economic criteria were used to select the optimal remediation methodology. Different methodologies were also evaluated according to efficiency and completeness of PCB destruction. *Administrative criteria* for environmental protection were proposed as guidelines for local authorities and environmental bodies when choosing a methodology.

Evaluation of PCB-contamination at the Serpukhov area

The city of Serpukhov is located in the Moscow Oblast. The polluted area is 6-7 km^2, with the heaviest pollution in the north, where storehouses of the plant '*Kondensator*' were located, and in the south, in the area of the former industrial activity of this plant. According to previous studies, in the dried-up core pools of the former sewage treatment system, the PCB content was 18,300 mg/kg, and in the flood-lands of Borovlianka Brook (micro-district

'*Zaborie*'), PCB content in soil was 8.5 mg/kg. Concentrations in the air, groundwater and surface water did not exceed the maximum allowable PCB concentrations given for the respective environmental media, with the water in the brook of Borovlianka being the only exception. The estimated total amount of PCB in soil at the Serpukhov area is ca. 340 tons.

Crops at micro-district '*Zaborie*' contain high PCB concentrations, and intake though ingestion of PCB present in food is the major exposure route for the local population. Calculated excess life-time carcinogenic risk, is 3.92 additional disease cases annually in the population of 140,000 people.

Evaluation of remediation methodologies

Both foreign and Russian 'on-site' and 'off-site' methodologies for treatment of PCB-containing soil were evaluated.

Evaluation of 'on-site' methodology

The following 'on-site' soil remediation methods satisfy the environmental criteria;

- Isolation
- Bioremediation
- Liquid-phase vitrification.

The following 'on-site' soil remediation methods satisfy the technological criteria and are the simplest applicable for large contaminated areas

- Isolation, and
- Bioremediation

The most complex method, from a hardware point of view, is the methodology of liquid-phase vitrification.

Based on economic criteria, the most favorable technologies are isolation and bioremediation. Considering administrative criteria for 'on-site' remediation methods, isolation is only applicable for unoccupied territories. Bioremediation may be used mainly for processing of large territories, including agricultural croplands.

Liquid-phase vitrification is the best remediation method for small areas with PCB content more than 50 mg/kg and when contamination extends to deeper soil layers.

Evaluation of 'off-site' methodology

Practically all of the considered 'off-site' soil remediation methods satisfy environmental requirements.

Landfill disposal, solvent extraction, and thermal desorption are the simplest technologies. However these methods do not accomplish PCB destruction. Other foreign technology considered was soil isolation. This technology postpones the soil remediation process and is of temporary character.

Compared with other methodologies, disposal investment costs and methodology preparation costs are lowest for landfills. As to administrative criteria, landfill disposal has preference on the basis of technological and economic criteria, but is hardly suitable for wide industrial application. Landfill disposal of PCB-containing soil is currently not a common practice in Russia. The '*Krasny Bor*' landfill does not receive PCB waste at the moment.

The technologies using a rotary kiln, mobile installations with 'oxy-fuel' torches and a cyclone kiln are complex multistage processes, but they bring about PCB destruction.
Among technologies of high-temperature oxidation, the technology using the mobile installation with 'oxy-fuel' torches has a slightly lower capital cost.

The most acceptable technologies are those using cyclone kiln and thermal desorption processes, which make it possible to reduce PCB content to levels in accordance with ecological requirements.

Evaluation of actions to reduce environmental and health risks

Both short-term and long term actions for reducing environmental and health risks caused by PCB-pollution were considered. Short-term actions are intended to give quick response and quick risk reduction. Long-term actions are intended to reduce spreading and diffusion of PCB and thus minimize the influence of PCB-pollution in a longer time perspective.

Short-term actions can be administrative and organizational, for example applying restrictions or drastic reduction to agricultural production from PCB contaminated ground. Administrative and organizational actions such as restriction of agricultural production or consumption of local PCB-contaminated crops reduces risks without significant investments. However, the source of risk will not be eliminated, and this action therefore cannot be the exclusive solution for the Serpukhov area. Therefore, these actions are recommended only as auxiliary ones. *Long-term actions* would include remediation with on-site or off-site methodologies as discussed in this report.

Conclusions and recommendations

On the basis of the cost-benefit analysis the following actions were proposed for remediation of the Serpukhov area:

- remediation of soil in the waste water treatment system's core pools of the plant '*Kondensator*', with an area of about 3 ha, using cyclone kiln technology;
- remediation of soil in the district '*Zaborie*', with the area of 200 ha, using treatment with humino-mineral concentrate and bioremediation;
- administrative and organizational actions aimed towards minimization of production and consumption of contaminated agricultural products to reduce human exposure.

The track record of these Russian soil remediation technologies is short, but they may be applied in the Serpukhov area. Additional information may, however, be required before their application, e.g. concerning the fate of humic acid bound PCB during the soil remediation using humino-mineral concentrate.

The methodologies presented are recommended for treatment of PCB-contaminated soil at the Serpukhov site, and they cannot be applied directly for the remediation of other PCB-polluted territories in Russia. Each new case requires a thorough site investigation of the area in order to choose the most appropriate methodology.

A preliminary study of a polluted territory should always precede the introduction of methodologies for PCB-containing soil remediation. This study should include full desk study, site inspection, delivery of the input data for carrying out a feasibility study, and design works, execution of a business-plan, etc.

7. Evaluation of production of alternative dielectric fluids for use in capacitors and transformers.

A number of Russian and international alternatives to PCB dielectric fluids (DEFs) have been evaluated with respect to technical requirements, health and environmental properties and economic feasibility for use in transformers and capacitors. For production in Russia, two aromatic compounds developed in Russia can be recommended for production for use in capacitors. A mono-chlororganic compound has also been suggested as a DEF for use in transformers, and this may be technically and economically feasible. It is recommended that additional studies on toxicity and environmental fate of these alternatives be carried out before a final decision on manufacturing the fluids in Russia is made.

A model prediction indicates that the perspective demand for alternative DEFs for capacitors is 350-400 t/year, which is ~5 times more than current demand. For transformers the perspective demand is 400-600 t/year. These needs for DEFs are lower than the former PCB production, primarily due to the use of dry capacitors for the medium voltage range.

Background

Approximately 30,000 tons of PCB-containing fluids remain in equipment and in storage throughout the Russian Federation. By 2005 more than 70% of this PCB-containing equipment will reach the end of its design life and will need to be replaced as the equipment is phased-out. At the moment there is no production of alternative dielectric fluids (DEFs) for high voltage capacitors and fire-resistant transformers in Russia. The technical requirements, the health and environmental properties and the economic feasibility for DEF use in transformers and capacitors have been evaluated for selected Russian and international alternatives to PCB dielectric fluids. The following dielectric and operational characteristics of alternative fluids have been assessed:

Technical	Economical	Environment and Health
Break-down voltage; Dielectric losses; Specific electric resistance; Ignition temperature; Kinematic viscosity; Solidification temperature; Dielectric permeability; Reutralization factor.	Raw material costs Treatment costs Maturity Production cost	Danger and risk Acute and chronic toxicity Sensitization Mutagenic effects Carcinogenic effects Bioaccumulation factor Degradability Eco-toxicity

Investigation on the possible production of the following types of DEFs was carried out:

- organofluorine compounds;
- silicon compounds;
- synthetic aromatic hydrocarbons;
- organochlorine compounds.

General assessment of DEFs

DEFs imported to Russia, and the majority of the alternative fluids on the market abroad meet the dielectric and operational requirements for use in capacitors and transformers.

The overall DEF demand was determined according to analysis of existing electrical equipment and expected design lifetime in the Russian industry. The perspective demand revealed this way was compared to the present demand obtained from Russian producers of capacitors and transformers. The former PCB production in the Russian Federation for transformers and capacitors was more than twice the demand estimated in this project. This may be explained by transition to other oils or to dry capacitors and transformers, because of lack of alternative DEFs, and also the general declines in production.

Evaluation of DEF demand for capacitors

The only manufacturer of capacitors in Russia, is presently JSC Serpukhov Capacitor Plant '*KVAR*' (city of Serpukhov, Moscow Oblast). The plant produces capacitors filled with phenylxylylethane as an alternative DEF purchased abroad.

The current Russian demand for alternative DEF for capacitors is 70-100 t/year. The perspective demand is approx. 5 times higher, and is estimated as 350-400 t/year. According to the plant '*KVAR*', the demand in alternative DEF is restricted by relatively high price of phenylxylylethane, which is 2 $US/kg.

Among the proposed alternative DEFs developed in the Russian Federation the following fluids for filling capacitors were selected: AZI-3 (1,1-phenylxylylethane) and DON (mixture of 70-75% of mono-benzyltoluene and 20-25% of dibenzyltoluene). These compounds have passed a number of technical tests and are accompanied by some information on their health and environmental properties. No impeding properties are reported, but the compounds do have adverse effects if not handled properly. The compounds used for capacitors on other markets are similar types of aromatic hydrocarbon-based fluids. The production of these fluids is secured with necessary raw-materials, and the production technology is experimentally tested. The fluids passed experimental tests in complete products.

Evaluation of DEF demand in transformers

At least three Russian manufacturers intend to produce transformers with alternative DEFs:

- OJSC '*Transformator*' (Tolyatti, Samara Oblast)
- OJSC Ural Plant of Electric and Heavy Mechanical Engineering '*Uralelectrotyazhmash*' (Ekaterinburg)

- OJSC '*Altrans*' - the Altay transformer plant (Barnaul, Altai Krai), holding company '*Electrozavod*' (Moscow)

Two plants have started to produce pilot lots of transformers filled with the alternative DEF '*Midel*' purchased abroad. According to manufacturers the perspective demand for alternative DEF for transformers is 400-600 t/year. The demand may be restrained by relatively high average costs estimated at about 4 $US/kg.
Among alternative transformer DEFs developed in the Russian Federation, only AZI-3X (monochloro phenyl xylyl ethane) has undergone testing for use in transformers, and this alternative may be technically and economically feasible. However, for a range of toxicity and environmental parameters no relevant data was identified for this compound, and it is recommended to carry out additional studies before a final decision on manufacturing the liquid in Russia is made. For production of this fluid, raw materials are available, the production technology has been experimentally tested, and the DEF itself was tested in transformers. The estimated price of AZI-3X is approx. 3 $US/kg.

AZI-3X is an organic compound with one chlorine atom attached. Objections by international experts were raised with regard to the feasibility of use and production of AZI-3X because of the possible formation of dioxins and lack of data on environmental fate properties. In the opinion of the Russian experts, the objections connected with the AZI-3X were exaggerated as it is a low-chlorinated compound. The Russian legislation does not prevent AZI-3X use in industry.

The possibility of alternative DEF production using a license purchased abroad was also evaluated. According to the estimated preliminary costs, this will be twice as expensive as the production of DEFs based on Russian technology. For purchasing DEFs abroad, the price should be lower than 4 $US/kg

<u>Utilization/modernization of pilot equipment for DEF production</u>

An investigation of Russian producers of capacitors and transformers filled with dielectric fluids has been done. The investigation was carried out by 'on-site' inspection of some operating facilities and by replies from capacitor and transformer manufacturers. The enterprises have access to raw materials of reliable quality, sufficient energy sources and have skilled personnel.

The Serpukhov capacitor plant '*KVAR*' has already used alternative DEF (phenylxylylethane) purchased in Japan. Certain transformer plants '*Uralelectrotyazhmash*' (Ekaterinburg) and '*Transformator*' (Tolyatti) have begun pilot production of transformers with alternative DEF '*Midel*' purchased abroad.

Existing Russian technologies for filling capacitors and transformers with DEFs may therefore be applied. According to Russian experts they are environmentally sound.

Two methods of filling capacitors with DEF under vacuum were compared. One method is to fill capacitors in one joint container. The other is to fill each capacitor individually. The last method was recommended, as it is considered safer for personnel and has practically no waste.

Organochlorine waste destruction technology must be applied for AZI-3X waste destruction. Waste treatment for capacitors and transformers filled with alternative DEFs are less expensive than PCB waste destruction.

Conclusions and recommendations

Alternative dielectric fluids for transformers and capacitors can be based on Russian compounds and Russian production technology. This may keep the costs for DEFs in a market acceptable range. The substances DON and AZI-3 are recommended for capacitors. It is recommended that additional test is carried out for the transformer fluid AZI-3X before a final decision on production is made.

8. Input to a «Least Cost» Overall Russian PCB Phase-out Strategy

A cost-oriented input, based on the findings of the PCB phase-out project, is provided to the Russian process for preparing a National Implementation Plan (NIP) on PCBs. A computerised cost model has been developed that allows strategic decisions to be tested for their cost. As examples, three phase-out scenarios addressing Convention requirements have been cost evaluated: a baseline scenario, a late compliance scenario, and an advanced compliance scenario.

Background

The Russian Federation signed the Stockholm Convention on POPs in June 2002 and the country will become a party to the Convention once it also ratifies the Convention. As a party, the Russian Federation is required to eliminate the use of PCBs in equipment by 2025, and environmentally sound management of PCB wastes is to be achieved as soon as possible but not later than 2028. The Stockholm Convention requires that a party endeavours to develop and implement a plan for meeting its obligations under the Convention. The plan is to be transmitted to the Conference of the Parties within two years of the date on which the Convention enters into force. Such plans may be referred to as a National Implementation Plan (NIP), including a plan element for PCBs. The Russian government may pursue alternative strategies for eliminating the use of PCBs in equipment and may also consider eliminating PCB use and achieving environmentally sound management (ESM) of wastes earlier than the deadlines stipulated in the Stockholm Convention. The different strategies may entail different costs, which may be estimated in advance.

Evaulation of phase-out strategies

The main goal has been to provide a cost-oriented input to the process of preparing a Russian NIP on PCBs, as well as to present proposals for regulatory, institutional and awareness oriented measures that would support elimination of PCBs and environmentally sound management of PCBs and PCB-containing waste. This has included the following:

- A synthesis of the PCB problems faced by Russia;
- An overview of recommendations and conclusions of other activities of Phase 2 of the Project;
- Descriptions of alternative, overall scenarios for elimination of PCBs use and environmentally sound management of PCB waste;
- Cost assessments of the above scenarios for PCBs elimination and PCB waste management;
- Proposals for regulatory, institutional and awareness-oriented measures that would support PCBs elimination and environmentally sound PCB waste management.

<u>Scenarios</u>

The Russian government may choose to pursue alternative strategies for eliminating the use of PCBs in equipment (e.g. transformers, capacitors or other receptacles containing liquid stocks) by 2025 and achieving environmentally sound management (ESM) of PCB wastes as soon as possible and not later than 2028. In this report three scenarios have been considered. They all rest on the assumption that in 2002 there were approximately 10,000 transformers in operation containing around 19,000 tonnes of PCB as well as 600,000 capacitors containing about 12,000 tonnes of PCB. The three scenarios are as follows:

- A baseline scenario. This scenario describes a situation where nothing is done but leaving equipment to be taken out of service at the end of its expected serviceable life, i.e. a 'business-as-usual' or 'no convention' scenario. It is assumed that destruction of PCBs is limited to 150 tonnes PCBs per year. By 2025 there will be an estimated 3,400 capacitors and 520 transformers still left in operation.

- A late compliance scenario[1]. In this scenario elimination of all PCBs from use in equipment is accomplished by 2025 and environmentally sound management of PCB wastes is achieved by 2028. This is achieved by premature replacement of transformers and capacitors (three sub-scenarios have been considered).

- An advanced compliance scenario. In this scenario elimination of all PCBs from use in equipment is attained by 2020 and environmentally sound management of PCB wastes is achieved by 2023. This is achieved by faster premature replacement of transformers and capacitors that in the preceding scenario. As for the late compliance scenario above, three sub-scenarios have been considered.

Computer model approach

A computerised cost model has been developed by COWI, Denmark, in support of the least cost strategy work. The model creates new elimination scenarios on top of a baseline scenario, which has been built into the model. In the baseline scenario all transformers and capacitors are taken out of service only when the general state of deterioration of the units makes further repair works either technically impossible or economically unjustified. A number of assumptions regarding life pattern, service termination and included cost components are taken. The cost model covers the period 2002-2050. The economic costs are expressed in constant 2002-prices, and exclude taxes, duties, etc.

The difference between the costs of the baseline scenario and the 'late compliance' or 'advanced compliance' scenario indicates the cost difference between 'doing nothing' and meeting the obligations of the Stockholm Convention. The cost estimates do not take into account that some of the costs will be covered by the financial mechanism of the Stockholm Convention.

Cost estimates

- [1] The late and advanced scenario assumes 5 stationary and 2 mobile disposal facilities for liquid PCB destruction and 1 disposal facility which can treat PCB solid waste.

- The costs of the Baseline Scenario, in which no premature replacement of transformers and capacitors takes place, is estimated at around USD 20 million.

- The costs of the Late Compliance Scenario, in which the use of PCB in transformers and capacitors is eliminated in 2025, and all PCB disposed of by 2028, is estimated at USD 22-73 million. The cost depends on the extent to which disposal of PCB wastes by destruction or by environmental sound management takes place.

- The costs of the Advanced Compliance Scenario, in which the use of PCB in transformers and capacitors is eliminated in 2020 and all PCB disposed of by 2023, are estimated at USD 36-87 million depending on the extent to which destruction takes place.

Cost elements included group in six basic overall cost categories:

- Costs for identification and labelling of transformers and capacitors

- Costs for premature replacement of transformers and capacitors (a unit represents a certain value to the owner - a scrap value, which is in principal lost when the unit is taken out of service prematurely, i.e. before the unit reaches the end of its serviceable life)

- Costs for storage of transformers and capacitors

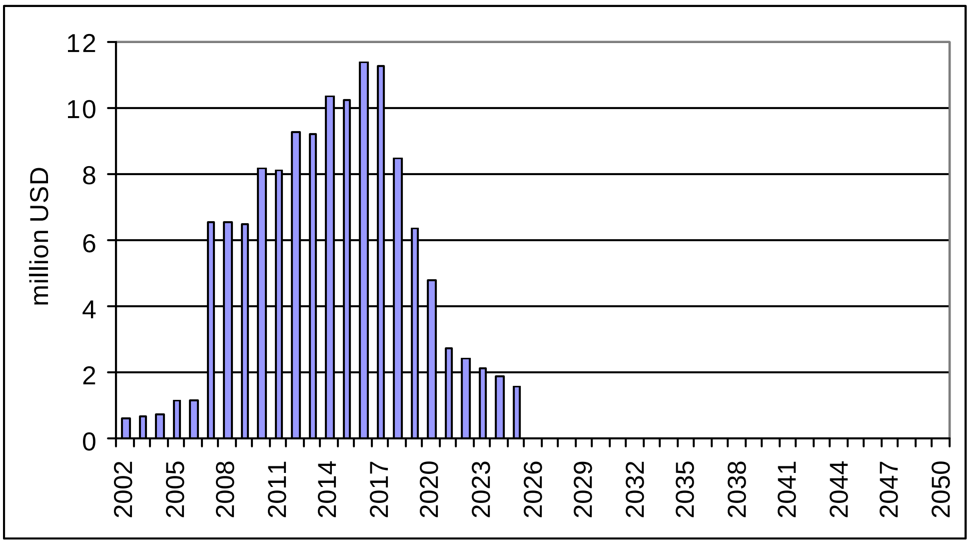
- Costs for transport of transformers and capacitors

- Costs for treatment (destruction or ESM) of PCB and PCB-contaminated transformers and capacitors

- Cleaning of emptied transformers

The cost estimates are particularly sensitive to assumptions regarding unit costs for destruction of PCBs, as destruction costs make up a major share of the total costs in most scenarios.

Figure 4. Example of Annual Cost Profile, Late Compliance Scenario (Full Destruction)



Incremental costs

The concept of incremental costs defines what Russia as a country would have to sacrifice measured in economic cost terms in order to meet its commitments under the Stockholm Convention to protect the global environment. If the cases where destruction of 50% of all PCB wastes are chosen as the points of comparison, the incremental costs of the Late Compliance Scenarios may be estimated at about USD 30 million and of the Advanced Compliance Scenario at USD 50 million.

Conclusions and recommendations

A National Implementation Plan on PCBs may include some of the following activities:

- Development of a more detailed PCBs inventory;
- Drafting of new legislation/regulation;
- Strengthening of compliance and enforcement of existing regulation;
- Identification of specific eco-systems or populations at risk;
- Evaluation and introduction of PCBs alternatives;
- Implementation of awareness-raising and education activities and establishment of mechanisms to involve local populations in the implementation of the plans;
- Training and capacity building activities on various issues such as sound management practices of PCBs, PCBs alternatives, EIA and risk, effective legislation and regulation, etc;
- Technology transfer activities;
- Development of a national waste management strategy;
- Monitoring, site auditing and other activities to ensure compliance and enforcement of regulations;
- Development of safe disposal plans for existing stocks of PCBs;
- Information dissemination through the mass media and at different conferences, workshops and seminars, establishment of specialized web-site.

Phase 2 Conclusions and Recommendations

The basic results of the analysis of the interconnected activities of Phase 2 of the project consist of practical recommendations. The main results of the work carried out are recommendations and substantiation for the following installations construction:

- destruction of liquid PCB;
- cleaning of PCB from electrical equipment and containers;
- destruction of capacitors, parts of transformers and containers with PCB;
- production of alternative DEFs for capacitors;
- production of alternative DEFs for transformers;
- application of alternative DEFs in the basic sector of PCB use;
- decontamination of PCB-polluted sites.

The basic characteristics of the proposed installations and the recommendation for their location are submitted in the table below (Annex 3).

In addition, evaluation has carried out of regulatory documents and requirements concerning use of PCB and PCB-containing materials in the Russian Federation, technological systems for gathering and storage of PCB. A general strategy for PCB elimination with 'least expenses' has also been prepared. As a result, the following pilot demonstration projects are recommended for implementation in Phase 3 of the Project:

Project name	Objective	Activities	Approx. cost & duration	Funding
Transformers cleaning	100 transformers with about 250 tons PCB	Emptying, cleaning and disposal of transformers in regions affecting the Arctic	0.9 million USD, 2Y	NEFCO full funding
Destruction of liquid PCB	250 tonnes of PCB	Collection, draining and destruction of PCB fluids from transformers in regions affecting the Arctic	1-2 million USD, 3Y	NEFCO full funding
Destruction of capacitors	12,000 capacitors with 200 tonnes PCB	Collection and destruction of capacitors in regions affecting the Arctic	1-1.5 million USD, 3Y	Donor countries + IFIs
Collection and storage	Up to 500 tonnes PCB (Oblast scale)	Development of means of identification, labelling, collection and storage of PCB in waste and equipment on an	100,000-200,000 USD 1Y	Donor countries + Russian in-kind

		oblast scale for the region affecting the Arctic		
Remediation of priority contaminated industrial site	Measurable risk reduction and optimal technology demonstration	Soil remediation and decontamination of structures in a pilot highly contaminated site	0.5-1.5 million USD, 3Y	Donor countries + IFIs

The first two pilot projects (PCB destruction and transformer cleaning) are proposed to be implemented in 2003-2005 under the 'Fast Tra?k Project' being executed in the northwestern Russia and funded by NEF?O. The three other pilot projects are suggested for introduced within Phase 3 of this ACAP Project.

Being aware of the importance of selection and production of dielectric fluid alternatives to PCB for sustainable development of the Russian economy under PCB use elimination, the Steering Group, however, considers these additional activities to be primarily a matter of economic rather than environmental concern. In this context, these activities are not recommended for further development under Phase 3 of the project. At the same time, the Steering Group hopes that the outcomes of the corresponding activities under Phase 2 will be useful for the Russian Federation in the development and implementation of the National Implementation Plan on PCB.

At this time it is intended that future industrial installations for destruction of PCB-containing capacitors and PCB drained from transformers may also be used for destruction of stocks of obsolete pesticides, which is the objective of another ACAP project. Such an approach should be taken into consideration during implementation of the pilot projects, as this will allow destruction of a range of hazardous wastes in a flexible and cost effective manner.

The results obtained and the methodological approach used in Phases 1 and 2 of this Project may also be relevant for solving PCB and other POPs related problems in CIS countries other than Russia, and in other countries where these problems exist.

Implementation of Phase 3 is envisaged to consist of several steps:

1st step:

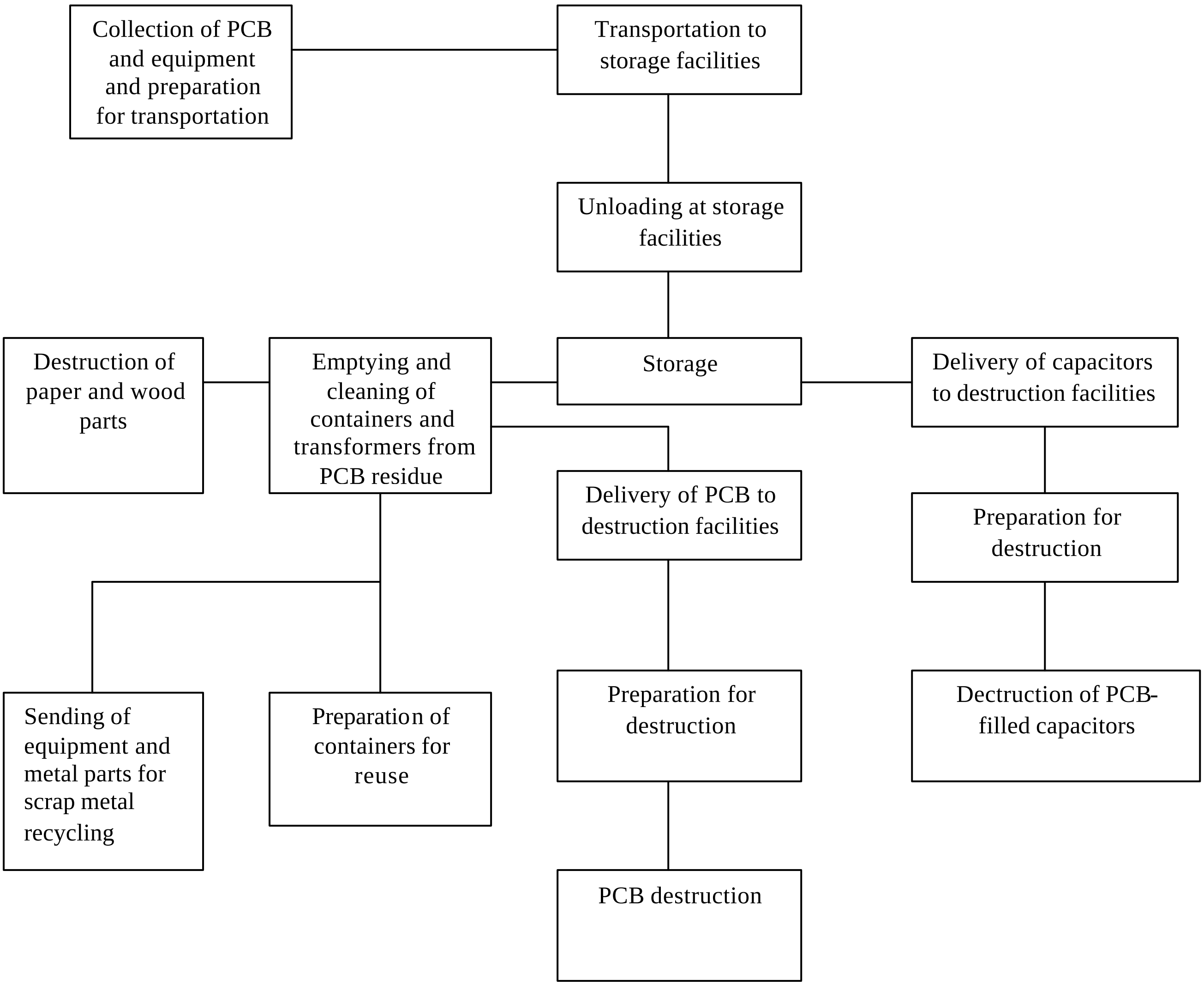
- Preparation of terms of Reference;
- Preparation of Feasibility Study;
- Preparation of Business Plan

2nd step: preparation of technical, including design, documentation;

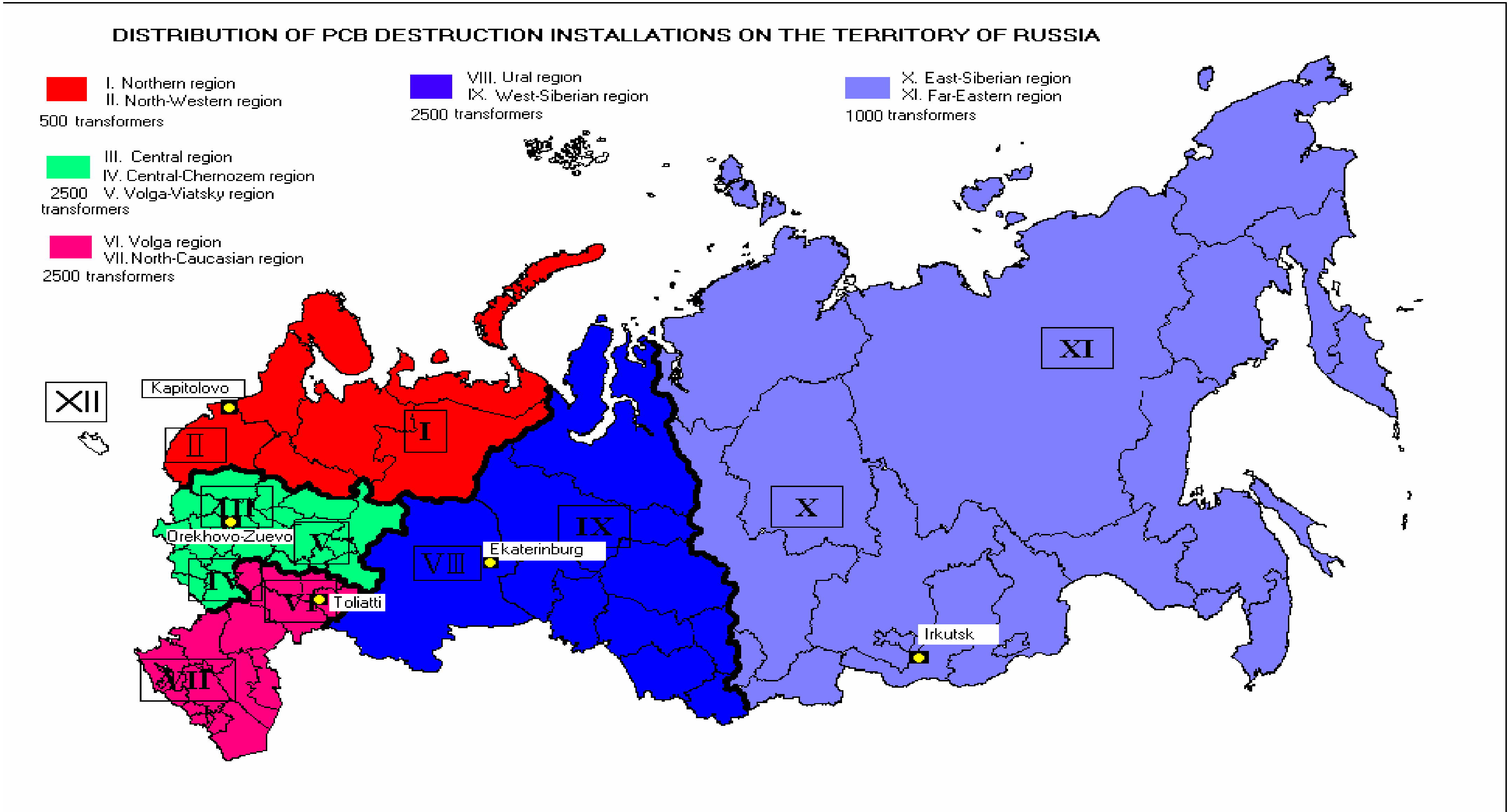
3rd step: construction and commissioning.

Annex 1

General Steps of Handling PCB and PCB-containing Equipment during Collection, Storage and Disposal



Annex 2


DISTRIBUTION OF PCB DESTRUCTION INSTALLATIONS ON THE TERRITORY OF RUSSIA
I. Northern region
II. North-Western region
500 transformers
VIII. Ural region
IX. West-Siberian region
2500 transformers
X. East-Siberian region
XI. Far-Eastern region
1000 transformers
III. Central region
IV. Central-Chernozem region
2500 V. Volga-Viatsky region
transformers
VI. Volga region
VII. North-Caucasian region
2500 transformers
XII
Kapitolovo
II
I
III
Orekhovo-Zuevo
V
IV
VI
Toliatti
VII
VIII
Ekaterinburg
IX
X
XI
Irkutsk

Annex 3

The basic characteristics of installations for transformers cleaning, destruction of capacitors and liquid PCB, the alternative DEF production for transformers and capacitors and recommendation for their location

Installation function	PCB destruction			Transformers cleaning			Capacitors destruction	Production of alternative DEFs	
								for capacitors	for transformers
Installation characteristic	Stationary		Mobile	Stationary		Mobile	Stationary	Stationary	
Processing or production method	Cyclone kiln	Rocket engine	Version of cyclone kiln	Methylene chloride vapours	Methylene chloride vapours	Methylene chloride vapours	Smelting and cyclone kilns or alternative to be selected	Phenylxylyl-ethane by condensation of o-xylol with styrene (AZI-3)	Monochloro-phenylxylyl-ethane by chlorination of phenylxylyl-ethane (AZI-3X)
Annual capacity	1000 tons of PCB	400 tons of PCB	80 tons of PCB	200 pcs.	100 pcs.	40 pcs.	4000 tons of capacitors	400 tons of AZI-3	600 tons of AZI-3X
Amount	5	1	2	5	1	2	1	1 + 1	
Location (Region, City)	N-West, Center, Volga region, Urals, East Siberia.	Norilsk	Central Urals	N-West, Center, Volga region, Urals, East Siberia.	Norilsk	Central Urals	Center	Volgograd, Sterlitamak, Yarovoye } one of the variants	
One installation construction cost, thousand USD	653	350	190	750	500	500	1600	Joint manufacture 7100	
Processing or production cost, thousand USD	320 per ton	1070 per ton	300 per ton	1180 per ton	1300 per ton	1560 per ton	1000 per ton	1500 per ton	3100 per ton