Limited Liability Company "Scientific Production Association
"CENTRE OF MUNICIPAL IMPROVEMENTS AND WASTE MANAGEMENT"

Final Report

Pilot Project on

ELABORATION OF TECHNOLOGICAL AND LOGISTIC OPTIONS FOR IMPLEMENTATION OF A SYSTEM FOR COLLECTION AND UTILIZATION OF PCB WASTES AND PCB-CONTAINING EQUIPMENT IN THE ARCTIC REGION OF THE RUSSIAN FEDERATION

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INTRODUCTION

Currently, the Russian Federation is one of the world's leading economies and consequently, environmental issues becoming the important ones in the life of the country.

In accordance with the objectives and actions to implement the state policy of the Russian Federation in the Arctic Region it is necessary to create a comprehensive system to protect the territory, population, facilities of the Arctic Region from the threats of natural and manmade characters.

In the area of environmental safety it is necessary to ensure the conservation of biological diversity of arctic flora and fauna, the natural environment, to carry out restoration of natural landscapes, disposal of toxic industrial waste, to ensure chemical safety in places of residence of the population.

All this is rather not an easy task, considering the patchy nature of industrial and economic activity, low population density, remoteness from the country's industrial centres, high resource intensity of works done.

From the perspective of the legislator it seems as if all the necessary actions have been taken: political will; developed programs, organized relevant working bodies. What should be the initial tool to identify the solution for these problems? The main information base for any further action at all levels of stakeholders institutions involved in the implementation of programs should become the State Waste Cadastre for the territory of the Russian Federation attributed to a circumpolar arctic zone. This Cadastre will render possible to assess waste volumes and composition, waste locations, identify the owners of waste, and most importantly formally legalize the presence of waste.

Carrying out this work will accustom the Arctic regions to the fact that they have wastes, which over the years passed have naturally or deliberately lost owners. Development of the Waste Cadastre will sooner or later lead to resolution of the waste issues, i.e. dispose or recover, by the respective regions, with or without a support from the state.

Development of the Waste Cadastre is fully consistent with the chartered objectives stated by SPA SMIWM (the development of normative documents).

Information obtained as a result of this work will be used in calculating the economic costs of environmental activities focus: purchase of equipment, collection and classification of waste, waste shipment to the locations of processing steps and much more.

None of the business plan could take place without the Waste Cadastre.

Anticipated waste in the Arctic Region of the Russian Federation are the residues of human activity. These are probably the remains of buildings, electric substations, boilers with heating system, containers, tanks, barrels with residues of fuel and lubricants and Sovols, as well as oils containing polychlorinated biphenyls (PCBs). PCB containing Sovols were used in transformers and other equipment for electric power substations, as well as in heating systems, as a good non-congealable coolant. PCB containing Sovols were produced in Russia up until 1993.

PCBs are classified as persistent organic pollutants (POP). POPs have the following properties: - extremely high toxicity, the ability to accumulate in the tissues of living organisms, extremely

slow decomposition under the influence of natural factors. Thus, within the waste range present in the region PCBs constitute a real danger.

According to the report of the Arctic Monitoring and Assessment Program (AMAP) on inventory of PCBs no less than 14,000 tonnes of PCBs are remained in the Russian Federation. Volumes of PCBs in PCB containing equipment, currently being in use and stored at the facilities of chemical and petrochemical industry, ferrous and nonferrous metallurgy, machinery, timber processing complex located within three neighbouring areas, namely Central, Northern and North-Western Federal Districts, exceed 4,000 tonnes. Probably these figures are not very precise, and most likely PCBs volumes are underestimated, so one shall focus only on their order - tens of thousands of tonnes. This once again underlines the importance of compiling the waste cadastre. It will provide a more realistic picture of the volumes and location of such hazardous substances as PCBs.

Setting up specific requirements to the system of collection, transport, storage and destruction of PCBs and PCB-containing equipment constitutes an extremely important component for the deactivation of PCB. The elaboration of such regulations is one of activity subjects of CMIWM as well. Currently no special environmental requirements to collection, transport and destruction of PCB and PCB-containing equipment exist in the Russian Federation. Wastes of materials and goods containing PCBs or contaminated with PCBs with concentrations over 50 mg/kg are attributed to the first category of hazard (abnormally hazardous waste)[1]. Federal Waste Classifier (FWC) attributes the transformer oils, containing polychlorinated biphenyls and terphinyls to the first category of hazard to the natural environment – abnormally hazardous waste. Obsolete PCB-containing equipment and PCBs management by the owner, including their storage and utilization, is to be provided in compliance with legal requirements[2], which envisages the responsibility for non-performance or improper execution. Such non-compliance with Russian Federation legal requirements in the area of waste management demonstrated by public servants and individuals leads to disciplinary, administrative, criminal or civil liability under Russian legislation.

Direct processing of such toxic chemicals such as PCBs is carried out using high-temperature processes. Confident destruction of polychlorinated biphenyls will be held at a temperature not below 1,100 °C and residence time in the reaction zone of at least 1-2 seconds. This will not provide for generation of secondary dioxins (PCB itself from a number of dioxins).

World practice of thermal decontamination uses for such compounds the following variants of the process:

- Fire reactors.
- Firing a plasma reactor with post-combustion flue gas.
- Fire reactors with additional plasma heating of the reaction mixture.
- Plasma-arc reactor.

According to some reports (LTD “Ekotekhprom”two installations for the disposal of PCBs have been created in the Russian Federation. Plasma-chemical plant in Sterlitamak (Bashkorkostan).

[1] Interstate StandardGOST 30774-2001 «Efficient Use of Resources. Hazardous Waste Passport. General Requirements», enforced on 01.07.2002.

[2] Federal Law «On Waste of Production and Consumption» No. 89-ФЗ of 24.06.1998, as amended by No. 309-ФЗ of 30.12.2008.

The second plant - mobile unit of the thermal destruction of liquid and suspension of wastes containing PCBs and pesticides. A setup is installed in TsNIIMASH (Korolev, Moscow region). This setup destroyed 130 tonnes of PCBs OAO Severstal (Cherepovets, Vologda oblast). The use of plants produced in St. Petersburg ZAO "Tourmaline." is possible. This installation for thermal disposal of waste is the incinerator. They have positioned the balance of PCBs in ash at the level of 2.2 mg/.kg, which corresponds to the hazard category 4 (permitted disposal at municipal waste landfills).

Installation with the application of low-temperature plasma torch to carry out such processes exists in LTD NPP "Hyperon" (Dmitrov, Moscow region).

In Volgograd, at PO Khimprom the facility of the U.S. origin based on plasma decomposition of PCBs was to be launched (information of 2004-2005).

The proposed scheme for preparation of “arctic” waste for thermal neutralization is as follows:

1. Selection of a thermal decontamination installation type.
2. Creation of an installation for thermal neutralization composed of two furnaces with capacity of at least 500 kg/hour (required working capacity to specified subject to waste PCB types to be disposed). Two furnaces are needed because the life of furnace refractory is usually not more than 6,000 hours (when one furnace is being repaired, the second one - operates). Thermal decontamination installation should be placed in an industrial area adjacent to one of the towns by selecting the optimal distance for transporting waste.
3. PCBs collection in special containers at their storage location and delivery to the thermal decontamination installation site.

There is one very important issue related to PCB waste collection, this is degasification of containers after draining of PCBs (drums, containers, tanks, etc.). It should be dealt with in parallel with the main issues, as the collected degasification fluid must also be neutralized by heat.

There is little sense to consider scrap metal collection, pressing and other operations in this Report.

To get a complete environmental picture while undertaking the inventory it is necessary to take soil samples for PCBs to make a decision on the need for soil remediation, and in cases when the source of PCBs is located in the vicinity of water bodies, to take the water samples for PCB content as well.

The main difficulty in this work is to obtain information on PCB-containing wastes and the choice of location for building a thermal decontamination station. Hence the motivation elements to deal with these issues are to be foreseen.

SOLVING THE PROBLEM OF PCBS AND PCB-CONTAINING EQUIPMENT IN THE ARCTIC REGION OF THE RUSSIAN FEDERATION

Polychlorinated biphenyls (PCBs) are among the POPs, and can be sources of more toxic polychlorodibenzodioxins (PCDDs) and polihlordibenzofuranov (PCDF). Persistent organic pollutants (POPs) are a special group of organic substances which are recognized by the international community as posing significant risk to human health and the environment. General characteristics of POPs - an extremely high toxicity, the ability to accumulate in the tissues of living organisms, long persist in the environment, and very slowly disintegrate under the influence of natural factors. The danger of PCBs as well as other POPs is that they are transported over long distances with the water streams and air currents, moving to regions far distant from the original source of discharge.

Currently, PCBs are found almost everywhere, even in the Polar Regions, where they have never been produced or used. Atmospheric transport to the Arctic from pollution sources in low latitudes may take from several days to several weeks time. In addition to atmospheric air flows also river and ocean currents deliver contaminants to the Arctic and distribute them within its territory. In Russia, the Yenisey, Ob' and other northern rivers are the source of delivery of pollutants in the Arctic region, especially during floods. Some of the largest industrial centres in Russia are located on the banks of rivers flowing into the Arctic seas. In the problem of pollution of the northern regions of PCBs, in addition to transportation from external sources, are of great importance industrial activities in the Arctic regions, where there are large sources of pollution (Norilsk Mining and Metallurgical Complex, Western Siberian oil and gas companies, etc.). Pollution of the Arctic with POPs among other reasons is due to specific climatic conditions and inherent arctic regions. Specific climatic conditions: low temperature and absence of light in winter provides for increase the PCBs and other POPs natural decomposition period and their intense accumulation in the environment.

Background concentrations of PCBs are detected in all objects of the Arctic environment - soil, sediment, ambient air. It should be noted that the highest background levels of PCBs in the air for a global Arctic were observed in 2008 in the Chukotka region on the weather station Valkaray. Distribution of PCB congeners in the air in Valkarkae practically corresponded to the Sovol - technical PCB mixture produced in the USSR.

To date, it is proved that PCBs have a pronounced embryotoxic and potential carcinogenic effects. However, the most dangerous of the effects is mutagenic action. The danger of PCBs is their ability to transfer up the food chain and accumulate in the blood and fat-containing organs of fish and animals, even at low concentrations of PCBs in environmental components. High proportion of fat in the structure of traditional food of indigenous peoples of the North promotes excessive transport of PCBs and other POPs in the human body. Specific risk of adverse effects occurs during pregnancy because of PCBs, like other POPs, are easily transferred through the placental barrier, entering the body in utero.

Quantitative assessment of waste PCBs and PCB-containing equipment in the Arctic Region of the Russian Federation

Polychlorinated biphenyls (PCBs) were produced in industry, mainly for use as insulators in transformers and capacitors, as well as for other types of applications: paints, varnishes, coatings, liquid coolants, etc. The production of PCBs ceased in Russia in 1990-1993, but they are still in use in electrical equipment under operation.

PCBs belong to the most stable known chemicals. Low dielectric constant and high boiling point make them ideal for use as dielectric fluid in electrical transformers and electric capacitors.

In addition to electrical transformers and capacitors, PCBs have many other applications: paints, waxes, synthetic resins, epoxy paints and paints for underwater parts of ships, coating, cutting emulsions, liquid coolants, hydraulic fluids, etc.

Types of industrial PCBs in the Russian Federation

In the former USSR K.A.Andrianov received PCB by the method of chlorination of biphenyl in 1934. The same method was applied in for industrial production. In the former USSR and later in Russia trichlorobiphenyl (TCB), pentachlorbiphenyl and its mix with tetrachlorbiphenyl, allocated from products of process of chlorination of biphenyl, were used in industry. PCB-production can be classified by the following types:

- Sovol plastizing and Sovol electrically insulating;
- Sovtol-10 (Sovol mixture with 1,2,4-trichlorobenzene at a ratio of 9:1);
- Trichlorobiphenyl (TCB).

Sovol plasticizing was used mainly by paint companies as an additive to improve the properties of paints, as well as the manufacture of various lubricants. The volume released until 1993 paint and lubricant products containing PCBs as additives, fully implemented and exhausted.

Sovol plasticizing and *Sovol electrically insulating* were slightly different in specific gravity, viscosity, solidification temperature, etc. There were additional demands on insulating Sovol on the breakdown voltage, dielectric loss tangent and dielectric constant.

Sovtol-10 was used as dielectric fluid for for transformers of the following types: TNZP to feed thyristor converters with –power of 400-1,600 kW to 10 kW; TNZ – three phase power transformers with filled with non-flammable liquid dielectric fluid and transformer power of 350-3,500 kW and 10 kW. Sovtol 10 is a mixture of Sovol with 10% 1,2,4-trichlorobenzene. Sometimes Sovtol-10 incorrectly referred to as "transformer oil", by analogy with mineral transformer oils, which can lead to incorrect assessment of the contents of the transformer.

Trichlorobiphenyl (TCB) was used as an insulating fluid in power capacitors of COP brand.

Manufacturers of PCBs in the Russian Federation

Manufacturers of PCBs in the USSR and then in Russia were "Plexiglas" Production Amalgamation (Dzerzhinsk, Nizhny Novgorod region) and "Orgsyntes" Production Amalgamation (Novomoskovsk, Tula Region). These enterprises produced Sovol, Sovtol. Trichlorobiphenyl was made only in Dzerzhinsk at "Plexiglas" enterprise.

The production of Sovol and Sovtol at "Plexiglas" was launched in 1939, trihlorbifenila - in 1968. The production of Sovtol was closed in 1987, Trichlorobiphenyl - in 1990, Sovol - in 1990.

The production of Sovol and Sovtol was launched in 1972 in Novomoskovsk at “Orgsintez”, and the production of Sovol was stopped in 1993, and of Sovtol - in 1990.

Over the entire period of operation of these plants from 1939 to 1993 about 180 thousand tonnes of various types of PCBs were produced (see Table 1).

Table1. The production of PCB (thousand tonnes)by the enterprises «Plexiglas» *(Dzerzhinsk) and «Orgsintez» (Novomoscovsk).*

PCB	«Plexiglas»		«*Orgsintez*»		Total, tonnes
	Production, tonnes	period	Production, tonnes	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*

After 1990-1993 both plants have completely stopped the production of PCBs, no stockpiles of PCBs were left. According to the companies information as of now all the machinery have been removed and after washing PCBs out with solvents the metal scrap was disposed. PCB containing washing solvents were disposed by incineration.

PCB-containing electrical equipment in the Russian Federation

Electrical equipment as transformers and capacitors of various power may contain PCBs with the following composition:

- Transformers - Sovtol-10 (90% PCBs and 10% 1,2,4-trichlorobenzene);
- Capacitors - 100% of TCB.

Transformers

The main manufacturer of transformers with non-flammable filling Sovtol-10 was the Chirchik Transformer Plant (Chirchik, Tashkent, Uzbekistan). It should be noted that a small amount of PCB-containing transformers at the initial stage was manufactured at the plant trhe Uralkhimmash and the Moscow Electrozavod plant.

In all Russian major transformers filled with PCBs, inside there are wooden blocks, made of dry beech, and for fixing the windings in the horizontal plane and the support and consolidate them in a vertical plane. Besides them, the transformers have cardboard items with thickness from 3 mm to 20 mm for the separation (layers) of the windings in the tangential and vertical directions,

as well as 2-3 hard-lined rectangular frame, intended to isolate the core from the windings (cores - are actually rectangular parallelepipeds - there may be 2 or 3 plates forming the core around which wire coils are wound). The total weight of cardboard and wood is not more than 20% of the weight of the active part of the transformer. All the free inner space in large transformers is filled with PCB-containing fluid, which mass is on average about 33% by weight of the transformer.

Knowing the brands of PCB-containing transformers and capacitors helps to avoid mistakes when searching for PCB containing equipment.

Grades and Specifications of PCB-containing transformers are presented in Table 2.

Table 2: Brands and characteristics of transformers containing PCBs

No.	Grade of transformer	Total power, kVA	Sovtol content in the product, tonnes
1	ТНЗ-25/10	19750	0,16
2	ТНЗ-40/10	51760	0,205
3	ТНЗ-630/10	136080	1,0
4	ТНЗП-630/10	83160	1,0
5	ТНЗ-1000/10	1110000	1,676
6	ТНЗП-1000/10	312000	1,786
7	ТНЗПУ-1000/10	94000	2,21
8	ТНЗ-1600/10	2617600	2,765
9	ТНЗП-1600/10	248000	2,85
10	ТНЗ-2500/10	3430000	2,98

Capacitors

Trichlorobiphenyl (TCB) was used in the manufacture of capacitors.

Depending on the installed capacity for different brands of capacitors consumption of TCBs varied.

Capacitors, similarly to transformers, are hermetically sealed containers with the active core inside. The core of the capacitor is a coil of two long strips of aluminium foil separated by an insulating film. This film can be made of aluminium oxide (for a low-voltage "electrolytic" capacitors), polypropylene, paper and other insulating materials, and in the "big" capacitors, it is often soaked with PCBs. In all these capacitors all the free space is filled with trichlorobiphenyl. Any others components, including fasteners, are usually absent in capacitors.

Manufacture of power capacitors, using a TCB insulating fluid was carried out in Serpukhov (Russia), and in Ust-Kamenogorsk (Kazakhstan).

Grades and characteristics of the main types of capacitors, filled with TCBs are presented in Table 3.

Table 3: Grades and characteristics of the main types of capacitors, filled with TCBs.

Grade of capacitor	Dimensions, mm	Volume of PCBs (trichlorobi-phenyl), kg	Type of solid dielectric
КШС-6.3-50	380x120x650	23	Paper
КС2-1,05-60-У1	380x120x650	23	Paper
КС-2-10.5-75-2У3	380x120x650	23	Paper
КС-2-10,5-50-2У3;	380x120x650	23	Paper
КС-2-6,3-75-2У3	380x120x650	23	Paper
КСК-2-10,5-150-2У3	380x120x650	19	Paper -film
КСК-1-10,5-75-2У3	380x120x335	10	Paper -film
КС-2-0,38-36-2У3	380x120x650	23	Paper
КС1-0,66-20-1У1	380x120x350	12	Paper
КС1-0,66-20-1У3	380x120x350	12	Paper
КС1-0,66-40-1У1	380x120x350	12	Paper
КСА-0,66-20	380x120x350	12	Paper
КС2-1,05-60-2У1	380x120x650	23	Paper
КС2-0,38-50-У1	380x120x650	23	Paper
КС2-1,05-60-1У1	380x120x650	23	Paper
КС2-0,66-40-2У1	380x120x650	23	Paper
КСК2-10,5-125-1У1	380x120x650	19	Paper -film
КС2-6,3-75	380x120x650	23	Paper
КСА-0,66-20-У1	380x120x350	12	Paper

During the period of 1960-1980th capacitor designs have been repeatedly upgraded, so the Table 3 shows the average volumes of PCBs, embedded in these capacitors. The actual number of PCBs, bathed in the capacitor can vary from an average for 10-15%.

Under the technology of electricity production for the electric energy sector the power capacitors with PCB-containing fluids are used only in distribution networks.

Equipments with PCB-containing fluids are not used at power stations. In addition, transformers, with PCB-containing liquids were not used and are not used now for electricity generation. At electricity generating facilities only power transformers filled with mineral transformer oils as insulating fluids, not containing any components based on PCB, are used.

Production of PCB-containing equipment was ended in 1997.

Standards for PCBs and PCB-containing equipment

All PCBs and PCB-containing equipment were manufactured in the USSR and then in Russia under the following standards:

1. GOST 16555-75. Three-phase power transformers and oil-sealed with a non-flammable liquid dielectric.
2. GOST 1282-79. Capacitors for building up electrical power factor of alternating current of 50 Hz and 60 Hz frequency electric installations.
3. Industry Standard OST 6-01-43-79. Electrically insulating liquid materials. Trihlordifenyl. Specifications.
4. Industry Standard OST 6-01-17-74. Electrically insulating liquid materials. Sovtol-10.

Data on the number of PCBs and PCB-containing equipment in the Russian Federation

Inventory of PCBs and PCB-containing equipment was carried out in Russia in 2000. The inventory took place on the following basis:

Order of the State Environmental Committee of the Russian Federation of 23.02.1999 No. 76 'On undertaking the inventory of production facilities, equipment and materials containing or using polychlorinated biphenyls (PCB), as well as PCB-containing waste on the territory of the Russian Federation',

Order of the State Environmental Committee of the Russian Federation of13.04.1999 No. 165 On recommendations to undertake the inventory of production facilities, equipment and materials containing or using polychlorinated biphenyls (PCB), as well as PCB-containing waste on the territory of the Russian Federation'.

After that, within the period of 2000 – 2010 no PCB or PCB containing equipment took place at the federal level. According to the information available some regions as well as some sector ministries have initiated the elaboration of inventories. Thus in the fourth quarter of 2009 the Ministry of Energy of Russian Federation has undertaken the inventory for fuel and energy complex.[3]

Inventory of PCBs and PCB-containing equipment of 2000 was based on data obtained from industrial enterprises, as well as regional environmental authorities.

[3] The Consultant is not aware on publication of the results . Neither the Consultant had access to the fuel and energy complex inventory results.

Possible sites for finding PCBs in Russia are the sites with electrical equipment (capacitors, transformers) in the fuel and energy complex, ferrous and nonferrous metallurgy, chemical, petrochemical and timber industry, engineering and other industries.

The inventory process was based on unified methodological framework introduced by the above orders of the State Environmental Committee of Russia which have sent to all territorial branch offices.

The documents have provided the format in accordance with which the initial inventory underwent, based on which the experts estimated the completeness and reliability of the data and compiled summary information about the presence of PCBs and PCB-containing electrical equipment in the federal districts and subjects of the Russian Federation. As of now, the procedures and formats of standard documents with the experience of holding inventory and the requirements of this project can be significantly improved.

The inventory covered in total approximately 950 large and medium size enterprises in Russia that, according to expert estimates, represent about 80% of the total number of enterprises, which can have PCB or PCB-containing equipment.

The Ministry of Defence of the Russian Federation was not involved in the inventory of PCBs and PCB-containing equipment, as PCB oils and liquids are not present in the currently used military equipment.

Data on the presence of PCB-containing liquids in the Ministry of Railways in Russia (IPU) in the framework of this project was not collected as it was not possible to cover the entire network of railway companies, numbering to about 6,000. Considering that the railways is energy-intensive industry the possibility of PCB-containing equipment use by the railways cannot be excluded. According to expert estimates, the volume of PCB-containing liquids in the specified equipment, distributed through the territory of the Russian Federation, can reach up to 1,000 tonnes.

It should be noted that when the inventory was held that many businesses did not have information on the composition of oils used in electrical equipment, as the documents accompanying the equipment were not always provided information on the presence of PCBs.

In this regard, it is possible that as a result of inspections conducted by inter-district, district, city and regional committees on environmental protection at the enterprises of several regions of Russia not all PCBs and PCB-containing equipment have been identified.

Constituents of the Russian Federation on whose territory PCB-containing equipment is not in use (data of the constituents of the Russian Federation):

The Republic of Dagestan

The Republic of Komi,

The Republic of Ingushetia,

Arkhangelsk Rregion,

Komi-Perm Autonomous District

Koryak Autonomous District,

Taimyr Region,

Chukotka Autonomous District,

Evenki Autonomous District,

Pskov Region,

The Republic of Kalmykia,

North Ossetia (Alania)

Jewish Autonomous Region,

Amur Region,

Magadan Region,

Tomsk Oblast

Novgorod Region,

The Republic of Bashkortostan,

Ulyanovsk Region.

The inventory data on electrical equipment in Russia containing PCBs therein revealed about 7,500 transformers and 340,000 capacitors with total PCBs volume of 21,000 tonnes.

Taking into account the fact that not all businesses, as well as not all sectors have been covered by the inventory (e.g., railways), according to expert estimate the total possible volume of PCBs in the Russian Federation could amount 28,000-30,000 tonnes. Number of transformers in use – up to about 10,000 units, and the number of capacitors - 450,000 units.

Data on PCBs volumes and amounts of PCB-containing equipment in Arctic Region of the Russian Federation

With respect to 2000 inventory data presence of PCB-containing equipment (transformers and capacitors) was indentified in the following Arctic regions of Russia:

- Murmansk Region,
- Yamalo-Nenets Autonomous District,
- Krasnoyarskii Krai,
- Republic of Sakha (Yakutia).

The presence of PCBs and PCB-containing equipments was not identified:

- in the Arkhangelsk region,
- in the Komi Republic
- in the Nenets,
- in the Chukotka Autonomous District.

As has been found out by the inventory about 1,269 tonnes of PCBs are accumulated on to the territories attributable to the Arctic Regions of the Russian Federation (AR RF).

The number of PCB-containing transformers amounts 644 units (1,204 tonnes of PCBs). Depending on the grade.type of transformer volumes of PCB in a piece of equipment may be amounted from 160 kg to 3 tonnes.

Number of PCB-containing capacitors amounts 3,422 units (65 tonnes of PCBs).

For different types of capacitors PCB volumes in one unit of equipment varies from 12 to 23 kg.

Thus, the essential volumes of PCB is placed in power transformers, and constitutes of about 95% of the total PCBs volumes (1,204 tonnes of PCBs). Capacitors stand fore about 5% of the total PCBs volumes (65 tonnes of PCBs).

Almost all the stocks of PCBs are concentrated in the Krasnoyarskii Krai – 990 tonnes (78% of the total) and in the Yamal-Nenets Autonomous District - 235 tonnes (18.5%).

Krasnoyarskii Krai stands for the largest number of transformers (466 units) and capacitors (2,919 units) with PCB content.

In Murmansk Region the entire volume of PCBs (36 tonnes) is found only in PCB-containing transformers (13 units).

In the Republic of Sakha (Yakutia) PCBs (8 tonnes) are found only in PCB-containing capacitors.

To date, it is necessary to update the data to accurately determine the number of PCB-containing equipment in service and number of unexploited equipment in reserve, as well as decommissioned. The volume of PCBs drained from the establishment is demanded to be defined. To obtain current data on PCBs in ARRF it is necessary to perform additional inventory of PCB equipments and wastes containing PCBs.

Information about the presence of PCBs and PCB-containing equipments in the constituents of the Russian Federation attributed to the AR RF is consolidated in Table 4.

Table 4. Number of PCBs and PCB-containing equipments in the regions of AR RF

The subject (entity) of the Russian Federation	Quantity, units		Quantity of PCB, tonnes		
	Transfor-mers	Capacitors	Total	Including	
				In transformers	In capacitors
1	2	3	4	5	6
NORTH WEST FEDERAL DISTRICT					
Murmansk Regiont	13	-	36	36	-
Ural Federal District					
the Yamalo-Nenets Autonomous District	165	41	235	234	1
SIBERIAN FEDERAL DISTRICT					
Krasnoyarskii krai	466	2919	990	934	56
FAR EASTEN FEDERAL DISTRICT					
the Republic of Sakha (Yakutia)	-	462	8	-	8
Total in AR RF	644	3422	1269	1204	65

Main places of disposal of PCBs and PCB-containing equipments in Arctic Region of the Russian Federation

Table 5 presents information about the location of PCB-containing equipments in enterprises of different industries, located directly in AR RF. According to the inventory AR RF PCB-containing equipments are available in 27 companies in four Russian regions:

• Murmansk region,

• Yamal-Nenets autonomous district,

• Krasnoyarsk Territory;

• The Republic of Sakha (Yakutia).

Not established the presence of PCBs and PCB-containing equipment in the subjects:

• Arkhangelsk region,

• The Republic of Komi,

• Nenets Autonomous Area;

• Chukchi Autonomous District.

Practically all the quantity of PCBs in AR RF is concentrated in the Krasnoyarskii Krai territory and the Yamalo-Nenets Autonomous District.

In Krasnoyarskii Krai the largest volumes of PCBs are located (about 990 tonnes in total for the region) and PCB-containing equipment are concentrated in the following cities:

- Krasnoyarsk - about 396 tonnes of PCBs in 197 transformers and 821 capacitors; major shareholder - the Krasnoyarsk Pulp and Paper Combine (Krasnoyarsk Pulp and Paper Mill), which is about 290 tonnes of PCBs in 151 transformers and 242 capacitors. OAO Krasnoyarskenergo is the largest owner of PCBs - containing capacitors – 1,669 units:
- Norilsk - about 461 tonnes of PCBs in 223 transformers and 397 capacitors, a single owner - the Norilsk mining plants.

In 2010, LLC “Yenisei pulp and paper mill. operates on the basis of the Krasnoyarsk Pulp and Paper Mill " The owner of the plant - the company Russian Aluminum (Basic Element), which manages LLC Yenisei PPM, controlled by a subsidiary TIC Continental Management. The structure of the LLC “Yenisei Pulp and Paper Mill” are:

- pulp and semi-chemical
- paper mill,

containerboard mill, etc.As for the Yamalo-Nenets Autonomous District, the largest volumes of PCBs (in total the district stands for about 235 tonnes) and PCB-containing equipment are concentrated in the following cities:

- Novy Urengoy - about 118 tonnes of PCB in 67 transformers;

- Noyabrsk - about 114 tonnes of PCBs in the 75 transformers and 41 capacitor.

Some large enterprises have started the elimination of PCB-containing equipments under their own initiative and at their own expense.

For example, the Joint Stock Company Interregional Distribution Grid Company of Siberia (IDGC of Siberia, JSC)[4] has begun the decommissioning and utilization of equipments containing PCBs.

The structure of IDGC of Siberia includes the following branches:

• Altaienergo,

• Buriatenergo,

• Gorno-Altaisk electric grids

• Krasnoyarskenergo,

• Kuzbassenergo-REC

• Omskenergo,

• Khakassenergo,

• Chitaenergo.

• Tomsk Distributive Company

• Ulan-Ude Energo

• Tyvaenergo.

IDGC of Siberia will decommission by 2015 the equipment containing PCBs in the amount of 28 tonnes. To resolve the environmental problems the programme of implementation of environmental policies at IDGC of Siberia for 2008-2010 has been developed and approved.

In May 2009 IDGC of Siberia received a single license for the collection, use, disposal, transportation and disposal of hazardous waste.

Storage for waste of PCBs.

In the Krasnoyarskii Krai in 2006, the Joint Stock Company "Green City" put into operation the landfill "Serebristy". The "Serebristy" landfill is a hazardous waste disposal site for hazard categroy 1-2 waste. The landfill is located 3.1 km southwest from Kuznetsova, Berezovsky District of Krasnoyarskii Krai. The landfill "Serebristy" is the only company in the Krasnoyarsk region, which can ensure the environmental safety of placing the entire spectrum of highly toxic waste. Among the wastes that may be taken to the landfill, the main place is occupied by:

- Chemical wastes.

[4] MRSK Sibiri ("Interregional Distribution Grid Company of Siberia" Joint Stock Company; IDGC of Siberia, JSC). Address: 144a, Bograda street, Krasnoyarsk 660021, Russia / Telephone: 8 (391) 274-41-74/ Fax: 8 (391) 274-41-25. e-mail: mrsk@mrsk-sib.ru www.mrsk-sib.ru

- Expired and banned pesticides and agrochemicals.
- PCBs containing waste.
- Landfill capacity is 12,000m^3.

Table 5 Main locations of PCBs and PCB-containing electrical equipments n Arctic Region of the Russian Federation

№ п/п	Name of the company	Branch of industry	Address of enterprise	Quantity, pcs		Quantity PCB, tonnes		
				Transfor-mers	Capacitors	Total	Including	
							In transfor-mers	In capacitors
1	2	3	4	5	6	7	8	9
	NORTH WEST FEDERAL DISTRICT							
	Murmansk oblast							
1.	PUBLIC COOPERATION «Apatit»	Mining	184250, KIROVSK, Leningradskaya st. 1	13	-	35,92	35,92	-
	Total:			13	-	35,92	35,92	-
	URAL FEDERAL DISTRICT							
	Yamal-Nenets autonomous district (YNAD),							
1.	LTD «Urengoigasprom» («УГП»)	Oil and gas, mining	629300, Noviy Urengoi, Zheleznodorozhnaya st. 8	27	-	76,95	76,95	-

№ п/п	Name of the company	Branch of industry	Address of enterprise	Quantity, pcs		Quantity PCB, tonnes		
				Transfor-mers	Capacitors	Total	Including	
							In transfor-mers	In capacitors
1	2	3	4	5	6	7	8	9
2.	CBM Utilities	Housing communnal	628611, Nizhnevartovsk	21	-	2,688	2,688	-
3.	MZHKP "Limbe"	Electro-energy	626671, Noviy Urengoi, Limbyakha	18	-	9,6	9,6	-
4.	Department of Housing and Public Utilities, Energy, Transport and Communications Administration of the Noviy Urengoi	Housing-communal	629320, Noviy Urengoi	3	-	4,5	4,5	-
5.	ZAO “Urengoigidro-mechanization»	Construction	629320, Noviy Urengoi, Oktyabrskaya st., 22	7	-	10,5	10,5	-
6.	ZAO «Rospan International»	Oil and gas, mining a	629300, Noviy Urengoi, Geologorazvedchikov st., 16в	12	-	16,5	16,5	-

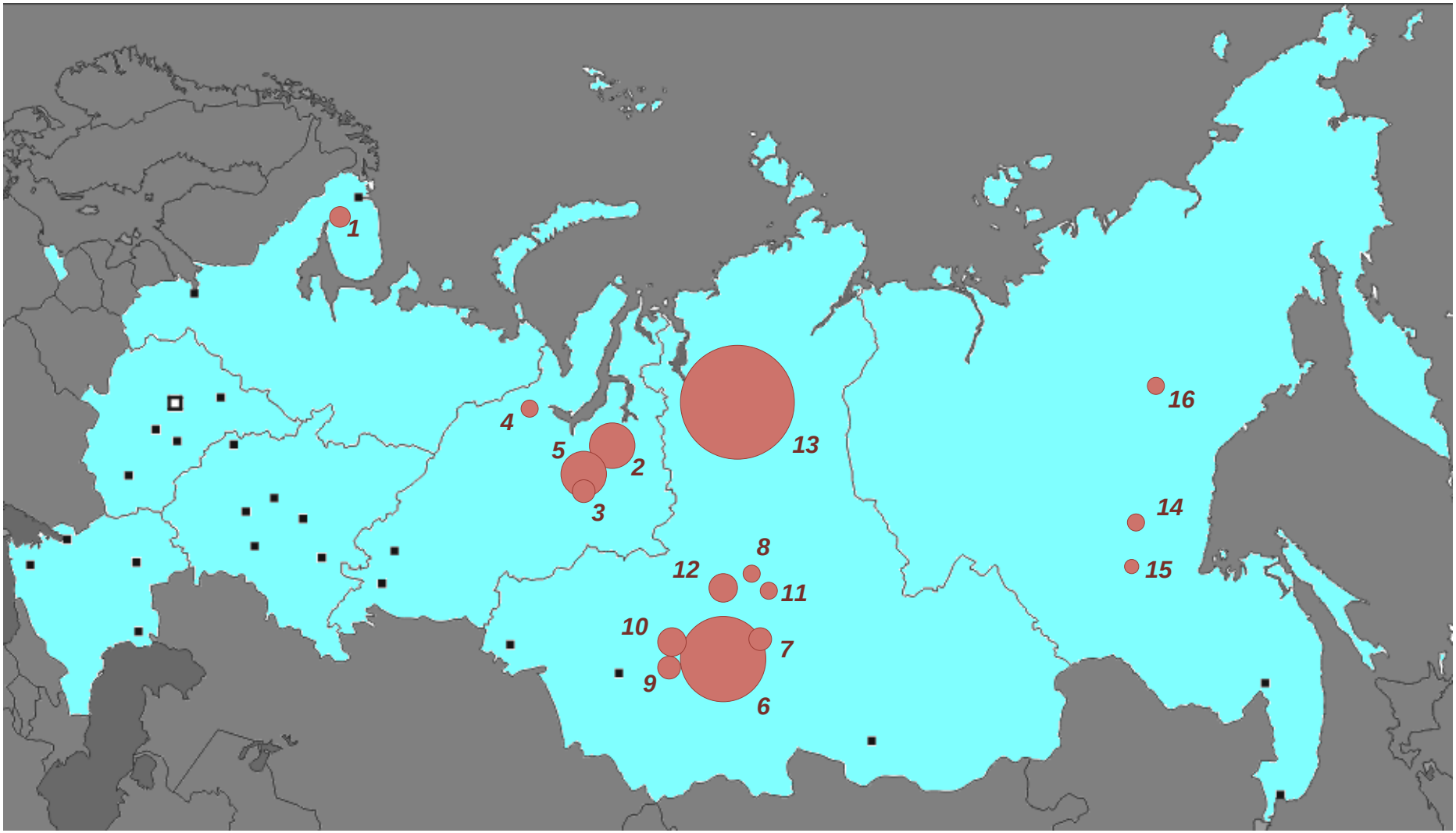
№ п/п	Name of the company	Branch of industry	Address of enterprise	Quantity, pcs		Quantity PCB, tonnes		
				Transfor-mers	Capacitors	Total	Including	
							In transfor-mers	In capacitors
1	2	3	4	5	6	7	8	9
7.	OAO Yamaltransstroy	Construction	629400, Labytnangi, Obskaya st., 39	2	-	0,911	0,911	-
8.	«Noyabrskgasmining»	Oil and gas, mining	629806, Noyabrsk, Respublika st., 20	18	21	27,72	27,3	0,42*
9.	The November manage pipelines (Numto)	Oilchemical	629800, Noyabrsk	57	20	85,5	85,1	0,4*
	Итого:			165	41	234,869	234,049	0,82
	SIBERIAN FEDERAL DISTRICT							
	Krasnoyarsk krai							
1.	OAO Krastsvetmet	Non-ferrous metallurgy	660027, Krasnoyarsk, transportnii proezd, 1	-	579	5,8	-	5,8

№ п/п	Name of the company	Branch of industry	Address of enterprise	Quantity, pcs		Quantity PCB, tonnes		
				Transfor-mers	Capacitors	Total	Including	
							In transfor-mers	In capacitors
1	2	3	4	5	6	7	8	9
2.	JSC "Krasnoyarsk Combine Plant"	Engineering	660049, Krasnoyarsk, Profsouzov, 3	8	-	32,02	32,02	-
3.	OAO “Emalposuda "	Metallurgical	663600, , Kansk, Volodarskogo St., 1	2	-	3,0	3,0	-
4.	OAO Kansk tannery "	Light	663606, Kansk, the 9th km. of Tasevskii tract	7	12	10,74	10,50	0,24*
5.	OAO ”Kansk plant materials "	Building materials industry	663614, Kansk, Panelnyi per.2	5	-	7,5	7,5	-
6.	Distant water supplying		663800, Ilanskii	3	9	4,68	4,5	0,18*
7.	OAO "East-Siberian Metal Plant"	Building materials industry	662200, Nazarovo, Lenin st., 5	13	2	20,0	19,96	0,04*
8.	OAO “Achinsk Alumina Plant”	Building materials industry	622150, Achinsk. South Promzona, Quarter IX	16	-	50,24	50,24	-

№ п/п	Name of the company	Branch of industry	Address of enterprise	Quantity, pcs		Quantity PCB, tonnes		
				Transfor-mers	Capacitors	Total	Including	
							In transfor-mers	In capacitors
1	2	3	4	5	6	7	8	9
9.	OAO Krasnoyarskenergo, Northern Electric Network	Electro-energy	663131, Lesosibirsk, Gorkii st., 126	-	1668	38,364	-	38,364
10	OAO «Krasnoyarskenergy», SVES	Electro-energy	663491, Kodinsk, Promzona, RPB	-	6	0,138	-	0,138
11.	OAO «Taimyrenergy», Ust-Khantai GES	Electro-energy	663253, Snezhnogorsk	-	4	0,048	-	0,048
12.	Metallurgical plant “Sibelectrostal "	Metallurgical	660050, Krasnoyarsk, Kutuzov st., 1	38	-	66,35	66,35	-
13.	Norilsk mining and metallurgical combine after A.P. Zavenyagin "	Non-ferrous metallurgy	663300, Norilsk, Gvardeiskaya sq., 2	223	397	460,95	454,12	6,83
14.	OAO Krasnoyarsk Pulp and Paper Mill	Pulp and paper and wood-chemical	660004, Krasnoyarsk, st. 26 Baku commissars, 8	151	242	290,48	286,32	4,16

№ п/п	Name of the company	Branch of industry	Address of enterprise	Quantity, pcs		Quantity PCB, tonnes		
				Transfor-mers	Capacitors	Total	Including	
							In transfor-mers	In capacitors
1	2	3	4	5	6	7	8	9
	Total:			466	2919	990,31	934,51	55,8
	FAR-EASTEN FEDERAL DISTRICT							
	The Republic of Sakha (Yakutia)							
1.	OAO Yakutskenergo, South-Yakutia Power Nets	Electro-energy	678900, Aldan, Lineinaya st, 4	-	242	3,072	-	3,072
2.	OAO Yakutskenergo, Neryungri HES (GRES)	Electro-energy	678900, Neryungri , stlt Serebryanyi Bor	-	24	0,552	-	0,552
3.	OAO Magadanenergo ", Western Power Nets	Electro-energy	678730, Oimyanskii district, stlt Ust-Nera, Kommunisticheskaya st.	-	196	4,508	-	4,508
	Total:			-	462	8,132	-	8,132

Schematic map of the location of PCBs and PCB-containing electrical equipment. (over 0.1 tonne)



1	Kirovsk, Murmansk Oblast	5	Noyabrsk, YNAD	9	Nazarovo, Krasnoyarsk Krai	13	Norilsk, Krasnoyarsk Krai
2	Noviy Urengoi, YNAD	6	Krasnoyarsk, Krasnoyarsk Krai	10	Achinsk, Krasnoyarsk Krai	14	Aldan, Sakha (Yakutia)
3	Nixhnevartovsk, YNAD	7	Kansk, Krasnoyarsk Krai	11	Kodinsk, Krasnoyarsk Krai	15	Neryungri, Sakha (Yakutia)
4	Labytnangi,YNAD	8	Ilanskii, Krasnoyarsk Krai	12	Lesosibirsk, Krasnoyarsk Krai	16	Ust-Nera, Sakha (Yakutia)

Size of the round icons spotting PCB and PCB-containing equipment locations reflect PCB accumulation volumes (Table 5 of the Report), not in scale.

Description of the managing system of the collection and disposal of PCBs and PCB-containing equipments in Arctic Region of the Russian Federation, including cleaning of electrical equipments and containers of PCB disposal of liquid PCBs, disposal of capacitors, transformers and parts of containers, cleaning of transformers

The system of collection and disposal management of PCBs and PCB-containing equipment in Arctic Region of the Russian Federation includes the following basic steps:

- Conducting a full inventory of PCBs and PCB-containing equipment in ARRF;
- Secure storage of stockpiles of PCBs and PCB-containing wastes (including unexploited equipment) in ARRF, ensuring safe transportation of PCB-containing waste and equipment;
- Disposal of PCBs and PCB-containing equipments in ARRF;
- Environmental monitoring at the sites of operation, storage, destruction of PCBs and PCB-containing equipments in ARRF.

Conducting a full detailed inventory and record inventory of PCBs and PCB-containing equipments and their locations

Carrying out a full detailed inventory and record inventory of PCBs and PCB-containing equipments and their locations is a priority of solving the problem, since preliminary inventory was conducted in 2000

PCBs - containing liquids to date exist as:

- Liquids stored in closed containers;
- Liquid waste, fusion of the transformers and capacitors;
- Dielectric fluids in transformers and capacitors;
- Residues in containers, transformers and capacitors and their components after discharge of PCB containing liquid.

For a full inventory of PCBs and PCB-containing equipments in the regions of ARRF needed:

- Organizational support for a full inventory of PCB-containing equipments;
- Organization of labelling of PCB-containing equipment, identifying equipment that is in disrepair and requiring urgent disposal.

The result of the inventory should be the registration of PCB-containing equipment, supplies, and waste storage sites (including landfills), PCBs, and the identification of subject waste with PCB concentrations higher than 50 mg/kg.

Register of PCB-containing equipments should be updated annually and contain information about the presence of:

- equipment in service (capacitors, transformers);
- equipment decommissioned (capacitors, transformers);
- equipment located in the reserve (capacitors, transformers).

According to the results of the inventory should be identified priority sites for the phased reduction of PCBs.

Based on the results of the inventory should be a detailed action plan on elimination of PCBs and PCB-containing equipments, which must first be provided with the following:

- Providing environmentally safe operation of PCB-containing equipments;
- Decommissioning and dismantling of being in poor condition of electrical equipments containing PCBs; ensure its environmentally safe collection and storage;
- Extracting and packaging in sealed containers of contaminated soils in the field of PCB leakage, ensuring their environmentally safe storage;
- Removal of the deposit of decommissioned equipments, materials and wastes containing PCBs at specialized sites;
- Monitoring of environmental components on the objects of exploitation of PCB-containing equipments, PCB storage sites and facilities for their destruction.

Ensuring the security of stockpiles of PCBs and PCB-containing wastes in ARRF

Transformers and capacitors have long life (25-40 years), so most of PCB-containing equipments in Russia are still in operation.

Environmental pollution of PCBs may in the operation and dismantling of PCB-containing equipments in the event of a spill of dielectric fluid and in emergency situations. Electrical equipments (transformers, capacitors) containing PCBs are a potential source of man-made emergencies.

Lately some of the equipments have been decommissioned. As shown by data obtained during the execution of the provisional inventory, most companies send defective transformers and capacitors, as well as the fusion of PCBs deposited in specially designated areas on the premises.

Among the industrial enterprises of the Russian Federation, most companies have fuel and energy complex, in the balance of which there are PCB containing equipments, which have an opportunity to significantly reduce the use of such equipments and stop using the equipments before 2025

Deterrent to a substantial reduction in the use of PCB-containing equipments is:

- lack of specialized facilities for transportation of PCB liquids and PCB contaminated equipments (transportation, recycling, destruction);

- lack of specialized facilities for handling of liquids containing PCBs and PCB-contaminated equipments (recycling, destruction);
- lack of specialized sites for safe storage of waste.

The main condition of the handling, transportation, disposal of PCBs is compliance with licensing requirements set out in the Russian Federation.

Licensing of environmental activities carried out in accordance with the laws of the Russian Federation:

- Federal Law "On Environmental Protection» of 10.01.2002 № 7-ФЗ (as amended 27.12.2009 No. 374-ФЗ);
- Federal :aw "On licensed activities";
- Regulation elaborated in accordance with the statutory provisions, approved by the Government of the Russian Federation.

In accordance with the laws referenced the following activities related to PCBs are subject to lisencing

- waste storage
- transport (including transboundary movement);
- disposal;
- disposal of industrial and other waste, materials and substances;
- destruction.

Requirements for the management of PCBs and PCB-containing equipments identified in the following existing rules and regulations of the Russian Federation:

- License legislation requires companies working with PCBs, obtain licenses and conduct activities in accordance with Russian standards;
- Occupational Health and Safety Regulations describe the requirements for occupational safety and procedures for supervision and control over their observance;
- Regulations on industrial safety at the enterprises with hazardous industries commit to organize and carry out internal control over compliance with the rules;
- Rules define the process control procedures for determining major risk to the industrial enterprise, planning and internal controls.

During the operation period of PCB-containing equipment owners of such equipments should take the following commitments:

- Use of PCBs only in intact and non-leaking equipment;
- To ensure control over the use of equipment and timely detection of leaks of PCBs;
- Not to allow the recovery for PCBs;

- Facilitate the identification and restoration of the damaged condition of territories contaminated with PCBs.

Particular attention should be paid to the decommissioning of the damaged equipments containing PCBs, and storage of such equipments. The main types of damage of the capacitors are: mechanical damage to the glands, swelling of the body of the capacitor, the complete breakdown of the capacitor. The average failure rate of capacitors is about 0.6% per annum of the total. Operation and maintenance of existing transformers leak of Sovtol an average of about 10 litres per year from a single transformer. Data loss of Sovtol all working in Russia transformers are estimated at 130 tonnes per year.

In Russia there is a set of rules for handling hazardous substances, obligatory for execution. These rules are set out in GOST 12.1.052-97 "The security certificate of the material (matter). Safety Instructions." Paragraph 4 of the State Standard "Requirements for the content of the safety certificate specifies the following requirements for the content of the security certificate for each chemical:

1. Name and composition of a substance or material;

2. Information about the manufacturer and the supplier;

3. Type of Hazards of its occurrence;

4. First aid measures;

5. Measures against fire and explosion;

6. Measures to prevent and cope with emergency situations;

7. Handling and storage;

8. Occupational health and safety, and personnel safety;

9. Physical and chemical properties;

10. Reactivity;

11. Toxicity;

12. Impact on the environment;

13. Regulation of waste management;

14. Security measures during transportation;

15. International and national legislation;

16. Additional information.

Minimising waste and pollution should, first and foremost, prevent leakage of fluid from any PCB - containing equipments. It is necessary to carefully collect even a small amount of liquid in special containers and then to provide adequate storage. Personnel performing such operations must be specially prepared and trained in cleaning equipments.

When the equipment is decommissioned, it should be treated carefully and put on a specially equipped site. Care should be taken to prevent pollution at the same warehouse, or other materials, including waste, in order to minimize the total amount of materials that are classified as PCB-containing, and therefore requiring special safety measures for disposal.

Any movement which involves the maintenance of equipment, storage or transport, it is necessary to produce such a way as to avoid spillage and leakage of fluid until the time of its disposal.

In cases where PCB-containing equipments or contaminated with mineral oil cannot be properly disposed of on-site storage of such materials it is necessary to ensure the following:

- To minimize environmental risks during transportation;
- Avoid spills and leaks;
- Ensure storage of such materials in secure containers until the time of disposal.

Store of PCBs and PCB-containing equipments and waste shall be clearly marked according to the requirements of relevant standards. Long-term storage of PCBs is allowed if there are measures to ensure their proper storage and disposal.

The situation with the storage of waste containing PCBs remains difficult, although there are examples of partial permission. In order to improve environmental safety and eliminate a potential source of environmental emergencies in the Krasnoyarskii Krai in 2006 was commissioned a unique facility of regional significance for disposal of hazard category 1-2 waste, namely "Serebristy" hazardous waste landfill, which is owned by JSC "Green City". Enterprise "Sibelectrostal" previously owned the object. The landfills intended for the disposal of waste hazard category 1-2, resulting from industrial activity of the plant, and was operated from 1976 to 1993.

At present landfill "Serebristy" meets all the hygienic and environmental requirements for the placement of toxic waste. JSC "Green City" has a license for the collection, use, disposal, transportation, disposal of hazardous waste issued by the Yenisei interregional territorial department of the technological and ecological supervision Rostekhnadzor.

The landfill is the only company in the Krasnoyarsk region, which can ensure environmental security placement of toxic waste. Landfill capacity is 12,000 m^3. Among the wastes to be accommodated the main place is occupied by waste containing PCBs, and pesticides and chemicals.

Waste is received at landfill only in special sealed metal containers made of metal 10 mm thick and having a corrosion-resistant coating, when accepting the filled container a worker of landfill conducts a visual inspection of the container, checking for radiation monitoring, a container arrives at a special area in temporary storage to accumulate the necessary amounts, placement of waste containers is carried in a reinforced concrete tank, internal and external waterproofing, in dry weather. For this, plates are removed from the middle of a crane bay tank and install a container. After a storage container mounted shot slab, and covered with a waterproof coating. In order to monitor the environmental safety of this technology of storage of toxic waste at the facility they provide a monthly environmental monitoring by an accredited laboratory.

Disposal of PCBs and PCB-containing equipment in AR RF

Decontamination of PCB-containing equipment includes carrying out the following:

- draining of PCBs,
- washing equipment

- decontamination of equipment,
- destruction of PCBs and PCB-contaminated waste.

Draining of PCBs from capacitors

Draining of PCBs from capacitors is difficult because of the design features - its internal filling, you cannot merge more than 50% contained PCBs. For this reason, methods of disposal of PCB-containing capacitors differ from the methods acceptable for transformers.

Draining of PCBs from transformers

The first step in the processing of transformers containing PCB dielectric fluid is draining it from them. In the presence of lower discharge valve and the upper vent valve such an operation seems to drain fairly simple. In fact, this operation is not simple for several reasons:

- The drain valve is usually not installed in the bottom of the hull but on the side of the transformer. Therefore, when there is the bulk fluid drain some PCB is left on the bottom, which cannot be drained. For a complete discharge of PCB transformer is tilted, which requires a special device;
- Russian Sovtol-10 (90% PCBs and 10% trichlorobenzene) is an extremely viscous liquid, so the transformer, before discharge of PCBs, if the temperature is below 20-25 ºC, must be heated;
- Draining hinder small gaps between the internal elements of the transformer;
- Wood fittings, cardboard and paper materials are porous and retain wellPCBs.

After discharge of PCBs from the transformer housing wall, electrical coils and packages transformer iron, contaminated with a thin layer of PCBs. The residual amount of PCBs on these studies, ranging from 2% to 10% by weight of PCBs, drenched in a transformer.

After the removal of PCB containing liquids transformers, capacitors and containers are treated as PCB contaminated waste to be disposed of in an environmentally sound manner.

In Russia there are no requirements governing the content of PCBs in the waste. Federal Waste Classifier lists only PCB containing transformer and other oils, and transformer oil as hazard category 1 waste.

In 2002 Russia acceded to the Stockholm Convention on POPs, signed in May 2001, though has not ratified it yet. Therefore, in their efforts to clean up PCBs from the transformer and the recycling of metals from their Russian enterprises and controlling bodies must adhere to standards and requirements adopted by the Stockholm Convention, in accordance with which by the year 2025:

- Any equipment containing more than 0,05% by weight PCBs and more than 5 litres of PCBs shall be removed from service;

- To the extent possible the equipment containing more than 50 ppm[5] PCBs and more than 0.05 litres of PCBs shall be removed from service as well;
- PCB-containing equipment cannot be exported or imported except for waste utilsation in an environmentally sound manner;
- Liquids with PCB concentrations exceeding 50 ppm must not be re-casted except for situations of minor repairs or maintenance. Transformer with PCBs can be repaired and be flooded back with the same liquid. In the case of lowering the level of the liquid, it is not allowed to add PCB containing liquid from a different transformer;
- Fluids containing over 50 ppm of PCBs and equipment containing more than 50 ppm of PCBs shall be disposed of in an environmentally sound manner no later than 2025.

Cleaning of transformers and containers from PCB

After draining transformers and containers from PCBs it is customary to wash them with the solvent from the PCB. As a result of equipment washing there are two possibilities: to re-enter the transformer in operation or to perform its disassembly recycling of metals by their melting and destruction (disposal) of the internal filling - wood, cardboard and paper. It should be noted that capacitors cannot be drained to a sufficient level and completely washing of PCBs because of their structural features.

In any case, the transformers and containers washing after draining them from PCB-containing liquids and recycling of the solvent left after the washing of PCB containing equipment is an important part of the elimination of PCB-containing equipment. Design features of transformers and capacitors drive the solutions for their destruction and regeneration.

Three of the Russian technologies of cleaning transformers and containers from PCBs are the closest to practical implementation:

– PCB washing with vapours of methylene chloride (pilot plant);

– PCB washing with liquid– toluene (pilot plant);

– PCB washing with water detergents (pilot plant).

Russian technology provides cleaning of assembled transformers with their subsequent disassembling and recycling of metal parts.

Assessment and justification for the selection of optimal treatment technology of PCB containing transformers and containers must be carried out on technical indicators, including ease and availability of equipment and materials, and environmental relevance of technology indicators to existing environmental requirements.

Environmental requirements for PCB cleaning technologies, are crucial in selecting appropriate technologies, as they allow one to estimate the completeness of decontamination of PCBs. Need to comply with environmental requirements for the destruction of PCBs and minimizing the

[5] ppm - *parts per million*

waste in the process of cleaning the electrical equipment is dictated by the risk of PCBs threatening the environment and human health.

It should be straight away noted that the Russian technology of washing out PCBs from transformers with water detergent currently does not provide for the required degree of treatment. Residual content of PCBs in transformers stands at 5,000 ppm, which under the European regulations corresponds to hazardous waste, requiring special additional measures for their disposal or destruction. For this reason, the technology of washing PCB transformers with water cleaning solution is not considered.

Technological scheme of PCBs washing from transformers with methylene chloride have technically much in common with the scheme, which is used for washing the transformers with the toluene.

Each of the above technological schemes using methylene chloride and using toluene practically can provide reduction in the concentration of PCBs on interior metal components to a level below 50 ppm (mg/kg). This conclusion is evidenced by the lack of technological limitations for varying the processing time. The necessary technological requirements can always be achieved with a corresponding increase in transformers processing time.

At the same time, after cleaning the transformer with either of these two technologies wooden and cardboard components of the transformers are containing more than 50 ppm of PCBs, and requiring to treat them as a hazardous waste.

It should be noted that the methylene chloride and toluene solvents are not a scarce commodity. Industrial production of each of them in Russia amounts to tens of thousands of tonnes per year. Widely used abroad perchloroethylene is not produced in Russia.

A common characteristic of both the technologies is the high reliability of the equipment. This is due to its operation without the use of high pressure and high temperatures.

The key distinction of a technique using toluene is the application of the second component - water vapour to remove the remaining toluene from the transformer after washing. Application of water vapour leads to the creation of additional stages of condensation of water vapour with toluene and PCBs, scaling and cleaning of wastewater from toluene and PCBs. Thus, the flow chart using toluene is more complicated than the technology that uses methylene chloride.

Both of the technologies also have different explosive and fire risks levels. Technology with the use of methylene chloride is classified as B-category and does not require special fire suppression systems. °Technology with the use of toluene with a flash point at 4ºC, belongs to the most rigorous of A-category and requires the obligatory installation of automatic fire fighting system.

Consideration of the environmental performance of the two discussed Russian technologies for PCBs washing showed that under the transformers treatment technology based on methylene chloride gas emissions are generated only after stripping the gas-phase of the solvent from transformer. These air emissions are ultimately go through the absorber with activated carbon to provide final purification of air from organochlorine contaminants.

Volume of activated carbon and, mainly, the final concentration of PCBs in it prior to its replacement can be adjusted in such a way that the activated coal contains less than 50 mg/kg of PCBs, and thus belongs to the non-classified waste according to European standards.

Both gas emissions and wastewater are generated in the transformers treatment technology based on toluene..

Undertaken comparison of the technical and environmental characteristics of Russian technologies for washing of PCBs from transformers and containers enables to recommend for Russia the technology based on methylene chloride vapours as a solvent . This technology was developed the NGO Petrokhim -Technology in conjunction with the RSC "Applied Chemistry" (St.-Petersburg).

The PCB cleaning technology for transformers was tested at a pilot scale.

According to the design scheme adopted “Petrohim-Technology”, the technological scheme includes:

- Collection of transformers and placing them within a dedicated area;
- Draining the transformer by heating them and due to gravity and then collecting the PCB-containing liquid in a separate tank for future disposal;
- Carrying out the transformer cleaning cycle using a vapour of methylene chloride;
- Disassembly of the transformer and sorting of components. I was established that the metal parts inside the transformer are cleaned to such extent that they are not to be considered hazardous waste when after cleaning with vapour of methylene chloride, and hence can be recycled without any problems;
- The articles of wood construction, cardboard and paper, which may still contain a residual amount of PCBs, are to be sent for incineration or when the concentration of the remaining PCB complies with the environmental requirements for disposal (PCB content less than 50 mg/kg) – to be landfilled.

This technology is optimal for implementation in the Russian Federation in terms of technical and environmental performance.

Disposal of PCB solvent

After washing, the PCB-containing equipment there is a new type of waste - a solvent containing PCBs, which is also subject to recycling (disposal or recovery).

When used for cleaning of PCB-containing transformers methylene chloride was easily recovered and purified from the PCB.

According to LLC “NIITS Synthesis” (Moscow), solvent recovery flowsheet includes: heating the PCB solution and evaporation of methylene chloride, which then condenses on cooling. Regenerated solvent - methylene chloride, is returned back to the transformer cleaning installation for reuse.

In All the required process calculations were fulfilled and a sketch of the design documentation was developed by LLC “NIITS Synthesis”. The process of regeneration (recycling) of solvent for cleaning PCBs can be easily implemented in the design of stationary and mobile installations for destruction of PCBs and PCB-containing equipment.

Destruction of PCBs

Currently, there are only a few companies in the Russian Federation (OAO Severstal, Novolipetsk Steel, AvtoVAZ) which on their own initiative provided industrial destruction of their accumulated PCBs, drained from transformers and capacitors. These same companies on their own have, eliminated the remnants of PCBs from the obsolete transformers and capacitors.

The most significant amount of work was performed by OAO Novolipetsk Steel Mill, the realization of the complex technology for disposal of PCB containing equipment has allowed them to treat more than 2,300 capacitors and 267 transformers, and respectively destroy 520 tonnes of liquid PCBs.

“Severstal” company has destroyed 130 tonnes of PCBs contained in the 40 transformers and 468 capacitors with missile engine based technology.

Ltd Togliatti NIIGIPROHIM according to an agreement with AvtoVAZ has neutralized 82.945 tonnes of capacitors, which with regard to an average content of PCBs in one capacitor being 17.2 kg stands for more than 4,800 capacitors. This was done in 2002 to 2007 at a pilot plant for neutralization of capacitors.,.

The largest energy company in Siberia (Siberia IDC "), uniting Altaienergo, Buryatenergo, Gorno-Altai electric network, Krasnoyarskenergo, Kuzbassenergo-RES, Omskenergo, Khakasenergo, Chitaenergo. OAO "Tomsk Distribution Company" and JSC "Ulan-Ude Energo OAO Tyvaenergo, received a license to operate the collection, use, disposal, transportation and disposal of hazardous waste, including waste containing PCBs. In the near future work on the decommissioning and disposal of PCB-containing equipment will begin ta two branches of the company - Altaienergo and Buryatenergo.

All technologies for handling hazardous substances should be subjected to state environmental review, undertaken by the Federal Service for Ecological, Technological and Nuclear Supervision[6].

Currently, methods of disposal of PCBs and PCB-containing wastes embedded in the global industrial practice can be divided into the following options:

- Disposal (landfilling) of PCBs and PCB-containing wastes in compliance with relevant regulations;
- Destruction of PCBs.

Currently, only the underground dumping of hazardous substances, including PCBs and PCB containing waste in the respective rock formations is the way to a long-term isolation of contaminants.

At the same time it is considered that dumping of PCBs and PCB-containing waste is only a temporary measure to reduce environmental pollution, since PCBs in this case are not destroyed, but stored and therefore disposal of these wastes is referred to as "deferred time" disposal.

In the Russian Federation ten technologies for destruction of PCBs are developing, including both high-temperature impact and chemical technologies.

[6] From the end 2010 the environmental supervision responsibilities as well as state environmental review powers have been transferred to the Federal Service for Protection of Natural Resources Use (Rosprirodnadzor)

However, there are still no industrial units to destroy PCBs.

Currently under the Federal Target Program ”The National System of Chemical and Biological Safety in the Russian Federation for 2009 – 2013”, approved by Government Decree on October 27, 2008, No. 791, works on the subject task "Development of technologies for destruction (recycling) of accumulated polychlorinated biphenyls and agro-chemicals unclaimed by industry and agricultural complex” are being undertaken.

Development of technologies is to be completed by 2013, creating a technological complex in experimental technology test centre in Shikhany and testing of a prototype plant.

Environmental monitoring at the sites of exploitation, storage and destruction of PCBs and PCB-containing equipment in Arctic Region of the Russian Federation

The degree of contamination of the environment in Russia is characterized by such parameters as the maximum permissible concentration (MPC).

In Russia, the MPC values apply only to industrial mixtures of PCBs. For a standard mixture, which is used for calculating the MPC, the Arochlor 1254 was selected.

Hygienic standards of PCBs have been approved in Russia:

MPC for working area sis set up at the level of 1 mg/m^3, vapours, the second hazard class (GOST 12.1.005-88; SSBT. General hygiene requirements for working area air);

MPC in water (water bodies and cultural-domestic water use) - 1 mg / l, the second hazard class (San.PiN. № 4630-88, "The maximum permissible concentration (MPC) and is tentatively permissible levels (TPL) of hazardous substances in water, water bodies and drinking and cultural-domestic water use);

MPC in fishery waters - the presence of PCBs is prohibited (Regulation of surface water protection from pollution by sewage, M 04/12/1911; instruction of the Ministry of Irrigation and Water Management, the Soviet Union from 16.05.1974);

MPC in soil - 0.1 mg/kg.

Permissible levels of PCBs in food raw materials and food are (in mg/kg):

- in the milk - 1.5;
- the fish - 2.0;
- in the liver of the fish and dairy products from it - 5.0;
- in fish oil - 3.0;
- a biologically active food supplements based on fish oil - 3.0;
- products in complementary feeding of young children on the basis of fish - 2.0.

In addition to these normative values there exist MPC for certain substances in drinking water and soils:

MPC in water:

- monohlorbifenily - 1 μg/litre;
- dihlorbifenily - 1 μg /litre;
- trihlorbifenily - 1 μg /litre;
- pentahlorbifenily - 1 μg /litre.

MPC in soil:

- trihlorbifenily - 0,03 mg / kg;
- tetrahlorbifenily - 0,06 mg / kg;
- pentahlorbifenily - 0,1 mg / kg.

Tentative allowable amount (TAA) in soil:

- PCBs (total) - 0.06 mg / kg;
- trihlorbifenily - 0,03 mg / kg;
- tetrahlorbifenily - 0,06 mg / kg;
- pentahlorbifenily - 0,1 mg / kg.

Hygienic standards for PCBs in ambient air of populated areas, and the allowable levels of contamination of the skin have not been established.

Comparison of standards for PCBs in the environment for the Russian Federation and the EU

Object	Russian standard	European standard
Water bodies for drinking water and for household needs	1 μg / l	
Water for fisheries	Prohibited the presence of PCBs	0,01 μg / l
Soil	0,06 mg/kg	
Atmospheric air	not rated	
Not classified waste	not rated	less than 50 ppm
Hazardous waste	not rated	more than 50 ppm

Of the group of POPs compounds covered by the Stockholm Convention, DDT and hexachlorobenzene (HCB) were the only one included in the observation program of Roshydromet until recently.

Monitoring of PCBs was not included in the programme of mandatory supervision.

To decontaminate land (including industrial) and natural objects from the PCB, one must have:

- information on contaminated PCB area or natural sites with ranking areas in terms of pollution, and / or areas that were (are) under prolonged exposure to spills of PCB-containing liquids;
- proven treatment technology for territories or natural objects from the PCB;
- preparedness of heads of regional administrations and enterprises dealt (dealing) with PCBs, to organize or carry out relevant work;
- needed sources of funding of these works from any source (federal or local budgets, sponsors and foreign investors);
- regulations of the federal or regional levels to encourage or oblige to carry out works to clean up areas or natural features
- organisation(s) having a licence for collection, use, treatment, transport and disposal of waste of I-IV hazard characteristics, providing for PCBs management.

In 1999 – 2001 under Arctic Council's AMAP programme SPA "Typhoon" in collaboration with the Canadian researchers conducted atmospheric monitoring of POPs, including PCBs, in Amderma (Arkhangelsk Region). Monitoring of POPs in ambient air has also been undertaken at the station Valkarkay (Chukotka) in 2002-2003, as well as in April 2008 within the framework of Russian-American-Canadian project.

It should be noted that levels of PCBs in the air in Amderma and Chukotka in the observation period are background, but nevertheless, in Chukotka, they are among the highest for the entire Arctic. According to the results of long-term observations by the Arctic air monitoring stations, both in Russia and abroad, POPs are dominated by trichlorobiphenyl presence.

In Russia there are only 4 specialized laboratories capable for monitoring of PCBs and dioxins in the environment.

For technical support of monitoring of PCBs on the objects of exploitation of PCB-containing equipment, storage areas and places of destruction upgrade with modern appliances of analytical control of the existing special laboratories and development of new laboratories with the involvement of qualified professionals are required

.

The system of collection management and disposal of PCBs and PCB-containing equipment

1. Development of organizational support for a full-scale inventory of stock, equipment, waste, and storage sites of PCBs;
2. Conduct a full inventory of stock, equipment, waste, and storage sites of PCB; Conduct labelling of equipment containing PCBs;

3. Develop a plan of measures to eliminate PCBs and PCB-containing equipment, based on the inventory results;
4. Decommissioning and dismantling of electrical equipment being in poor condition and containing PCBs; ensure their environmentally safe collection and storage;
5. Extracting and packing in sealed containers of contaminated soils from the locations of PCB leakage, ensuring their environmentally safe storage at the enterprises sites;
6. Removal of decommissioned equipment, materials and wastes containing PCBs for storage at specialized landfills;
7. Creation of facilities for the disposal of transformers and thermal decontamination of PCBs removed from them;
8. Decontamination of PCB-containing transformers (transformer drainage from PCB, washing them with solvents, and disassembly of the transformers);
9. Thermal destruction of PCBs drained from transformers and PCBs drained from capacitors;
10. Construction of the destruction installations for capacitors with PCB residues
11. Thermal destruction of capacitors with PCB remnants;
12. Monitoring of condition of environmental components on PCB storage sites and facilities for their destruction. Maintenance support of laboratories.

Science-based technological and logistical solutions that are optimal for use in arctic conditions, taking into account the previously developed proposals for the collection and disposal of PCBs and PCB-containing equipment in Arctic Region of the Russian Federation

The choice of optimal technology of waste disposal is based on the analysis of the following criteria:

- Environmental security (degree of neutralization of toxic components of the initial and residual concentration of gaseous emissions and solid or liquid residues of waste disposal).
- Degree of working out of processing equipment (for laboratory, pilot, demonstration or industrial design and practical experience).
- The complexity of the equipment (maintainability, ease of its service, operational reliability, resource).
- Versatility.
- Economic indicators.

To date, the main method of destruction of PCBs and chlorinated pesticides, accepted in international practice, is a high-temperature oxidation using reactors with different design features. The basic technology of high-oxidation of PCBs are installed using a rotary kiln, a cyclone reactor, static kilns and plasma technology.

The effectiveness of decontamination of PCBs (not less than 99.9999%) combustion is achieved by complying with the following norms:

- temperatures above 1,200 °C;
- the retention time in the gas phase is no less than 2 seconds;
- ensure turbulence and excess oxygen not less than 5% by volume;
- obligatory presence of post-combustion chamber with controlled temperature;
- availability of off-stage quenching gases;
- scrubber to neutralize the fumes of hydrogen chloride and filter for a removal of mineral dust.

Under certain conditions, in an oxygen environment of the furnace when the combustion gases and utilised the dioxins can be generated. The content of dioxins in the combustion gases must not exceed the accepted safety standards (no more than 0.1 ng/m^3)[7].

Table 7 compares the Russian and European standards on emissions of harmful PCBs, dioxins, and others in the combustion conditions.

[7] ng/m^3 – 10^{-9} grams per cubic metre

Table 7. Maximum permissible concentration of hazardous and harmful substances in the production environment, including high-temperature combustion installations

Substance	Russian standard: Maximum Permissible Concentration in workplace air	EU regulation: DEQ
PCB	1 mg/nm^3 (GOST 12.1.005-88)	not regulated
Dioxins, furans	not standardized, recommended by the Ministry of Natural Resources and Environment - 0.1 ng/nm^3	0.1 mg/nm^3
CO	20 mg/nm^3	50 mg/nm^3
HCl	5 mg/nm^3	10 mg/nm^3
HF	0.5 mg/nm^3	1 mg/nm^3
Dust	4 mg/nm^3	10 mg/nm^3
SO_2	10 mg/nm^3	50 mg/nm^3
Organic carbon	4 mg/nm^3	10 mg/nm^3
Dioxins, furans in wastewater	not regulated	0.3 mg/l

Selection of PCB Destruction Technologies

Several technologies for PCB destruction have been developed in the Russian Federation.

High-temperature oxidation in the cyclone reactor

Technology of destruction of toxic organochlorine liquid waste with a capacity of 200-250 kg per hour worked in the NGO Tehenergohimprom "led by Dr. MN Bernadiner. One of the plants operated at the pilot production plant wastewater treatment plants of Orekhovo-Zuevo in Moscow region

Plant consists of a reception and consumables containers of liquid waste filters coarse and fine; plunger pumps feed waste a vertical water-cooled cyclone reactor for post-combustion flue to burn out products of chemical decomposition of the residual concentration of nitrogen oxides, scrubber-evaporator and a fabric filter, the sleeves of which are made of phenylon fibers - similar to the foreign material "Nomex."

The main tool of the technological scheme is a cyclone reactor. Cyclone, it is called because of swirling vortex motion of the working gas in it, which ensures high turbulence, and hence efficient mixing.

$$C_{12}H_5Cl_5 + 12\ O_2 = 12\ CO_2 + 5\ HCl$$

Air for combustion and oxidation of chlorinated waste, and fuel enters the cyclone furnace (reactor) at 100 m/sec. The residence time of the combustible product in the incinerator is 0.3 seconds at a temperature of 1,600-1,700 ºC. Thermal oxidation of liquid PCBs is done in the cyclone reactor in the flow of combustion products of natural gas in accordance wth the reaction:

$$C_{12}H_5C_{l5} + 12\ O_2 = 12\ CO_2 + 5\ HCl$$

A 20% solution of caustic soda is introduced through separate nozzles directly into the cyclone zone of the reactor and the temperature is lowered to 1,250-1,400 ºC.

Input of caustic soda solution directly into the high-temperature combustion zone is the key of the technology utilizing the cyclone reactor. This part of the method is protected by the Russian patent.

The main reaction occurring at the same time is:

$$NaOH + HCl = NaCl + H_2O,$$

and the remaining caustic then reacts with carbon dioxide:

$$2\ NaOH + CO_2 = Na_2CO_3 + H_2O$$

Submission of a solution of caustic soda directly into the hot zone combustion technology is the foundation of the cyclone reactor. This part of the method is patented in Russia.

As a result of combustion of fuel, thermal decomposition and oxidation of PCBs, and neutralization of hydrogen chloride the flue gases containing carbon dioxide, oxygen, nitrogen, water and mineral dust particles with a diameter of 0.1-0.2 microns, consisting of sodium chloride (about 85 %) and sodium carbonate (15%) are generated.

Flue gases with mineral dust from the cyclone reactor proceed to a lined gas flue (afterburner) located under the reactor and being an extension of the high-temperature zone. This afterburner provides residence time of gases in it for about two seconds. After the afterburner the gas mixture enters the cooling towers on quenching, where the temperature drops down to about 200 ºC. In this case, mineral salts from the gas phase transit into the solid state, forming a fine-grained dust. This dust is captured by fabric filter.

During the continuous operation of the installation the specialized ecotoxicological laboratory of SPA "Typhoon" conducted regular tests of dust on dioxins. However, even their traces were not detected. Numerous measurements of dioxins in flue gases showed values below 0.1 ng/nm^3. The results of the July 2001 trial for the destruction of liquid PCBs showed a good agreement of emissions in the flue gases and mineral dust accepted by European standards.

The list of mandatory technical requirements for high-temperature PCBs oxidation technology is fully executed on systems with cyclone reactor:

- The temperature in the reaction zone - at least 1,200 ºC;
- Residence time of PCBs in the reaction zone - at least 2 sec.;
- Ensuring the turbulence of the gas flow in the reaction zone;
- A 10% (by volume) excess of oxygen relative to PCB;
- The effectiveness of the destruction and disposal of PCBs at least 99.9999%;
- A special attention paid to monitoring of the level of CO concentration.

Burning of CO is slower than the burning of dioxins. Experience has shown that if the CO content is below 5 mg/m^3, the level of dioxins will be lower than 0.1 ng / m^3;

In the technological scheme there are mandatory stages: stage of afterburn with temperature-controlled and the stage of hardening, representing a scrubber for evaporative cooling of flue gas with a filter for trapping mineral dust.

The technological scheme is not a separate unit of neutralization of hydrogen chloride. This stage is carried out directly in the cyclone reactor to form solids

This technology is tested in pilot-industrial scale and adequately meets the environmental and technological requirements, it is the most widely used abroad and is therefore recommended for a feasibility study on PCB Destruction Technologies.

High-temperature oxidation using a rocket engine (PRT)

This technology is more commonly known by the name of its developer, Doctor of Technical Sciences A.I. Papusha, called "Papusha Rocket Technology" (PRT), or missile engine technology. In the field of recycling of hazardous chemical waste, this happen to be a new technology. It is protected by the patent in Russia; patent No. 2005519 of 01.02.1994.

PRT process was pre-tested on a pilot-industrial stand in TsNIIMASH (Korolev, Moscow region), and on this basis industrial unit was established at OAO Severstal in Cherepovets. Installation operated since 1998 for about 5 years, and during that time about 100 tonnes of

product, "Sovtol-10, representing a mixture of 90% and 10% pentahlordifenila trichlorobenzene was destroyed.

The PRT technology is based on using the rocket engine. This type of rocket engine standard size was developed to target space stations. Nozzle for mixing the fuel has a length of about 10 cm and maximum diameter of 8 cm

Through steel pipes with very small diameter of 10 mm, the engine is served with the reaction components. The engine consists of two parts:

- High temperature gas generator in which the fuel (kerosene) and oxygen react at a temperature of about 3000 ºC.
- A reactor that receives PCBs and oxygen.

Operating pressure in the first chamber is about 16 bar.

At transonic (and even supersonic) velocities of the order of 1,000-1,500 m/s and at temperature of 3,000 °C reaction products come from the reactor into the afterburner, which additionally sucks the air from the escaping outside ring holes. High speed and turbulence provide exceptionally efficient mixing of components. And this is a peculiar feature of PCB waste utilization with a rocket engine based technology. In the afterburner the temperature decreases down to 2,000 ºC due to an additional air intake. At the exit from the afterburner chamber the solution of caustic soda to neutralize the products of combustion is fed in. The resulting flow of gas-vapour-drop mixture bubbles through the liquid in a special separation chamber. At OAO “Severstal” fluid level in the chamber was kept constant to ensure the completeness of cleaning. For this to happen, part of the liquid is constantly pumped out into a container which has been filled with a 10% sodium carbonate solution at the beginning of the process, and from which the separation chamber is replenished. In the course of operation this concentration is reduced to 1%, and the process stops. Therefore, the duration of one operation cycle (3.2 hours) is determined by the size of the container containing a 10% solution of sodium carbonate. After stopping the engine the container with a 1% sodium carbonate solution is emptied and refilled again with a 10% solution of this chemical.

The waste gas from the separation chamber flows to the stack.

In addition to the basic equipment items, including the rocket engine itself, afterburner pipe chamber and the separator (separation chamber), the PRT installation includes a number of secondary systems providing maintenance engineering support:

- Kerosene supply system;
- A system of compressed oxygen with a pressure of about 25 bar. The in-house system for delivery of oxygen can be used;
- A water system for cooling jacket of the rocket engine and afterburners;
- A system of compressed nitrogen to boost supply of kerosene to the plant and the pneumatic controller;
- Storage, preparation and filing solution of soda ash (sodium carbonate);
- Control and monitoring system - manually by remote control. Monitoring and control process is carried out by three operators;

- Monitoring the exhaust gases. This system was bought in Germany and is used to measure excess oxygen concentrations of NO, NO2, SO2 and CO, as well as to measure temperature.

Monitoring of environmental indicators for the installation of industrial operation was carried out by the accredited at the federal level, mass-spectral Laboratory of SPA 'Typhoon' from the city of Obninsk, Kaluga Region.

The analysis showed that:

- the content of dibenzo-p-dioxins and polychlorinated dibenzofurans in the original sovtol-10 from 410 to 1100 ng/g;
- concentration of dioxins in the flue gas installation from 3.5 to 14 ng/m^3 (no filter);
- the concentration of PCBs (sovtol-10) in the flue gas installation 4.07 mg/m^3;
- the concentration of PCBs in the solution used, the neutralizer 52 micrograms per litre.

In this case, the wastewater must undergo additional treatment at water treatment plant, prior to discharge into the environment.

According to the developers of the PRT method to meet the European environmental standards at the facility it is necessary:

- To provide a longer residence time of reagents in the first chamber;
- To eliminate the uneven oxygen supply taking place in the installation;
- Install a filter at the output of waste gases;
- To increase the specific volume of flue gas flow.

The above activities are quite easily achievable and should significantly improve the environmental performance of industrial installations. Therefore, the method of PRT with respect to environmental requirements may be recommended for further feasibility studies.

Review of implementation of the other mandatory requirements shows the following:

- the temperature in the reaction zone is 2,000-3,000 ºC;
- the residence time of PCBs in the reaction zone is less than 0.1 seconds, which is much less than the required 2 seconds;
- high speed of a gas flow in the reaction zone is provided;
- an excess of oxygen relative to the PCB is not less than 13% of volume;
- the destruction and removal efficiency of PCBs equals to 99.9999% (according to the designers);
- the level of CO in the exhaust gases exceeds a value of 5 mg/m^3, which may indicate a higher content of dioxins;
- stages of post-combustion, quenching of the products of destruction of PCBs, as well as a separator for separating the waste gases from the wastewater are included in the technological scheme.

The disadvantages of the method of PRT include:

- the intermittence of the plant's operation, which requires daily start-up and debugging process;

- the difficulty of monitoring the supply of reagents, especially of oxygen;

- no filter at the output of waste gases;

- the need for additional wastewater treatment;

- high noise levels.

It should be once again mentioned that a short residence time of the reagent in the reaction zone is another disadvantage of the installation.

As there are no approved rules of dioxin in Russia, the authors of PRT Technology concluded that the rate of DRE = 99.9999%, they have achieved in the industrial setting, is comparable with the results being achieved by treatment plants in Europe and the USA.

In accordance with Federal Law "On ecological expertise" the chairman of the Russian Federation State Committee (decree No. 235 of 11.04.2000 was) approved the positive conclusion of the state environmental review of "high technology and basic execution units for disposal of highly toxic substances and waste."[8]

Subject to required regulatory and legal requirements, instructional methodology and normative documents regulating the operation of the plant, measuring and monitoring environmental parameters of the process, at OAO Severstal pilot plant capacity of 200-250 kg/hour was established. PRT technology is included in "Overview of advanced non-traditional PCB Destruction Technologies", United Nations, UNEP, August 2000.

The technology of high-temperature oxidation using a rocket engine (technology PRT) is developed at a pilot scale and is characterized by a fairly high technical level. Therefore, this technology is recommended for further feasibility studies.

Plasma chemical destruction

Experimental work for the destruction of PCBs began in 1997 in conjunction with the NGO Petrokhim Technology "(St. Petersburg).

The destruction process (heating of PCB-containing wastes, pyrolysis and oxidation) takes place in two stages. The first stage is called preliminary, it is sold outside of the plasma torch at temperatures close to thermal degradation detoxifies substances. At this preliminary stage the heating of PCB is done to reduce the viscosity, spray with high quality and evaporation. Then vapour of PCBs intensively is mixed with steam. Implementation of the various preparatory processes at the first stage can significantly reduce the size of the reactor, greatly reduce heat loss and significantly reduce the cost of production reactor.

A mixture of PCBs and water vapour is heated up to 600°C before it enters a reactor and the tangential channels direct it to the entrance. Nitrogen is used as the plasma gas, which is heated by an electric arc in the plasma torch. High-temperature jet of nitrogen comes from the plasma torch in front of the reactor at a temperature of 5,000°C and is mixed with the first flow.

[8] The conclusions of the State Environmental Review authority are valid for 5 years.

Pyrolysis process takes place at about 2,000°C with residence time of the reaction products in the high zone of about 6-7 ms.

Pyrolysis products come from the reactor in site of quenching and neutralization. They are quenched, neutralized and sent to a separator, which separates the liquid and solid phases.

The gaseous pyrolysis products pass capacitor, then an absorber health after treatment and fed into the system of incinerator of flue gas and catalytic oxidation CO.

Liquid phase, which is spent caustic solution is sent to a centrifuge to separate the precipitated salts. Solid phase is sent for recycling, and spent caustic solution is strengthened (reinforced) to the desired concentration and supplied for reuse.

When using steam as a source of oxygen the main reaction products in the flue gas are: nitrogen, CO_2, CO, H_2 and H_2O.

Solid waste in the form of a paste is composed mainly of NaCl, a small amount of $NaHCO_3$ and up to 10% of water.

In a plasma-chemical destruction of PCBs using steam as a source of oxygen the main products in the waste gas are nitrogen, hydrogen, water, CO_2 and CO. The developers of process project the dioxin emissions to be below 0.1 ng/m^3 in this gas. The waste gas is to be burned in order to use its calorific value, as well as to reduce CO emissions to the environment.

Analysis of the special technological requirements to the conditions of the process of plasma PCB destruction shows that:

- The temperature in the reaction zone is considerably above 1,200 ºC°, and is about 5,000 °C
- The product residence time in the reaction zone is much less than 2 seconds, and is 5-7 ms;
- The design of the reactor and the flow rate of reagents provide turbulence of the reaction mixture;
- Within a plasma-chemical destruction of PCBs the source of oxygen is water in excess of about 10-15%;
- Destruction removal efficiency DRE is projected to 99. 9999%;
- Mandatory installation stages of plasma PCB destruction are under quenching and neutralization of the reaction products, separation of gas and liquid flows and their subsequent processing.

Technology developers considered the power of plasma torch of 200 kW as the standard. In their view, this module - plasma torch with the reaction chamber is fully developed and tested. If the performance greater than the 25-30 kg/h for PCBs (or 135 tonnes/year) is needed, multiple installations, operating in parallel shall be installed. Thus, for the performance 1,000 tonnes of PCBs per year 8 standard units with plasma torch power of 200 kW each would be required. The equipment should be duplicated all the way up to the separator for each parallel installation. A single system for processing of off-gas and pasty wastes treatment can be used for all units working in parallel..

Bottlenecks of the plasma torch is the anode and cathode. Even in an atmosphere of inert nitrogen tungsten the anode can withstand 100 hours of work only, and copper cathode - 300

hours, after which they must be replaced. Electrodes are easily replaced, and the whole cycle of change, including a stop, the cooling and the replacement of the electrode itself takes up to 30 minutes.

Techno-economic assessment of incineration technologies

Based on the developed technical, environmental and economic requirements for technology, preliminary assessment was completed on all the above processes for the destruction of PCBs and its results are selected for the subsequent feasibility study following the Russian technology of high temperature oxidation using:

- cyclone reactor;
- rocket engine;
- plasma-chemical reactor.

Prototypes of the three technologies were tested. The main environmental criteria for these technologies were the degree of destruction of PCB (%) and the sum of dioxins and furans in gas emissions (ng TE/nm^3). The main economic criteria were the cost of creating the installation and the cost of processing 1 tonne of PCBs (in U.S. dollars).

Table 8 below presents data on costs of stationary installations for PCBs destruction with capacities of 1,000 tonnes of PCBs per year. Data for the PRT-based installation reflect cost of 3 rocket engines to provide a total destruction capacity of 1,000 tonnes of PCBs per year.

Table 8 Comparison of PCB destruction

Destruction technologies	Environmental indicators		Expenditures	
	Destruction of PCB %	Dioxins + furans, ng/m^3	Construction, $US, thousand	Processing 1 tonne of PCBs, $US
Cyclone reactor	99,9996	0,1	653	320
Rocket engine	99,9992	45	1041	1070
Plasma-chemical reactor	99,9993	55	3430	1000

As can be seen, high-temperature oxidation technology with the use of a cyclone reactor has significant advantages.

High-temperature combustion results in virtually complete oxidation of organic matter to carbon dioxide, water and other oxidation products. All the available chlorine is converted into hydrogen chloride, which is removed or neutralized or isolated for further use.

Approximate cost of creating a permanent installation with capacity of 1,000 tonnes of PCBs per year was estimated at 653,000 U.S. dollars under an estimated cost of processing of 1 tonne of PCBs at 320 US dollars.

The Russian Federation has vast experience in the development and operation of waste incineration in cyclone furnaces.

In addition to the JSC "NPO Tekhenergohimprom", where the vertical cyclone furnace for the incineration of industrial liquid organochlorine waste fuels from Ufa JSC Ufakhimprom was developed, experience in building and operation of cyclone waste incinerators is available on the sites for destruction of chemical weapons at Russian enterprises: JSC" Salavatnefteorgsintez", Cheboksary ON "Khimprom", Shchekinsky and Novokemerovsky chemical plants.

Proposals for the performance and placement facilities for the destruction of PCBs

Apparently, the actual creation of the industrial operating units can be expected no earlier than 2015. Considering that under the Stockholm Convention equipment with PCBs must be decommissioned by 2025, and the PCBs should be destroyed by 2028, for installations for washing and disposal of PCB transformers in the Russian Federation is about 10-15 years.

Based on the 2000 inventory of the number of transformers and PCBs accumulated in some Russian regions, and in the Russian Federation in general, the creation of five stationary installations for the destruction of PCBs and of one small installation for the city of Norilsk, given the remoteness of the city and a large number of transformers at the Norilsk Nickel plant was recommended.

For the destruction of PCBs in ARRF stationary combustion plants with capacity of 200-1,000 tonnes per year seems to reasonably enough.

Performance of small-scale unit with a rocket engine in the city of Norilsk is determined by the total amount of PCBs that are available on the company Norilsk Nickel - about 400 m.

For the local destruction of PCBs from transformers located at Norilsk Nickel, may be recommended permanent installation of high-temperature oxidation using a rocket engine with a single base unit capacity of 100-400 tonnes of PCBs per year. Installation is chosen because of the low cost of building (350,000 U.S. dollars). Low cost of this installation due to the low performance of one module rocket engine. The choice of a rocket engine based technology for the town of Norilsk which is accessible from the main land only by air and sea was based on a possibility of sea transport of the equipment. On completion of PCBs destruction (about 1 year time period) the rocket engine installation can be dismantled and shipped back to the main land. However, there may be other options.

Number of treatment plants transformers

Number and location of plants to clean up PCBs from transformers must, of course, be combined with the number and location of destruction of PCBs extracted from the transformers. Therefore, each of fixed installations for the destruction of PCBs is associated with plant for washing of PCB transformers, consisting of two modules.

One such two-module installation will clean up to 200 transformers within a year In addition, another stationary single-module facility would be in the city of Norilsk, where Norilsk Nickel has 222 of the transformer.

Technology of destruction of capacitors with PCB

Existing in the Russian Federation, methods and technologies of destruction / disposal of capacitors, by analogy with the global practice can be divided into two areas of implementation:

- destruction of capacitors;
- disposal of components of capacitors, followed by reclamation of metals.

The first direction includes methods such as burning, where are used:

- Explosion of patronize explosive, chemically neutralized containing PCBs in the chips (particles) of crushed condenser;
- The fuel of high-powdered mixture of filtration combustion;
- A bubble furnace with afterburner systems and neutralization of waste gases.

A second area is the method of capacitor calcination.

Technology of Chemical neutralization

The technology is offered by LLC “Promtehvzryv”. It is designed to destroy ground capacitors, liquid PCBs and other PCB-containing wastes.

The technological process packaged explosion-protected (PEP) has the following main stages:

- hydro milling contaminated items capacitors to the required dimensions using a jet of water systems, high pressure
- preliminary chemical neutralization of PCBs contained in capacitors chopped ingredients, preparation "Achlorin-H", which composition is unknown and is the know-how of developers;
- add a complex matter, neutralizers, providing education in the process of explosive transformation of environmentally friendly combustion products;
- manufacturing and packaging of PEP.

The amount of PCBs added to the PEP is regulated by technology, which should not exceed 13% by weight. Per tonne of PCBs requires 8 tonnes of chemical decontaminant “Achlorin-H” and one tonne of ethanol.

Destruction of PCBs, located in the particles of shredded capacitors, there is an explosion under pressure 5,700 MPa. This high pressure and temperature created by the explosion (a few thousand degrees Celsius) can provide a fairly high degree of conversion of PCBs. According to the developers is almost reached the depth of conversion of 99.99%, which does not comply with

internationally accepted practice value of 99,9999%. It is noted that in the explosion products PWV any organochlorine compounds are absent. Explosion products are composed of NaCl, H_2O, N_2 and Al_2O_3.

According to the developers of technology, environmentally friendly product composition of the explosive conversion of PEP in the implementation of blasting provides the chemical composition of PEP, the technology of its manufacturing and conducting blasting. There are no gas emissions from the degassing of PCB-containing capacitors and ground particles of manufacturing PEP.

The enlarged material balance of the plant shows that from one tonne of waste containing PCBs is obtained up to 50 tonnes of PEP, which include up to 10 tonnes of semi - Achlorin-H and ethyl alcohol, and about 40 tonnes of explosive components of the matrix. The developers selected cell embodiment of the installation of container. The main technological equipment is manufactured commercially at the enterprises of Moscow. The cost of one of the complex is $ 2 million, and the cost of processing one tonne of PCBs – 1,350 U.S. dollars.

The main equipment includes:

- ultra-high pressure waterjet cutting materials with a remote control actuator working head;
- special chemical reactor;
- special pumps for corrosive, high viscosity and explosive environments;
- fall mixer;
- metering of bulk, liquid and viscous substances;
- hydrocyclone;
- Autonomous power supply unit;
- the main oxidizer tank, tanks for liquid components;
- control unit;
- technology transportation;
- conveyor;
- Installation of patronage.

Performance of a single mobile unit is on request from 200 to 500 tonnes of PCB-containing waste per year.

This technology has passed industrial tests in Kovdor Murmansk region and was prepared 16 thousand tonnes of industrial explosives. During the installation of specialized industrial operation ecotoxicological laboratory for testing the completeness of the transformation of PCBs and dioxins in compliance with the decomposition products have never been involved. The main reason is likely impossibility of organizing a reliable sampling for analysis of both flue gas explosion and the solids on the bottom. It can not be said with certainty that there are no emissions as undecomposed PCBs and dioxins.

Thermochemical disposal technology

The technology offered by LLC “NET”. It is based on the application as a powder blend of high fuel filtration combustion (PSFG) and the authors characterize :

- High (over 2,000 °C) temperature of thermochemical decontamination:
- Using special equipment to grind parts of capacitors to the required sizes;
- Absorption of chlorine from PCBs;
- Long (0,5-3 hours) high-destroyed by the impact on waste;
- According to the authors - ecological safety;
- The minimum airflow for combustion, a factor of 2-5 compared with traditional fuels, as oxygen is in the oxidizer.

The essence of technology lies in the thermochemical pyrolysis of PCBs contained in the shredded particles of capacitors, which are placed between the upper and lower layers PSFG, the burning of which is ensured by air and, possibly, due to degradation products of PCBs.

Specifics of the process that determines the high efficiency of PCB destruction was based on the phenomenon of filtration combustion. PSFG used for the destruction of PCBs are mixtures of metal powders with a small amount of fuel and oxidizer processing aids. Common materials are used as the fuel and oxidizer.

Propagation mechanism of the reaction zone in such systems consistently involves heating the starting materials before the combustion front and the local chemical interaction of reactants with the release of large amounts of heat - the so-called "contact heating”.

An important feature is the accumulation of filtration combustion of the gas flow of energy released during combustion in the reaction zone. This contributes to the high temperatures in the combustion zone (above 2,000°C) and prolonged heat treatment of the source of PCBs before the reaction zone.

Possible applications of technology:

- option number 1, - with stationary units with combustion chamber volume from 0,1 to 1,0 m3 and gas treatment units;
- option number 2, – without apparatus, i.e. destruction of PCBs produced in the trenches or hangar type buildings. The volume of the trench should refer to the amount of material being destroyed as a 1,2-1,3 1,0;
- option number 3, - using the mobile unit mounted in a standard container length of about 7 m, and transported by container trailer.

Thermochemical decontamination materials and equipment are used for manufacturing facilities that are not in short supply on the Russian market.

PSFG consumption per 1 kg of waste (in terms of PCB) is 0,1-0,2 kg. Performance of stationary or mobile plant is at least 1 m per shift. The cost of one unit in the base is 70 thousand U.S.

dollars and the cost of thermo-chemical disposal of 1 tonne of waste in terms of PCBs is approximately 4-6 thousand U.S. dollars.

Technology verified through extensive laboratory, bench and pilot tests; was interdepartmental tests and was proposed for the destruction of various hazardous wastes. Tests for the destruction of PCB-containing wastes are not carried out, but the developers of this technology recommend it for this purpose. Therefore, any test results of flue gases to complete destruction of PCBs and dioxins are not available.

Thermal destruction of capacitors after draining the liquid

Technological scheme of the thermal destruction of PCB capacitors after draining the fluid containing was proposed by JSC "Tehenergokhimprom" and OAO Institute "Stalproekt".

This scheme provides for thermal processing as a whole capacitors after discharge of these PCB containing liquids without the prior stages of cutting and crushing as well as other solid wastes containing PCBs.

Plant capacity (aggregate load) for the disposal of capacitors with the remnants of PCBs is 500 kg/hour.

Description of the technological scheme

Installation of thermal decontamination of capacitors consists of a bubbling melting furnace, lined with afterburners with built-in recuperators and neutralization chamber with nozzles for supplying a solution NaOH, the scrubber-evaporator, bag filter, flue pipe and auxiliary equipment: tanks and pumps, compressors, fans and smoke.

NaOH solution is prepared in a tank and pumped into the mechanical injector neutralization chamber.

Arriving capacitors at the thermal processing are directed to the bubbling melting furnace 1, which is their primary heat treatment at a coefficient of air flow $\alpha \cong 0.5$.

Paper, paperboard and polypropylene included in the capacitor are partially decomposed and oxidized. PCBs evaporate and also partially oxidize. The gaseous products are submitted to the afterburning chamber, the metal components are melted and oxidized. To reduce the melting temperature of the melt the flux is added into the bubbling melting furnace The melt has a temperature of about 1,550 ºC. To maintain the temperature level of the primary heat treatment of capacitors in the melting furnace natural gas and heated air to 500 ° C are fed. Products of incomplete combustion are directed through a side opening in the afterburning chamber.

This camera completely oxidizes products of incomplete combustion of all components to the CO_2, N_2, H_2O and HCl. The chamber is fed with a cold air with $\alpha \cong 1,3$. Since the afterburning temperature increases from 1600°C to about 1800 °C , recuperators 3 and 4 are built in the afterburning chamber to reduce the temperature by heating the air. The temperature of the air heating is 550 °C. In recuperator 4 the air is heated and directed into the chimney to increase the temperature of flue gases and reduce their moisture.

The temperature of flue gases in afterburning chamber is about 1,320-1,380 °C.

Volume of afterburners provides the residence time of gases in it more than 2 seconds for complete oxidation of all organic components.

Flue gases from the afterburning chamber proceed into the chamber of neutralization, where HCl binds with NaOH in the gas phase to form NaCl. A 20% NaOH solution is fed in the volume of 120% of the theoretically necessary. Excess of NaOH becomes Na_2CO_3. Spraying of solution is done by mechanical sprayers.

In the course of gas neutralization chamber provides input of water or, if appropriate, urea solution to restore the NOx. The temperature of flue gas at the outlet of the neutralization chamber is about 1,000 °C. Flue gases from the neutralization chamber enter the scrubber 6, which due to evaporation of water supplied by pump 12 from container 10, its temperature drops to 200 ºC.°

Then the flue gases are sent to the bag house 7 for the cleanup of mineral dust (a mixture of salts, NaCl and Na_2CO_3).

Cleaned and cooled flue gases from the bag filter exhauster are transported to the chimney, where it mixes with the hot air coming from the exhaust. The resulting mixture of gases emits into the atmosphere.

The developers note the originality of the technological scheme, which is patented in Russia.

Non-standard equipment is produced on developed drawings.

A bubble furnace

Designed for the primary thermal processing of capacitor to produce gaseous products and molten slag.

Furnace equipped with a system of flow condensers, burners, natural gas, air lances, taphole for slag melt and the gas duct for removal of gaseous products. Entering the furnace capacitors are subjected to heating and melting on the melt surface, with such components as paper and cardboard partially burned. PCBs evaporate and partially oxidize and polypropylene is expanded. Metal components are oxidized and melted.

Afterburners

Designed for reliable and complete post-combustion of combustible components of gaseous products coming from the melting furnace. Post-combustion chamber is lined with refractory bricks. To facilitate the lining on the walls of the regenerative heat exchanger chamber are placed for heating air to be sent to the smelting furnace and for heating flue gases. Post-combustion chamber is equipped with air nozzles.

Regenerative heat exchangers

Designed for heating high-pressure air supplied to the furnace.

The second unit is designed for heating low-pressure air delivered to the chimney to heat the flue gases and reduce their moisture.

Heat exchanger is made on developed drawings.

Quantity - 1 pc.

Neutralization chamber

Designed to transfer the acid components of gases into mineral salts.

Designed as a lined chamber, equipped with nozzles to introduce a solution of alkali and urea.

Scrubber-evaporator

Designed to cool the flue gas to a temperature of 200-220 °C by complete evaporation of atomized water droplets.

In addition to standard equipment, technical installation includes a variety of capacitive equipment such as agitators, and without them, pumps of various capacities, compressor for supplying air through the heat exchanger in a bubbling melting furnace, fans for supplying air to the heat exchanger and smoke to transport the flue gases in the gas tract.

Secondary waste and emissions

During thermal processing of capacitors solid and gaseous emissions are formed. The yield of molten non-toxic slag from the smelting furnace is 564.7 kg/hour. Slag composition (% vol.): Al_2O_3 – 32.87; FeO – 23.18; SiO_2 – 36.75; and other impurities – 7.2 Dry non-toxic mineral dust from the hopper bag filter - 56.94 kg/hour; consists of sodium salts NaCl (≅ 85%) and Na_2CO_3 (≅ 15%)).

- CO_2 - 3,6
- N_2 - 55,9
- H_2O - 31,2
- O_2 - 9,3

Dust from the hopper filter is directed to the use or deposit. Slag is a glassy matrix, non-washed structure in which the PCBs and dioxins are completely absent. It is directed to use in construction or in escrow.

Flue gas-air mixture is supplied into the atmosphere in the amount of about 7,700 nm^3/hour of the following composition, % vol.:

- CO_2 - 3,6
- N_2 - 55,9
- H_2O - 31,2
- O_2 - 9,3

The content of harmful substances in gases:

- NOx (for NO_2) no more than 200 mg / nm^3
- CO no more than 20 mg/nm^3
- HCl no more than 5 mg/nm^3
- C no more than 4 mg/nm^3
- mineral dust no more than 4 mg/nm^3
- Dioxins and furans
- (PCDD / PCDF) no more than 0,1 ng/nm^3 dry gases

Emissions of harmful substances into the atmosphere satisfy the most stringent European standards (00/76 EC).

Developed technical proposals for the installation of thermal decontamination of capacitors after discharge of PCB-containing liquids can be used to implement processing technology capacitors filled with PCBs. It can be subjected to adjustments only the consumption of an alkaline reagent in the cell of neutralization and the number of mixtures of salts, NaCl and Na_2CO_3.

The purification technology of capacitors by their calcination

The industrially developed method, worked out by the Novolipetsk Metallurgical Combine and the NNP "Eco-spectrum" refers to the direction "Neutralization of capacitors with subsequent recycling of metals". The basis of this method is firing (calcination) of capacitors in special equipment.

Capacitors for disposal come to the site already assembled. PCBs are poured through the drain plugs into special containers for transportation to the site for incineration. The operation of discharging PCBs sufficiently long and continue 12-18 hours.

After draining capacitors from PCBs, the capacitors in batches of 3-5 pieces depending on their size, are set in a metal autoclave with tightly fitting lid. Autoclave is installed in a special insulated chamber equipped with an electric heater. The autoclave is hermetically connected to the heat exchanger-condenser vapour PCB of the 1-st stage which is connected tightly with the capacity for accumulation of PCBs. At the top of the container is hermetically mounted heat exchanger-condenser vapour PCB of the 2-nd stage, which, in turn, is tightly connected to the condenser, washer, filled with cold PCBs so that the outlet of the heat exchanger was immersed in the liquid to 50-60 mm. Here is the final separation of vapour of condensed PCBs. In the case of a minor collapse of PCBs to the formation of others, more volatile chlorinated compounds, cartridge of industrial gas mask of grade B is installed for trapping them. Cartridge is easily removable and replaceable when it detects the presence of chlorinated compounds on atmospheric emissions. The air-ejector is mounted to overcome the resistance of the evolved PCB vapours

On the first stage heating of the case of capacitors is held at a temperature close to 270 °C (temperature of thermal decomposition of PCBs). After the cessation of the accumulation of condensed PCBs in the container they start to calcinate capacitors at temperatures up to 500 °C. One technological operation lasts 8-12 hours. After that, the autoclave lid is removed, the capacitor is removed, cooled in the air and their demolition is begun.

As a result of calcination of the case of capacitors and their cores do not contain even trace of residues of PCBs. Paper insulation is charred, and aluminium foil passed through calcination. Such an appearance of residues of capacitors allows the use of metal components as a mixture of electro-melting shop complex. Condensed PCBs are transferred to the area of destruction in a blast furnace.

Technical and economic assessment

According to the results of technical, environmental and economic assessment of the three Russian technologies for destruction of PCB-containing capacitors the technology bubble with a melting furnace with afterburner systems and neutralization of waste gases is selected, a similar cyclone reactor burning PCBs. The preliminary drainage of trichlorobiphenyl from the capacitors is established in the adopted technology, but in principle it is possible to destroy the capacitor without discharge of PCBs. The estimated cost of installing a capacity of 4000 tonnes of capacitors in the year amounts to 1,6 million U.S. dollars and the cost of processing one tonne of capacitors is about 1,000 U.S. dollars.

To calculate the performance of installation we base on the average content of TCBs in the capacitors of about 20 kg. The average content of TCBs in the condenser is 32%, i.e. a medium capacitor weighs around 63 kg. If we consider that it is possible to merge only 50% of the available TCB in the condenser or about 10 kg, then the remaining mass of the condenser will be in average of 50 kg.

Thus, the capacity of 4,000 tonnes per year allows to destroy 80,000 capacitors per year.

Selecting a location for the destruction of PCBs and PCB-containing waste in a steady-state conditions in Arctic Region of the Russian Federation

In order to choose the placement of stationary PCB destruction and disposal of PCB-containing equipment one should have:

- presence of the large number of PCB-containing equipment and PCB-containing wastes near the location of fixed (stationary) installations for the destruction of PCBs, their high storage density, which would provide long-term operation of the plant;
- availability of production facilities, equipment, infrastructure, skilled workforce,
- environmentally acceptable situation in the place of the possible location of stationary equipment for the destruction of PCBs and PCB-containing waste;

- developed and validated technologies for destruction of PCBs and PCB-containing wastes;
- presence of a potential investor who is ready to invest in the creation of permanent installation for the destruction of PCBs and PCB-containing wastes;
- readiness of the leadership (the owner) of the enterprise, suitable for placement of permanent installation for the destruction of PCBs and PCB-containing wastes to enter the business;
- willingness of the local administration to have fixed installations for the destruction of PCBs and PCB-containing wastes in its territory.

For the destruction of PCBs and PCB-containing wastes using mobile units you must have:

- availability of an organizational structure in areas with lots of equipments containing PCBs, and related waste, ready to construct and operate a mobile installation (installations) for the destruction of PCBs and PCB-containing wastes;
- sites for the alleged movement of the mobile unit are available in terms of requirements for environmental protection of the plant;

  Locations for units operation are selected in a way to provide compliance with the requirements of sanitary and epidemiology norms and standards:

  - SanPiN 2.1.7.1322-03 Hygienic requirements to placing and treatment of waste of production and consumption
  - SanPiN 2.2.1/2.1.1.1200-03 Sanitary protection zones and sanitary classification of enterprises, installations and other objects;

- location for recycling of PCB-containing equipment and PCB-containing wastes.

  The mobile installation is delivered to PCB containing equipment and PCB contaminated waste storage sites; the destruction of PCBs takes place at those sites. PCB containing waste include PCBs drained from equipment, PCB contaminated solvents, etc.
- the consent of regional administrations for this operation, where the expected operation of the installation for the destruction of PCBs and PCB-containing waste;
- developed and proved technologies that can be implemented in mobile applications for the destruction of PCBs and PCB-containing wastes;
- the potential investor (potential investors), including foreign (bank, financial institution, fund, state of the donor organization, etc.), ready to invest in the creation of mobile plant for the destruction of PCBs and PCB-containing wastes;
- availability of the developed road network in the region of a plant to allow moving the installation to the places of destruction of PCBs and PCB-containing wastes. Mobile PCB destruction units are usually transported by special automotive vehicles

In Arctic Region of the Russian Federation for the territories outside the European part of Russia a potential candidate for the installation location for the destruction of PCBs and disposal of PCB-containing equipments is the place near the city of Krasnoyarsk and the landfill, "Serebristy" where there are:

- a large number of PCB-containing equipments in the Krasnoyarsk region and directly in Krasnoyarsk;
- a large amount of waste PCBs at the site "Serebristy";
- manufacturing facilities, equipment, infrastructure, skilled workforce.

A high-temperature oxidation technology with the use of a cyclone reactor is recommended in Russia which is based on the work carried out to assess the technical, environmental and economic characteristics of the methods of disposal of PCBs.

A developed industrial technology for destruction of PCBs will appear in Russia, apparently, not before 2015. Solutions for the installation of destruction must undergo a mandatory environmental and legal expertise. The above mentioned examples of PCBs destruction at a pilot stage have been targeted to development of respective destruction technologies. Permits to undertake such pilot projects on PCBs destruction is issued by the territory branches of the environmental regulatory authorities for the period of one year. It is not clear if the local administration and the public have a willingness to have fixed and mobile installations for the destruction of PCBs and PCB-containing wastes on its territory.