Executive summary

This work has been carried out in accordance with the EMEP/MSC-E work-plan for 2002 approved by the Executive Body for the Convention on Long-Range Transboundary Air Pollution (CLRTAP) [ECE/EB.AIR/75, Annex VI, item 2.2]

The report considers dioxin/furan (PCDD/F) and polychlorinated biphenyls (PCB) atmospheric emission evaluation for NIS (within the geographical scope of EMEP) for main source categories. Basic years are 1990, 1995 and 1997.

Procedure applied was based on the UNECE EMEP methodology. Wide range of sources of information on production statistics, technological processes features and emission factors were used. When it was impossible to obtain an acceptable quantitative estimate of emission qualitative ranging of sources into 3 categories was done.

Maps of pollutants emission distribution over the 50x50 km^2 EMEP grid were prepared; for gridding information on the main point sources was collected.

Estimations have showed, that Russia and the Ukraine provide more than 90% of total dioxin/furan emission for domen. Among source categories sharp prevalence of production processes is evident. From this group greatest contribution makes sintering. Decreasing trend of emission is evident in all countries.

For PCBs emission estimation leakage from transformers and damaged capacitors were estimated as the main source of polychlorinated biphenyls (PCB) discharge into the environment. Emission calculation was based on material balance of PCBs production and application in the countries.

Expert estimates of polychlorinated biphenyls emissions in the Russian Federation from electrical equipment with $1^{o}x1^{o}$ degree spatial resolution based on AMAP PCB inventory [*PCB in the Russian Federation…., 2000*] were included in the report also.

The obtained estimates of POPs emissions with spatial distribution are intended for the transboundary air pollution modeling; they can be also used by experts of the NIS countries for preparation of national emission estimates.

CONTENTS

Preface

POP emission inventory is a basic element of POP environmental regulation. Parties of the Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Persistent Organic Pollutants are obliged to present information about national emissions meeting the requirements of EMEP in regard to completeness and structure. In particular, in the annual information Parties submit data on national annual emissions of selected POPs.

It is recommended to present the information in SNAP source-sector split. In certain intervals of time the Parties are recommended to submit data about large point emission sources and emissions, distributed over 50x50 km^2 EMEP grid etc.

National POP emission reported data are available for some of the Newly Independent States (NIS) countries and Baltic countries and for a limited number of POPs.

At present unification and improvement of the emission inventory methodology is under way.

As a result of close co-operation between EMEP and CORINAIR Atmospheric Emission Inventory Guidebook was issued (first edition – 1996, second edition - 1999). The recommended methodology is based on the use of specific indices of pollutant emissions (emission factors).

Adaptation of methodology of the Guidebook to the NIS countries technological conditions. This work was started in 1996 under the MSC-East supervision and it included:

- Guidebook translation into Russian;
- workshops on the Guidebook use (1977, 1999);
- co-operation with to national experts;
- elaboration of emission factors;
- preparation of additions to the Guidebook.

Specialists from the Institute for Problems of Natural Resources Use & Ecology (IPNRUE, Minsk, Belarus) and the Scientific Research Institute “Atmosphere” (SRI Atmosphere, S.-Petersburg, Russia) and national experts from countries were actively involved in this work.

In 1996 - 2000 special projects on elaboration of HM and POP emission factors were fulfilled taking into account technological peculiarities of the NIS countries.

In the framework of this activity in 1996-2000 a series of reports on HM and POP emission factors was prepared by specialists of IPNRUE and SRI “Atmosphere” [*Belarusian contribution to EMEP,* 1997-2000; *Compilation of the database.*., 1999; *Reference book on emission factors*.., 1999]. The results of emission factor assessments have been reported at the Task Force meeting [*Kakareka et al.,* 1998;].

Present estimates are focused on the following groups of pollutants listed in the POP Protocol: dioxins/furans and PCBs.

Project objectives: numerical appreciation of dioxins/furans (PCDD/Fs) and polychlorinated biphenyls (PCBs) emissions to the air over the territory of the former USSR (within the geographical scope of EMEP). Basic years - 1990, 1995 and 1997.

The obtained estimates of POP emissions with spatial distribution are intended for the formation of the database for the transboundary air pollution modeling and for the usage by the NIS and Baltic countries in preparation national emission estimates of these compounds.

Estimates obtained were transmitted to national experts on emissions for their consideration; in most cases approvals were obtained. In some cases corrections were made according to data and comments of national experts.

Part I

EXPERT ESTIMATES OF DIOXIN/FURAN AND POLYCHLORINATED BIPHENYL EMISSIONS IN THE BALTIC AND NIS COUNTRIES (WITHIN THE GEOGRAPHICAL SCOPE OF THE EMEP)

1. Introduction

Outline of PCDD/F and PCB properties

PCDDs and **PCDFs** are compounds which have in their composition chlorine-substitution dibenzodioxins and dibenzofurans complexes. There are 75 isomers of PCDD and 135 isomers of PCDF differentiated from each other by number and location of chlorine atom addition. Together with polybromated and mixed chlorine-brom-substitution dibenzo-n-dioxins and dibenzofurans the number of dioxin/furan isomers reaches 4600.

Chemical and biological properties (including toxicological) depend on the position of chlorine atoms. It is determined that most toxic are 17 isomers of PCDD and PCDF with substituted chlorine atoms in 2,3,7,8-positions. The toxicity rate of each isomer is represented by toxicity equivalency factor (TEF), which is the ratio of the toxicity of a given isomer to the toxicity of 2,3,7,8-tetrachlorodibenzodioxin. For the calculation of toxic equivalent (TEQ) of dioxin/furan mixture their weights are multiplied by relevant TEFs and summed up. Traditionally emission factors are calculated in grams of toxic equivalent. Usually the toxicity scale suggested in 1988 by NATO CMS Committee is used.

Polychlorinated biphenyls (PCB) is a group of organic compounds containing a chlorine-substitution biphenyl complex. There are 209 PCB isomers. They are chemically and thermally stable, poorly decomposed in the environment. Depending upon the chlorination degree different products are produced: from monochlorobiphenyl to decachlorobiphenyl.

PCB toxicity varies with the chlorination degree. Among polychlorinated biphenyls there is a group of compounds close to dioxins in regard to toxicity (e.g. coplanar compounds with chlorine atoms in ortho-positions). In view of the fact PCB toxicity scale similar to that of dioxins has been developed. However, it is seldom used since there are few isomer-specific determinations of PCB and corresponding emission factor. PCB emissions are usually assessed in mass units.

The procedure and the state of the art of POP inventory

A detailed and preNISe inventory of POP emissions as well as of other compounds is necessary first of all for management organizations to make deNISions oriented to ecology and for the assessment of transboundary pollution fluxes and their effects.

Emission inventories may be divided into national and expert ones. National inventories are carried out in accordance with the standards of a country and they are different in regard to the number of considered sources and pollutants as well as methodologies.

In the Newly Independent States (NIS) countries the inventory of stationary source emissions on the state level is based on statistical reports of the plants. For regional and national assessments emissions of individual sources are summed. The inventory

of mobile source emissions is fulfilled on the basis of fuel consumption data.

The inventory of POPs is made only for those substances which input to the environment is of a deliberate character (pesticides). All the countries keep a record of pesticide input. At the same time there is no record of usage and consequently unpremeditated input of POPs. These pathways are main for PCB used in closed systems (electrical equipment, hydraulic systems, cooling equipment, cables) or at open application (paints, plastics, paper). The same situation exists with the record of emissions of POPs contained as an admixture in other substances. This pathway of emissions is characteristic of dioxins contained in pesticides, commercial PCB, solvents, means of wood impregnation (e.g. pentachlorophenol).

Expert estimates usually are made under some international projects. One of the first of POP inventories was presented by *J.A.Duiser and C.Veldt* made within the framework of Dornier project [*Axenfeld et al.*, 1989]. It included emissions of PAH, PCB, γ-HCH (lindane) and hexachlorobenzene for 1982. European emissions of lindane and benzo[a]pyrene for 1990 were included later as a part of ESQUAD project [*Berdowski et al*., 1994].

One of the most complete inventories for Europe for 1990 has been made under UBA project [*Berdowski et al*., 1997]. It includes calculations of emissions of 16 substances (groups): PAH, PCDD/F, PCB, HCB and others. Estimates are made for countries and according to SNAP source categories over the 50x50 km^2 EMEP grid. According to *J.J.M.Berdowski et al*. [1997] total European emission of PCB in 1990 is 119 tonnes, of dioxins - 11.3 kg TEQ.

Most recent European emission inventory is made under POPCYCLING-Baltic project [*Pacyna et al.*, 1999]. It included emissions of PCDD/F, benzo[a]pyrene, DDT and metabolites, HCB, PCB, HCH (α,β,γ). A special attention is paid to individual isomers (congeners). The time period – 1970 - 95.

Recently data of national and regional inventories of PCDD/F emissions are obtained under UNEP Programme [*Dioxin and Furan Inventories…*, 1999]. National inventories of dioxin emissions have been made nearly in 20 countries. The greatest number of inventories are made in EU countries. Inventories are made in North America (The USA, Canada), Japan, and Australia. According to these estimates in 1995 dioxin emissions amount approximately to 10500 g TEQ. In the majority of countries the inventory has not been made or it is at the initial stage.

2. Methodology

The following methodological principles make the ground for estimates of PCB and PCDD/F emissions:

- use of official statistical information on product output and amount of fuel combustion and waste incineration on the regional level (in case such information is not available expert estimates and assumptions are used);
- for the acquisition of the information required for the estimation of emission factors various data and methods are used: literature data, contacts with national experts, own experimental investigations;
- estimates are made for the maximum possible sources; in those cases when it was impossible to make quantitative estimates we made qualitative ranging of sources;
- a special attention is focused on reliable spatial distribution of emissions and on the identification of point sources.

Identification of PCDD/F and PCB emission sources

PCDD/F emission sources

According to the Technical Paper to the OSPARCOM-HELCOM-UNECE Emission Inventory (1995) main sources of dioxin emissions are waste incineration, sintering, ferrous and non-ferrous metallurgy, stationary fuel combustion, road transport, and pesticide use.

For European inventory [*Berdowski et. al*., 1997] TNO has calculated dioxin emissions from the following sources: fuel combustion (brown and hard coal, fuel oil, peat, wood); electric arc furnaces (040207); sintering (040209); secondary copper and lead production (0403cu, 0403 pb); other mobile sources and machinery (080000); waste incineration (090200). It should be emphasized that in this inventory emissions from the transport under SNAP code 08 have been estimated. For the transport under SNAP 07 emission factor and emission have not been estimated if there were no official data.

In the list of other sources of dioxin emissions considered by TNO there are the following industries: production of paper (040602, 04060x), of cement (040612); of glass (040613); road paving with asphalt (040611), ferrous industry – coke production (040201), blast furnaces (0402xx), pig iron casting (040203), open-hearth furnace (040205), converter (040206); non-ferrous metallurgy - aluminium production (040301), nickel (0403ni), copper (0403cu), other metals (0403ot), lead (0403pb), zinc (0403zn), production of chlorinated hydrocarbons (040524); solvent use (060000), wood preservation (060406); cremation (090000), passenger cars (0701-5), solid waste disposal on land (090400), other sources and sinks (110000).

These emissions are estimated on the basis of data presented by some countries (e.g. dioxins emissions from paper production - Sweden data).

According to TNO estimates [*Berdowski et. al.*, 1997] the input of different sources to the total dioxin emission for Europe is as follows: stationary fuel combustion - 38%, sintering - 15%, copper production - 13%, waste incineration - 24%, other sources -10%.

The preliminary report on the inventory of dioxin emission on the territory of the USA presents estimates of PCDD/F emissions from waste incineration, cremation, transport, stationary fuel combustion, production of cement, forest fires and vegetation burning, secondary production of non-ferrous metals (aluminium, copper, lead), cigarette smoking, craft process. About half of the total emission is due to the municipal waste incineration, approximately by 20% falls on hospital waste incineration and secondary non-ferrous metallurgy each.

In the report by *I.Holoubek et. al.* [1993] the authors indicate as dioxin emission sources industrial processes with chlorine (phenol chlorination, chlorine production with graphite anode, pesticide production, pulp and paper bleaching, water desinfection and some other processes), thermal processes (waste incineration, ferrous and non-ferrous metallurgy, secondary ferrous and non-ferrous metallurgy), transport fueled by non-leaded gasoline, fires on landfills, power and heat generation, domestic heating, evaporization from landfills and others. Actually emission factors are estimated for a considerably less number of sources (stationary fuel combustion, road transport, incineration of different wastes, metallurgic processes).

PCB emission sources

According to [*Technical Paper…,* 1995] PCB is used in transformers, capacitors, hydraulic liquids, lubricating oils etc. Main sources of PCB are direct emissions from open use, leakage from transformers, waste incineration, coal combustion, metallurgy, landfills.

In European PCB emission inventory [*Berdowski et. al*., 1997] a great number of sources has been estimated: brown and hard coal (one emission factor for SNAP codes 01, 02, 03); open hearth furnace (040207); basic oxygen furnace (040206); sintering (040209); waste incineration (090200), electrical equipment (transformers and capacitors); re-emission from soil and water.

In addition PCB emissions from other sources such as pig iron casting (040203), electric arc furnace (040207), rolling (040208) and road transport (070000) have been calculated. These estimates were added using data provided by individual countries (e.g. Poland provided data on emissions for pig iron, electric arc furnace and rolling).

While inventorying PCB emissions in the USA [*Locating and Estimating…*, 1987] open use, losses and evaporization from closed systems, incomplete combustion of PCB and wastes containing PCB, keeping in storage of wastes and equipment (transformers, capacitors etc.) containing PCB were considered as potential sources of PCB emissions.

According to estimates of Czech and Slovakian experts [*Holoubek et. al.*, 1993] PCB emission sources are: PCB use and production, treatment of wastes containing PCB, secondary non-ferrous metallurgy (mainly secondary production of lead), pulp and paper production, evaporization from landfills.

It should be mentioned that according to the available data the bulk of PCB emission to the environment is due to leakage from electrical equipment (according to TNO estimates - more than 90%).

The analysis of available data on PCDD/F and PCB emission sources collected and considered the following statistical information on the following processes:

- stationary fuel combustion (fuel oil, coal, peat, wood);
- mobile sources (fuel structure);
- waste incineration;
- steel production (first of all electric arc furnace steel);
- sintering;
- coke production;
- secondary production of copper, lead and aluminium;
- production of PCBs and other products containing chlorine;
- PCB use in transformers and capacitors.

In addition as far as it was possible we considered iron production and casting, production of cement, asphalt, lime, glass and some other sources.

The procedure of emission calculations

We used a simple methodology of PCDD/F emission calculation based on emission factors with appropriate activity statistics:

Emission = Emission factor x activity

The concept of emission spatial distribution

In accordance with the volume of emissions, peculiarities of geographical location and availability of information two types of sources were considered:

- area sources;
- point sources.

The majority of source categories belong to the first type (stationary fuel combustion, mobile sources, iron cast production, cement, lime, asphalt etc.). Area source emissions were distributed over the 50x50 km^2 grid in proportion to population in grid cells.

The second category includes waste incineration plants, sintering plants, production of coke and non-ferrous metals (except secondary aluminium). Spatial distribution of point source emissions included the determination of its emissions and coordinates.

Installations with PCB fluids (transformers, capacitors etc.) represent a special case. Their inventory now are at the initial stage and at present more common estimates of such installations are available for an individual enterprises (point sources), than for a region or country (area sources). The inventory of this emission is described in detail in section 4.

3. Sources and emission factors of PCDD/Fs

This section describes briefly the information used in calculations of dioxin/furan emissions and the substantiation of the emission factors selected.

3.1. Stationary fuel combustion

Stationary fossil fuel combustion is an essential source of dioxin emissions. In the countries of the former USSR various types of fuel are consumed. The dominant fuels are residual fuel oil, hard coal, natural gas, firewood, in less quantities peat, shale oil and other types.

For calculation of emissions from fuel combustion by SNAP source categories (level 1) an appropriate information structure is necessary. This is a complicated task because in the NIS countries the statistical reporting was based on the classification different from that of SNAP. To distribute the available official data with SNAP source categories additional information is needed otherwise to make some assumptions.

The statistics on quantities of fuel consumed was provided by national Ministries (State Committees) of Statistics. When the official data were incomplete we use expert estimates and interpolation. We consider each country separately taking into account the structure of fuel consumption and possible changes in the period from 1990 to 1997, industrial production dynamics and other factors.

Measurements data of dioxin emissions were taken from the Netherlands, Denmark, Germany, the USA and some others. These measurements demonstrate a wide range of concentrations. Therefore estimates of the total emission and the share of dioxin emissions from combustion in it are different.

Technical paper… [1995] recommends emission factor 1 μg TEQ/t for fuel oil combustion, 0.1-10 μg TEQ/t for coal and peat combustion, 0.1-5 μg TEQ/t for firewood combustion.

In the US inventory of dioxins the following factors were used: 2 μg TEQ/t (domestic sector) and 0.82 μg TEQ/t (industrial combustion and utility sector) for firewood combustion; 0.087 μg TEQ/t for coal combustion in the industrial and utility sectors; 0.2 μg TEQ/t for fuel oil combustion in the industrial and utility sectors.

In estimates of dioxin emission from fuel combustion in the Czech Republic and Slovakia the following factors were used: 0.15 μg TEQ/t of hard coal, 0.62 μg TEQ/t of coke, 2 μg TEQ/t of brown coal, 0.054 μg TEQ/t of fuel oil [*Holoubek et. al.*, 1993].

Solid fuels in the NIS countries are burnt in various boilers, heat generators, furnaces different both in design and fraction of emitted ash but these differences cannot be taken into account so far.

In calculations of dioxin emission factor for coal combustion it is important to know the content of volatile organic compounds, for firewood - usage of polluted wood (treated by preservatives, varnish, paints, etc.). Burning of such wood causes a sharp increase of dioxin emissions; according to the *Technical paper*... [1995], the recommended factor for such cases - 20-100 μg TEQ/t.

Dioxin emission is highly increased also for the combustion of polluted oil. But the fraction of polluted oil consumed is impossible to consider now.

Data on dioxin emission factors for shale oil combustion are not available in the literature. We accept they are the same as those for coal combustion.

In recent inventories [*Dioxin and Furan Inventories*…, 1999] natural gas is not considered as a source of dioxin emission. We also do not consider this source in our calculations.

Emission factors used in calculations of dioxin emission from stationary fuel combustion are demonstrated in Table 1.

Table 1. PCDD/F emission factors for stationary fuel combustion, μg TEQ/t

Fuel	Fuel combustion		
	Power generation	Industrial & municipal	Resi-dential
Fuel oil and other liquid fuels	0.2	0.2	0.2
Coal	0.2	1	2.5
Peat	0.2	1	2.5
Firewood	0.2	1	5
Shale oil	0.2	1	2.5

3.2. Industrial processes

In this section combined sources under SNAP codes 04 (production processes) and partially 03 (processes with contact) are discussed (except of processes referring to combustion for generation of power and heat considered in the previous subsection).

Processes in iron and steel industries

Coke Production

Measurements carried out in the Netherlands [*Bremmer et. al*., 1994] showed that dioxin emission from coke production (wet quenching) is 0.23 μg TEQ/t of coal. We use emission factor 0.25 μg TEQ/t of coal.

Coke production was considered as a point source.

Sintering

Statistical information on sinter production was received from Ministries of Statistics of Russia, the Ukraine and Georgia (in other countries there is no sintering industry).

Raw components undergoing sintering contain some quantities of chlorine and organic compounds stipulating dioxin formation.

Technical paper... [1995] recommends to use factor 0.5 μg TEQ/t of sinter cake for the treatment of high efficiency, 5 μg TEQ/t - for the treatment of moderate efficiency and 50 μg TEQ/t - without treatment. Measurements in Sweden fixed dioxin emission up to 3 ng TEQ/ nm^3, in the Netherlands - 2-3 ng TEQ/nm^3 (at volume of flue gases 2000 nm^3/t of cake the emission factor is 4-6 μg TEQ/t). In the USA in the assessments of dioxin emission from sintering emission factor equal to 14.5 μg TEQ/t is used. *Atmospheric Emission Inventory Guidebook* [1999] recommends to use factor 0.3 - 6 μg TEQ/t.

In view of low efficiency of control and worn out equipment in the countries of the former USSR we have accepted 15 μg TEQ/t as the emission factor for dioxin emission from sintering.

The number of sintering plants is small but their input to dioxin emission is essential; for this reason we considered them as point sources.

Electric furnace steel production

Metallic scrap from various economic sectors are widely used as the raw material (75-100%). Use of the scrap contaminated by lubricating oil and plastics containing chlorine may stipulate the formation of chlorinated aromatic compounds.

In the NIS countries charging includes only preparation and sorting of the scrap. It does not undergo thermal treatment and washing thereby increasing the emission and the number of chemicals contained in it.

Emission factor recommended by the *Technical Paper*... [1995] - 2 μg TEQ/t of steel. Measurements in Germany [*Umweltbundesamt…*, 1996] pointed out mean emission 1.15 μg TEQ/t of scrap, measurements in the United Kingdom - from 0.7 to 10 μg TEQ/t of scrap [*Eduljee and Dyke*, 1996].

Investigations carried out in Sweden with 10-tonne electric arc furnaces [*Tysklind et. al*., 1989] showed that the quantity of components containing chlorine is very important but the construction of metal loading is more important in regard to dioxin emission. Measured quantities of dioxins ranged from 0.1 to 1.5 μg TEQ/m^3 of gas. The highest emission was measured at loading of scrap containing PVC-plastics (7.7 μg TEQ/t of scrap at cleaning by a bag filter). The scrap free of PVC resulted in dioxin emission 0.8-0.9 μg TEQ/t.

Atmospheric Emission Inventory Guidebook [1999] presents a wide spectrum of emission factors for dioxin emissions from electric arc furnace - from 0.068-0.23 μg TEQ/t (German measurements) to 2-20 μg TEQ/t (Dutch measurements). We use factor 2 μg TEQ/t of steel.

Electric furnace production in Russia and the Ukraine where it is well developed is considered as an area source. In countries where this production is concentrated on one plant - as a point one (Belarus, Moldova).

Grey iron foundries

Like in the case of electric arc furnaces the source of PCDD/F emissions is the use of scrap contaminated by lubricating oil and plastics with chlorine, chlorine containing components used for scrap preparation.

Experimental data for the calculation of emission factor in literature is very scarce. *Holoubek et. al.* [1993] suggest dioxin emission factor 2 μg TEQ/t. German measurements fixed mean emission equal to 1.26 μg TEQ/t of loading scrap.

We accept the factor 2 μg TEQ/t.

Grey iron production in foundries is presented at many metallurgical and machine building plants; we consider it as an area source.

Non-ferrous industry

Secondary copper production

Secondary non-ferrous metallurgy (production of non-ferrous metals and alloys from scrap and slag) is an essential source of dioxin emission. Scrap and metallic wastes may contain organic pollutants - plastics, paints, solvents. In some processes salts are used (NaCl, KCl etc.). Combustion of these admixtures and chlorine salts in the process of

reduction may result in the formation of PCDD/Fs.

Experimental data on dioxin emission from secondary copper production are isolated. *Technical Paper*… [1995] recommends to use the emission factor 20 μg TEQ/t of secondary copper. Measurements made in the USA gave the value of emission as much as 779 μg TEQ/t of copper scrap [*Locating and estimating...*, 1998]. The measurements were carried out on a shaft furnace loaded by 4-5 tonnes of scrap and fueled by coke. In the course of testing the furnace was charged by telephone scrap and metallurgical slag and other copper containing wastes. The telephone scrap amounted to 22% of the weight of total scrap. It was the only raw material which contained plastics.

We accept the factor equal to 200 μg TEQ/t of secondary copper.

This source category was considered as a point source.

Secondary lead production

Dioxin emission from secondary lead production is connected first of all with PVC use in automobile accumulators.

USA measurements carried out at plants of lead scrap processing showed emission from blast furnaces 0.63-8.31 μg TEQ/t of lead, from reverberatory furnaces - 0.051-0.41 μg TEQ/t, rotating furnaces - 0.24-0.66 μg TEQ/t of lead. The emission from blast furnaces was the highest since low temperature in the loading column brought about the incomplete combustion of organic matter contained in raw materials. However, emission factors used in the USA cannot be applied to the former USSR since in the USA PVC is not used in the production of automobile accumulators. We use the factor 20 μg TEQ/t of lead. It is a mean value of the recommended factors presented in the *Atmospheric Emission…* [1999] (5-35 μg TEQ/t of secondary lead).

The number of secondary lead production plants is not great. This source category was considered as a point source.

Secondary aluminium production

Aluminium production from aluminium containing scrap has two stages - preparation and melting. Each stage may be a source of dioxin emission.

Generalized statistical data on the secondary aluminium production is not available. Thus the estimates of its production for the NIS countries were made reasoning from the assessment of the ratio of primary and secondary aluminium production available in the literature. According to [*Khudyakov et. al.,* 1987; *Kuprjakov*, 1995] about 20% of aluminium production is accounted for the secondary raw material. According to data of IPAI the relationship of primary and secondary aluminium production is about 10:1. In the USA, France and Austria the fraction of secondary aluminium production is up to 50% of its total production [*Atmospheric Emission Inventory Guidebook*, 1999].

Measurements demonstrate high variability of dioxin emissions. According to [*The Protocol on Persistent Organic Pollutants*, 1998], the level of PCDD/F emissions from melting furnaces for secondary aluminium production varies within the limits of 0.1-14 ng TEQ/m^3. These levels depend upon the type of melting aggregates, used raw materials and control equipment for flue gas cleaning. According to German measurements [*Umweltbundesamt…*, 1996] dioxin emission varies from 0.01 to 167 μg TEQ/t of scrap, accepted mean dioxin emission factor - 42 μg TEQ/t. According to measurements carried out in California mean dioxin emission - 37 μg TEQ/t of scrap. In the USA for calculations of emissions from the

secondary aluminium production the factor 13.1 μg TEQ/t of scrap was used. *Technical paper*..., [1995] recommended to use the emission factor 2 μg TEQ/t of aluminium.

For our calculation we have accepted the factor equal to 50 μg TEQ/t of scrap.

It is hardly possible to estimate spatial distribution of emissions from secondary aluminium production. It was considered as an area source.

Other processes in ferrous and non-ferrous industries

Many other thermal processes in ferrous and non-ferrous metallurgy can be considered as sources of dioxin emission: primary production of aluminium, nickel production, magnesium production, blast furnace etc. In Germany high dioxin concentrations were measured at secondary zinc production - 62.2-379 μg TEQ/t [*Quass and Fermann*, 1997]. Since only odd information is available it is difficult to estimate emissions from these processes. These productions usually are not considered in national inventories: either dioxin concentrations in flue gases are not high or insufficient data are available for the assessment of emission factors. Among this group of sources we have estimated emissions from blast furnaces (emission factor - 0.3 μ TEQ/t).

Cement production

Raw materials for cement production contain organic admixtures which may be a source of dioxin formation. However, the principal source of dioxin emission (when wastes are not combusted in furnaces) is fuel combustion.

Data on dioxin emissions from cement production is rather few and emission factors are rarely available in literature. In the US dioxin inventory for cement production the emission factor is accepted equal to 0.29 μg TEQ/t of clinker (coal fired).

Cement production may be a significant source of dioxin emission when hazardous wastes are incinerated in cement furnaces. In these cases dioxin emissions abruptly increase: in the inventory mentioned above at the incineration of hazardous wastes in cement furnaces the emission factor was taken equal to 24.34 μg TEQ/t of clinker.

But wastes incineration in cement furnaces is not characteristic of the NIS countries. No information on such incineration is available. Thus we use the factor 0.2 μg TEQ/t for an approximate estimate of dioxin emission from cement production.

Statistical data on cement production is published regularly by statistical agencies. The information on individual cement plants, however, is not complete. With allowance made for the fact that the contribution of cement production is relatively small this source category was considered as an area source.

Other production processes

In the literature many other production processes are considered as dioxin emission sources: production of pulp and paper, asphalt, glass, lime, brick etc. On the whole their input is not high. We estimated emissions from lime and asphalt production (emission factors are 0.08 and 0.007 μg TEQ/t respectively).

Production and use of chlorinated products

Dioxins as many other POPs enter the environment also as a result of production and use of chemicals contaminated by dioxins.

Essential dioxin emissions are recorded at the production of pesticides, in particular 2,4,5-T and 2,4-D. Dioxin emission is observed at the production of chlorinated paints, polyvinyl chloride, chlorophenols and some other chemicals.

Dioxins are typical pollutants of such products as chlorophenols, chlorobenzenes, chloroaniline paints and PCBs. For example a kilogram of pentachlorophenol may contain 2320 μg TEQ of dioxins, Chlophyne A 60 (one of commercial PCBs) - up to 2179 μg TEQ [*Dioxin and Furan Inventories…*, 1999]. However, data on emissions to the atmosphere from these productions very are scarce; some of them were stopped (e.g. PCB, 2,4,5-T).

3.3. Mobile sources

Calculations of emissions from mobile sources can be performed by two methods: based on mileage emission factor and emission factor per fuel unit. The first method requires information on the total mileage of different transport categories, the second one - the volume of different fuels consumed.

More reliable for NIS is the second method because fuel is better accounted than mileage.

There are odd and often contradictory data on dioxin emission from transport. For the most cases they are based on experiments carried out in tunnels and garages. For example, in [*Holoubek et. al.*, 1993] dioxin emission from the combustion of leaded gasoline is in the range 0.035-1.4 μg TEQ/t, of unleaded gasoline - 0.0062-0.07 μg TEQ/t, diesel fuel - 0.015-62 μg TEQ/t. *Technical paper*... [1995] recommends to use emission factor 0.5 μg TEQ/t of fuel for calculations of emissions from the combustion of leaded gasoline. The same factor is recommended by specialists of IEIA (Katovize) for the whole transport fueled by gasoline. For SNAP category of transport vehicles under code 08 *Technical Paper…* [1995] recommends to use factor 1 μg TEQ/t. In the US dioxin inventory the following emission factors are used: diesel transport - 172 pg TEQ/km, transport fueled by leaded gasoline - 45.7 pg TEQ/km, transport fueled by unleaded gasoline - 1.7 pg TEQ/km.

Experimental investigations of dioxin emissions from mobile sources are of a single character in the NIS countries. Investigations carried out within the framework of Programme “Dioxin” (Russia) showed that road transport is an essential source of dioxin emission. The pollution level from engines fueled by leaded gasoline appeared to be comparable with emissions from furnaces incinerating chlororganic wastes. Cars working on the fuel containing tetra-alkyl lead and dichloroethane emit each kilometer up to 12 pg of 2,3,7,8-TCDD or 30-540 pg TEQ/km.

For calculations of dioxin emissions we used the factors demonstrated in Table 2. Regional peculiarities were not taken into account.

The emission distribution over the 50x50 km^2 EMEP grid was made proportionally to the population density.

Table 2. Emission factors for PCDD/F emissions from all the transport categories, μg TEQ/t

Fuel	Emission factor
Unleaded gasoline	0.05
Leaded gasoline	0.5
Diesel fuel	1

3.4. Waste incineration

Domestic waste incineration

Incineration of solid municipal wastes is the main thermal method of their neutralization. The incineration is aimed at the reduction of waste amount, destruction of pathogenic

microflora, decomposition and oxidation of organic substances.

In the NIS countries installations for mass incineration of wastes are used. They have no pre-treatment of wastes before incineration. The main technique is incineration on steady or travelling chain grates. At plants of the first generation electrofilters with the efficiency of 97.6-99% are used. These plants have no control system of the second stage. Only some plants have been reconstructed and equipped with bag filters. In view of aged equipment when calculating dust emission to the air it is necessary to use the lower limit of efficiency - 98%. Measurements carried out at reconstructed waste incineration plants are of most interest. The measured mean dioxin concentration in flue gases after ESP was 1.1 ng TEQ/m^3, after the bag filter - 0.5 ng TEQ/m^3. The emission factor is 3 μg TEQ/t (at 6000 m^3 flue gas per tonne of wastes). These are very preliminary results applicable to relatively efficient plants.

It was reasonable to use results of measurements carried out in the Czech Republic and Slovakia where a similar technology is used [*Holoubek et. al.*, 1993]. For calculations of dioxin emission in these countries the emission factor is equal to 60 μg TEQ/t. This factor is close to that recommended in the *Atmospheric Emission…* [1999] (50 μg TEQ/t).

Taking into account conditions of equipment operation, availability of the first abatement stage only, absence of waste separation for old waste incineration plants the emission factor equal to 50 μg TEQ/t may be accepted. For reconstructed plants we take the emission factor equal to 5 μg TEQ/t.

Incineration of industrial and hospital wastes

This waste category involves all the wastes of industrial and medical origin which can be utilized by incineration: fuels, oils, acids, halogenized products, wastes of organic raw material processing, hospital wastes etc. and incineration of sewage sludge. This category of incineration, in particular incineration of hospital wastes, is most dangerous in view of dioxin emission.

Information on the incineration of these wastes is very sparse for the NIS countries.

Data on industrial waste incineration are also odd. The analysis of the available data suggested that in the NIS countries there are no large installations for centralized incineration of industrial wastes. Large-scale incineration of industrial wastes in cement kilns does not take place. However, at the same time plants have installations for the incineration of their own wastes.

Data on sewage sludge incineration (SNAP 090205) in the NIS countries are not available.

Within the framework of this inventory it is impossible to estimate quantitatively volumes of the incinerated wastes.

Cremation

On the territory considered 9 crematoria are functioning. Cremation furnaces of Czech production are most widely used. These furnace are not equipped with cleaning devices, except for several furnaces of a new generation (TABO-STANDARD) installed during recent years and equipped with secondary furnaces. They are fuelled by natural gas.

No data on POPs concentrations emitted from crematoria have been found in the NIS countries. For approximate estimation of dioxin emission we use the factor of 3.65 μg

TEQ/body. It is the mean value of measurements results made in the Netherlands [*Bremer et. al.*, 1994].

3.5. Fires

This source category includes different burning of natural and man made character: forest fires, burning of stubble and grass, landfill fires, building fires, cars etc. This source category may contribute essentially to emissions of different POPs. It is conditioned both by a burning substance and peculiarities of fire conditions. Direct measurements, however, are few and in the majority of inventories they are estimated qualitatively.

Forest fires

Conclusions on dioxin emission from forest fires have been drawn on the basis of measurements of their concentrations in the ash and soil. There are several approaches to estimating emission factors from forest fires but due to lack of information none of them can be considered efficient. At present these estimates are preliminary useful for the identification of potential sources.

One of possible approaches is an application of the same factors as for firewood. Using mean emission factor 5 μg/t of the burnt biomass, the volume of accessed for burning material - 1.5 kg/m^2 [*Holoubek* et al., 1993] and having the data on forest fire areas [*The Environment in the NIS*…, 1996] we obtained emissions in 1990 in Russia –103 g TEQ, in the Ukraine – 0.18 g TEQ, in Belarus - 0.075 g TEQ.

As it was mentioned any emission estimates from forest fires are very uncertain because no measurements were made during real fires. For this reason the presented calculations are not included to dioxin emission inventory.

Fires of PCB containing equipment

The formation of dioxins in fires of transformers with PCBs was documented by the analysis of soot. For example, in the soot at the fire place of the administrative building in Binghamton (New-York) 20 mg/kg of PCDDs and 765-2160 mg/kg of PCDFs were measured. From estimates of [*Thomas and Spriro*, 1995] at fires the emission factor for dioxins is 20 mg TEQ/t of PCB burnt. In the USA every year 1% of PCB in use is burnt. High dioxin concentrations result from relatively low temperatures and excess of oxygen at fires.

The statistics of fires of PCB containing equipment is absent. The assessment of dioxin emission from such accidents is very complicated. For its evaluation it is necessary to have information on the quantity of the equipment containing PCB and burned volumes.

Other open burning

This category of open burning includes various types of fires which covered different areas and lasted different time:

- open incineration of domestic garbage in the private sector;
- fires at landfills of domestic wastes;
- structure fires;
- incineration (burning) of railway sleepers;
- deliberate or accidental automobile fires (case, tyres and other components);
- biomass burning (for example, stubble, grass, leaves or branches).

On the whole these processes are important sources of dioxin emission. It is connected with peculiarities of conditions under which fires take place, involvement of a great amount of plastics in particular PVC. At open burning of garbage the emission factor is 140-300 μg

TEQ/t of garbage; at landfill fires - up to 1000 μg TEQ/t. However, measurements of emissions of such events are few. Within the framework of our inventory it is not possible to make a quantitative estimate of emissions from these sources.

3.6. Electrical equipment

The electrical equipment filled with PCB is the most essential source of emissions of PCB and dioxin contained in commercial PCB. It is reported that Arochlor 1242 and 1254 on the average contain dioxins as much as 84 μg TEQ/kg. On the basis of this information and estimates of PCB losses from PCB containing electrical equipment it is possible to make an approximate estimate of the emission (leakage) of dioxins. According to our estimates it amounts to 60.9 g TEQ per year over European part of the NIS countries. This estimate, however, is not incorporated to the total inventory due to its low reliability.

The summarized emission factors used are presented in Table 3.

Table 3. Emission factors used for PCDD/F emission calculations

Source category	SNAP	PCDD/F, µg TEQ/t
Stationary fuel combustion	**01+02+03**	
Combustion in energy production and energy transformation	**010000**	
Fuel oil	01fo	0.2
Coal	01c	0.2
Peat	01p	0.2
Firewood	01w	0.2
Other liquid fuels	01ol	0.2
Other solid fuels	01os	0.2
Combustion in commercial, institut., resident. sectors and agriculture, forestry, fishing	**020000**	
Fuel oil	02fo	0.2
Coal	02c	1/2.5*
Peat	02p	1/2.5*
Firewood	02w	1/5*
Other liquid fuels	02ol	0.2
Other solid fuels	02os	1/2.5*
Combustion in industry	**030000**	
Fuel oil	03fo	0.2
Coal	03c	1
Peat	03p	1
Firewood	03w	1
Other liquid fuels	03ol	0.2
Other solid fuel	03os	1
Production processes	**03&04**	
Iron and steel industries		
Sinter plants	030301	15
Coke oven furnaces	010406	0.25
Blast furnace	030302	0.03
Electric furnace steel plant	040207	2
Grey iron foundries	030303	2
Non-ferrous metal industries		
Aluminium production	040301	-
Primary copper production	030306	-
Secondary lead production	030307	20
Secondary copper production	030309	200
Secondary aluminium production	030310	50
Cement	030311	0.2
Lime	030312	0.08
Container glass and glass wool	030315&16	-
Asphalt concrete plants	030313	0.007
Proc. in organic chemical industr. (bulk production)	04050x	-
Processes in wood, paper pulp, food&drink industries & other industries	04060x	-
Solvent and other product use	**060000**	
Paint application	06010	-
Degreasing, dry cleaning and electronics & other use of solvent and related activities	0602&0604	-
Preservation of wood	060406	-
Use of PCB	06PCB	-
Road transport & Other mobile sources and machinery	**07+08**	
Non-leaded gasoline	07gs	0.05
Leaded gasoline	07e	0.5
Diesel fuel	07+08d	1
Fuel oil	08fo	1
Other liquid fuels	07+08olf	1
Waste treatment and disposal	**090000**	
Incineration of domestic or municipal wastes	090201	50/5[1]
Incineration of industrial wastes	090202	-
Incineration of hospital wastes	090207	-
Cremation	090901	3.65[2]
Open burning of wastes	090907	-
Landfills	091004	-
Structure and other fires	09f	-
Agriculture	**100000**	
Stubble burning	100300	-
Use of pesticides	100600	-
Electrical equipment	**eel**	
Transformers	eeltra	-
Capacitors	eelcap	-
Nature	**110000**	
Forest fires	110300	-

[1] For reconstructed plants [2] Per body * Domestic combustion - not applicable

4. Sources and emission factors for PCB

The main PCB emissions to the environment can be divided into 4 groups:

1) production of PCB and products (equipment) containing PCB;
2) use of products containing PCB;
3) utilization of PCB and materials containing PCB;
4) emission from reservoirs polluted by PCB.

At present in the countries of the former USSR commercial PCBs and products including PCB are not produced. This production was stopped in the early 90-s. Therefore the first group may be eliminated from the consideration. For the retrospective consideration of emission this group is important because it is known that the production of capacitors with PCBs reached 10-20% of dielectric used for filling.

Polychlorinated biphenyls had and partially have various application - in closed systems (such as dielectric liquids in capacitors and transformers, in hydraulic and cooling equipment, cables) and as a peptizers for paper impregnation, in production of paints etc. (so-called open application).

As it was already mentioned that the bulk of PCB emission to the environment is due to leakage from electrical equipment. Thus in the current estimates the main attention is paid to this source category. The approaches are described in the following sector. Utilization of PCB and materials containing PCB and emission from reservoirs polluted by PCB were not estimated quantitatively due to lack of data.

4.1. Electrical equipment

The bulk of PCB emission results of direct leakage from damaged electrical equipment. The reason for damage may be break-down (sometimes seal failure of metallic frame), physical wear, frame corrosion.

For calculations of PCB emission data on the total amount of PCB contained in the equipment is required. In the USSR no inventory of electrical equipment with PCBs has been made. In 1995-96 the State Committee on Ecology of Russia inventoried the electrical equipment containing PCBs. In 1999 PCBs inventory was started in the Ukraine and Belarus.

At this stage to estimate PCB volume used in the electrical equipment we made expert estimates with allowance made for the volume of liquid produced and its use at electrical-technological plants.

PCB production in the USSR

On the territory of the former USSR PCB was mainly produced by production associations “Orgsteklo” and “Orgsintez”. By the data [*Shulyakovsky and Treger*, 1999] the USSR has produced about 180 thous. tonnes of PCB (Table 4).

Table 4. PCB production in the former USSR, thous. tonnes

PCB	“Orgsteklo”		“Orgsintez”		TOTAL
	Production	Period	Production	Period	
Sovol	43	1939 - 1990	9.5	1972 – 1993	52.5
Sovtol	32	1939 – 1987	25	1972 - 1990	57
Trichlorodiphenyl	70	1968 – 1990	-		70
Total	145		34.5		179.5

Trichlorodiphenyl (TCD) was used in capacitors only. The principal consumer of Sovol was paint and varnish industry (70% of total use); for lubrication - about 20%. The fraction of electric-power industry is about 10% of the total production of Sovol that is 5 thous. tonnes (without import). Sovtol-10 was used in transformers only.

Estimate of PCB quantity in capacitors

In the USSR during 1959-90 for the production of capacitors 90 thous. tonnes of PCB was consumed. An essential part of it entered the environment in the processes of filling of capacitors (we assume that this fraction is equal to 10% of PCB consumed). Since the service life of capacitors is 20-25 years, an essential part of them is out of date and substituted. For example, according to the inventory of electrical equipment in Belarus and the Ukraine at present capacitors produced after 1972-75 are being used or kept (there are rare cases of availability of capacitors of 1968-70 production), i.e. capacitors of 1959-71 production are “lost” in the majority of cases. It means that about 38% of the total amount of PCB or about 30-31 thous. tonnes is dispersed in the environment.

On the territory of the former USSR according to our estimate about 50 thous. tonnes of PCB should be in capacitors (at service, reserve, damaged) of which 34 thous. tonnes are accounted for European part.

Estimate of PCB quantity in transformers

In the USSR 57 thous. tonnes of Sovtol-10 have been consumed for the transformer production. Transformers with Sovtol-10 have been in use for 60 years. Their mean life lasts 40 years. Before 1960 it was produced and consequently used 13 thous. tonnes of Sovtol-10. Evidently this quantity has been dispersed by present. About 44 thous. tonnes of Sovtol-10 could be kept in transformers. About 31 thous. tonnes are accounted for European part of the USSR.

The obtained data of PCB amounts in capacitors and transformers in the NIS and Baltic countries are demonstrated in Table 5.

Table 5. Expert estimates of PCB in capacitors and transformers, t

Country	PCB in capacitors	PCB in transformers
Azerbaijan	360	300
Armenia	180	150
Belarus	495	500
Georgia	261	200
Latvia	117	100
Lithuania	180	150
Moldova	207	150
Russia (European part)	12870	11500
Ukraine	10710	8500
Estonia	72	70
Total for European part of the former USSR	34452	31120

Emission factors

Investigations carried out at a number of plants and power stations of Belarus equipped by transformers and capacitors with PCBs and the analysis of literature data make it possible to estimate releases (leaks, spills) of PCB from the equipment in use. They are 0.3 kg/t for transformers and 2 kg/t for capacitors.

It is known that not all PCB flown out volatilizes. The volatilization process is very complicated and depends upon many local conditions. It is determined that on the whole volatilization rate decreases with the growth of chlorination degree. For this reason PCB of capacitors containing trichlorodiphenyl volatilizes more rapidly than Sovtol-10 run out of transformers. Taking into account literature data and peculiarities of equipment operation we assume that during the first year 40% of run out trichlorodiphenyl and 20% of Sovtol-10 volatilize. These coefficients are used for the estimation of PCB emission factors (Table 6).

Table 6. Releases (leaks, spills) of PCB from electrical equipment and its emission factors, kg/t per year

Equipment	Release	Emission
Transformers	0.3	0.06
Capacitors	2.0	0.8

4.2. Other sources of PCB emissions

In many countries incineration of domestic, hospital and other wastes are the significant sources of PCB emission. Measurements carried out in the Czech Republic and Slovakia showed that the level of PCB emission is equal to 1.0-1.9 mg/t; the mean value is taken equal to 1.5 mg/t [*Holoubek et. al.*, 1993]. Later at waste incineration plant in the Czech Republic mean emission of total PCBs is estimated equal to 5.8 mg/t of wastes [*Parma et al*., 1995]. For provisional estimates we take mean emission as 5 mg/t of incinerated domestic wastes. At volumes of incinerated wastes of about 1 mill. tonnes in the Ukraine and Russia in 1990 PCB emission is 5 kg, in 1997 (incineration of about 600 thous. tonnes) - 3 kg. Regarding industrial and hospital wastes, as it was mentioned earlier, there are no data on the volumes of their incineration.

Other processes in various inventories are mentioned also as sources of PCB emissions. Reservoirs and open application may be considered as the most significant sources among them. The equipment containing PCB (if it has not run out into soil or water) mainly ends its life on landfills. Besides essential quantities of PCB are accumulated in soil of plants producing PCB and equipment containing PCB. However, within the scope of this investigation it is impossible to estimate emission from these categories of sources – there are no statistical data and emission factors.

Spatial distribution of emission

Emission distribution over the 50x50 km^2 EMEP grid was made for the country (region) proportionally to the population number in grid cells.

5. Results

The annual PCDD/F emissions in the NIS and Baltic countries in 1990, 1995 and 1997 are presented in Table 7.

Table 7. Annual PCDD/F emissions in the NIS and Baltic countries (g TEQ)

Country	1990	1995	1997
Azerbaijan	2.95	2.69	1.46
Armenia	2.63	1.02	1.10
Belarus	22.3	13.9	16.4
Georgia	24.4	28.5	28.2
Latvia	3.83	3.80	11.8
Lithuania	6.98	3.88	5.94
Moldova	8.10	3.20	2.26
Russian Federation*	669	473	441
Ukraine	1074	476	518
Estonia	8.58	6.41	10.1

*- European part

The calculation results of PCDD/F emissions from source categories in the countries are demonstrated in Annex A (Tables A.1 – A.10). For the convenience of use the tables have a standard format.

The tables include quantitative estimates of emissions. When it is impossible to obtain an acceptable estimate of emission we suggest qualitative ranging of sources of 3 categories:

1) the process (source) is not represented on the territory of a given country or is insignificant;
2) there is information that a given sector (process) is a source of PCDD/F emission;
3) there is evidence that a given sector (process) is an important source of

PCDD/F emission but the assessment of its quantitative contribution with a sufficient accuracy appears to be impossible.

This ranging can be useful in subsequent inventories.

Maps of PCDD/F and PCB emission distribution over the 50x50 km^2 EMEP grid are shown in Figures 1-4.

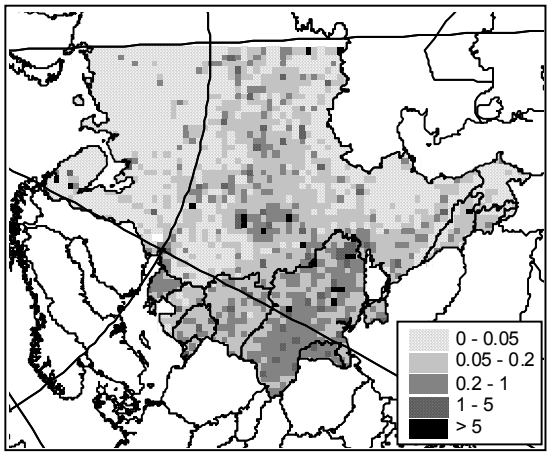

Figure 1. Distribution of dioxin emission over European part of the former USSR for 1990, g TEQ

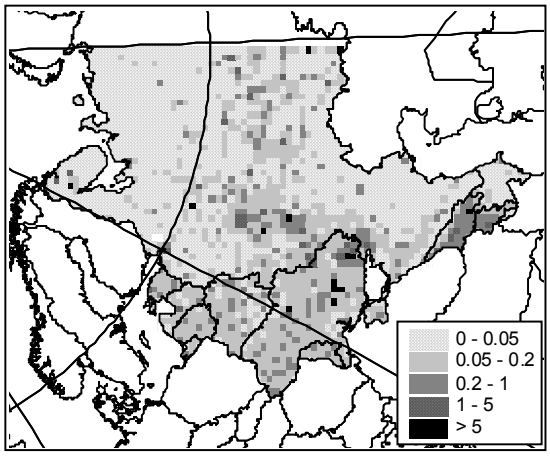

Figure 2. Distribution of dioxin emission over European part of the former USSR for 1995, g TEQ

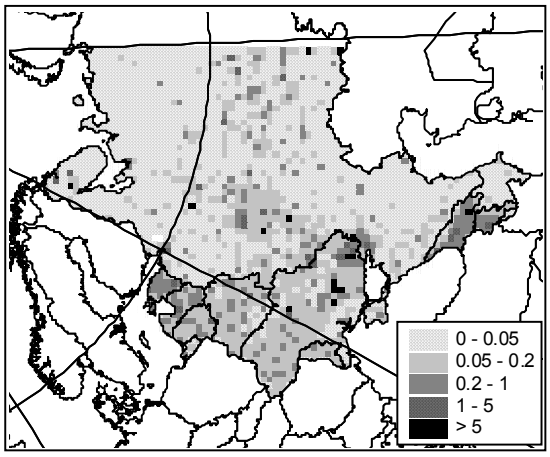

Figure 3. Distribution of dioxin emission over European part of the former USSR for 1997, g TEQ

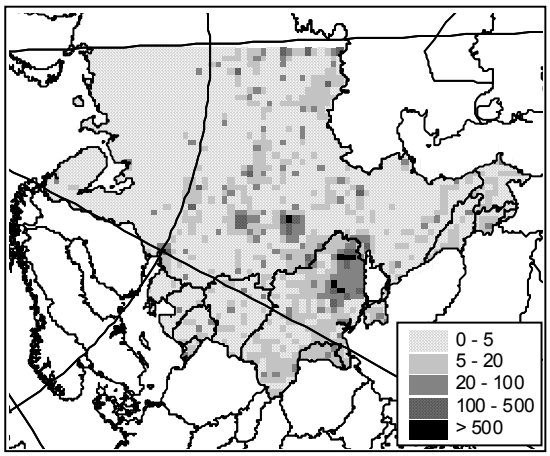

Figure 4. Distribution of PCB emission over European part of the former USSR for 1997, kg/y

The calculation results of PCB releases and emissions from electrical equipment are summarized in Table 8. Calculations for individual years have not been made since the determination of dynamics of PCB emission from electrical equipment is impossible so far. The data of the table characterize PCB emissions reasoning from the current state i.e. approximately for 1997.

Table 8. Releases and emissions of polychlorinated biphenyls from electrical equipment in the NIS and Baltic countries, kg/y

Country	Source	Source code	Releases	Emissions
Azerbaijan	Capacitors	eelcap	720	288
	Transformers	eeltra	90	18
	Total		810	306
Armenia	Capacitors	eelcap	360	144
	Transformers	eeltra	45	9
	Total		405	153
Belarus	Capacitors	eelcap	990	396
	Transformers	eeltra	150	30
	Total		1140	426
Georgia	Capacitors	eelcap	522	208.8
	Transformers	eeltra	60	12
	Total		582	220.8
Latvia	Capacitors	eelcap	234	93.6
	Transformers	eeltra	30	6
	Total		264	99.6
Lithuania	Capacitors	eelcap	360	144
	Transformers	eeltra	45	9
	Total		405	153
Moldova	Capacitors	eelcap	414	165.6
	Transformers	eeltra	45	9
	Total		459	174.6
Russian Federation*	Capacitors	eelcap	25740	10296
	Transformers	eeltra	3450	690
	Total		29190	10986
The Ukraine	Capacitors	eelcap	21420	8568
	Transformers	eeltra	2550	510
	Total		23970	9078
Estonia	Capacitors	eelcap	144	57.6
	Transformers	eeltra	21	4.2
	Total		165	61.8

*- European part

Part II

EXPERT ESTIMATES OF POLYCHLORINATED BIPHENYLS EMISSIONS IN THE RUSSIAN FEDERATION

Inventory of PCB emission for the former USSR countries (European part) described in the previous chapter is based mainly on the balance of PCB production/application. In this chapter estimation of PCB emissions in the Russian Federation with the use of another approach is described. The informational base for a given assessment was the results of PCB inventory in the Russian Federation carried out in the framework of AMAP project [*PCB in the Russian Federation*…., 2000]. The inventory included the identification of equipment with PCB-dielectrics (operating, stored, phased out), as well as wastes with PCB. On account of data obtained from different branches of industry and territorial environmental agencies quantity of equipment, PCB volumes in this piece of equipment, as well as volumes of releases from this equipment were estimated. Data on the releases from electrical equipment containing PCB were used for calculations of PCB emission in the Russian Federation.

Emission calculation

Emissions were calculated per calendar year in relation to leakage for the same year. PCB accumulation factors in the environment due to leakage excess over evaporation was not accounted. Estimation results of PCB emissions from the equipment are presented in Table 9.

Spatial distribution of emissions

PCB emission was distributed with grid cells with resolution $1^{o}x1^{o}$. In the report [*PCB in the Russian Federation*…., 2000] there are data on point sources, areas, economic regions and on the country as a whole. Depending on the structure of the original information different algorithms of territorial distribution of releases and emission were used.

Transformers in operation were essentially considered as point sources. Emission calculation was performed directly for point sources. All emissions from point sources were summed in the range of a grid cell.

Not all point sources with transformers were identified, since in the report [*PCB in the Russian Federation*…, 2000] in a number of cases only the region of a source location was indicated. Such sources were considered as area ones, and their emissions were distributed in proportion to urban population in the grid cell of the region.

Releases from phased out transformers and capacitors are given in the report [*PCB in the Russian Federation*…., 2000] for some economic regions and for the country as a whole. In such cases emissions were distributed proportionally to urban population share of region/country in a grid cell.

PCB total emissions spatial distribution from electrical equipment contained PCB is presented in Figure 5.

Table 9. PCB emissions on source categories

Equipment type	Transformers		Capacitors		Total
	t/y	%	t/y	%	t/y
In operation	24.3	93.6	-	-	24.3
Phased out	0.04	0.2	1.6	6.2	1.64
Total	24.34	93.8	1.6	6.2	25.94

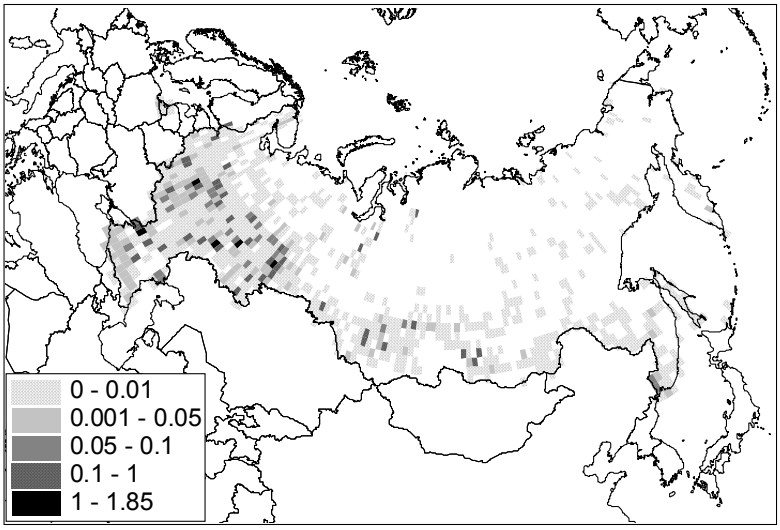

Figure 5. PCB total emissions spatial distribution from electrical equipment contained PCB, t/y (1x1 degree)

Uncertainty of emission estimates

Uncertainty of calculations of PCB emissions distributed over territories is connected with a combination of factors. They may be divided to some groups:

1) Uncertainties in estimates of PCB used.

PCB was produced during decades, consumers of products contained PCB were hundreds of enterprises and organizations.

This group of factors includes the accuracy of identification of all modern and previous PCB emission sources (manufacturers, consumers, houses, store, landfills).

2) Uncertainty of PCB release factors.

The key element of the assessment of PCB input to the environment from electrical equipment is the determination of release factors from individual transformers and capacitors, as well as their dependence on equipment type, wearing rate, etc. Such data are scarce and often inconsistent: release factors can differ by 2 orders of magnitude.

3) Uncertainty of PCB emission factors.

It is known that not all quantity of leaked PCB volatilizes. The process of volatilization is very complicated and depends on many local conditions (soil, meteorological, climatic, hydrological and others). At present the accuracy of PCB emission factors is rather moderates .

4) Uncertainties of PCB source allocation.

It is necessary to make difference between factors affecting the uncertainty of total emissions, spatial distribution of emissions, and emission dynamics. The procedure of emission distribution from area sources for which administrative areas and regions were used introduces an essential uncertainty. The distribution was made in proportion to population that is rather arbitrary.

To quantify these uncertainties seems impossible. We can perform only their ranking. The most uncertain are estimates of emissions from electrical equipment due to uncertainties of leakage factors and uncertainties of emission factors. The error in the assessment of PCB volume being used or has been used on a certain territory is also significant. The contribution of other factors (group 4) drastically affects only spatial distribution of emissions.

Comparative analysis of PCB emission calculation results for European part of Russia

Accordingly to estimates PCB emission on Russian territory was 26 tonnes, from which 18 tonnes fall on European part of the country. On estimates presented in Table 8 the emission from European part of Russia was 11 tonnes.

Analysis of calculation data on PCB emission over administrative areas showed, that results for about half of areas are close enough. Maximal discrepancies in PCB emission calculations were obtained for Samara region (increase 23 times), for Tatarstan (10 times) and Rostov, Ivanovo, Smolensk region (6 times).

At the same time PCB emission components differ very significantly. On estimates presented in Chapter 1 (Table 8), the main contribution to emissions was due to releases from capacitors, and estimates obtained on the base of the PCB inventory [*PCB in the Russian Federation…*, 2000], showed that emissions from transformers predominate (Table 10).

On the whole, main differences of obtained values of PCB emissions are due to different calculation methods of releases from transformers and capacitors.

Table 10. PCB emissions on European territory of Russia, t

Emissions	Estimates on the base of PCB inventory	Estimates on the base of PCB balance
From transformers	17.0	0.7
From capacitors	1.2	10.3
Total	18.2	11

On the data [*PCB in the Russian Federation…*, 2000] 93.6% of all releases from electrical equipment with PCB (including phased out) fall on transformers. The authors assumed, that average transformer with 1700 kg volume of PCB releases for 25 years of operation were 375 kg (or 15 kg per year). It means that, specific indices of PCB releases from transformers equal to 8.8 kg/t – the value emission factor) significantly higher, than that used in other countries in PCB emissions inventory (Table 11). At the same time it is supposed that when capacitor is in operation there is no emissions (excluding accident and fire).

It also assumed that releases from damaged equipment are negligible.

For comparison Table 12 shows PCB emission estimates for European territory of Russia obtained in a given in work and works of other authors.

Table 11. PCB releases from electrical equipment, kg/t

Equipment	Releases	Country (region)	Reference
Transformers	0.06	Europe	*Berdowski et al.*, 1995
	0.3	North America	*USEPA*, 1987
	0.3	NIS countries	*Study for Evaluation…*, 1999
	8.8	Russia	*PCB in the Russian Federation..*, 2000
Capacitors	1.6	Europe	*Berdowski et al.,* 1995
	4.2	North America	*USEPA*, 1987
	2.0	NIS countries	*Study for Evaluation…*, 1999
	0	Russia	*PCB in the Russian Federation..*, 2000

Table 12. PCB emissions in European part of Russia, t/y

Country	*Berdowski et al*., 1997	*Pacyna et al*, 1999	*Data from this report*	
Russia	10.2	8.9	11*	18.2 **

* - estimates on the base of PCB balance; ** - estimates on the base of PCB inventory

PCB emission trend analysis

In the USSR the production transformers with PCB began in 1939, capacitors - in 1958-59, and ceased by the early of 90-s. It means, that during 40 years total amount of equipment with PCB, increased and the maximum fell on the late 80-s and early 90s. Accordingly for that period we can also suppose that there was a tendency towards the increase of PCB emissions from a given sources category.

As far as PCB containing equipment was damaged it was put out of operation. A noticeable part of electrical equipment has exhausted its resource. After 1990-1992 electrical piece of equipment with PCB was not renewed, thus the share of the equipment in operation decreased and the damaged part of it increased. Little by little the damaged part accumulated and by 2010 - 20 incompletely turned to the range of damaged, as far as it will exhaust its resource. At the same time PCB emission from damaged equipment increases and at any stage its share in total emission becomes dominant.

PCB input with leakage and release to the environment is known to be accompanied by processes of volatilization, degradation and redistribution in natural components. At present it is very difficult to correlate these processes; however, PCB input to the environment due to volatilization from polluted places is supposed to keep increasing. On the whole we think that the maximum PCB emission on the territory of the former USSR should fall on the beginning of the 90-s. During the subsequent years for the lack of PCB and PCB-contained equipment production and due to gradual decrease in abundance of PCB emission inevitable reduces. At the same time the share of PCB emission as a result of volatilization from polluted places (landfills, store houses of damaged equipment) is increasing. On the estimates of [*Breivik et al.*, 2000], PCB emission maximum from small capacitors and other closed systems on the global scale falls on the end of the 70-s, when most of developed countries put under a ban the production and use of PCB and PCB-contained products.

Conclusions

Polychlorinated biphenyls emissions on the territory of the Russian Federation calculated on the base of inventory data [*PCB in the Russian Federation*…., 2000] were 26 t/y, on European part of the country - 18 tonnes.

94% of PCB emissions is from transformers releases for Russia us a whole. Such high emission share was due to assumed in [*PCB in the Russian Federation*…., 2000] method of estimation and coefficients of leakage from electrical equipment. Taking into account the analysis of literature data and own experience it seems overestimated.

For the improvement of PCB emission estimation quality in the future we should pay general attention to refinement of PCB emission factors, both from open and closed systems, that will allow to diminish the uncertainty of emission estimates.

It is reasonable to continue the inventory of PCB-contained equipment on the plants. We believe that investigations of PCB contained waste utilization, in particular electrical equipment is needed.

PCB use in open air – paints, lubricants, plasticizers – has not been studies up to now.

Reference

Atmospheric Emission Inventory Guidebook [1999]. A joint EMEP /CORINAIR Production Prepared by the EMEP Task Force on Emission Inventories, (1st edition - 1996; 2nd edition - 1999).

Axenfeld F., Munch J., Pacyna J.M., Duiser J.A. and C.Veldt [1989]. Emissionsdatenbasis fur die Spurenelemente As, Cd, Hg, Pb, Zn und fur Spezielle Organische Verbindungen γ-HCH (Lindan), HCB, PCB and PAK. Umweltforschungsplan des Bundesministers fur Umwelt Naturschutz und Reaktorsicherheit. Luftreinhaltung. Forschungbericht 104 02 588. Dornier, Juli.

Belarusian contribution/Annual report 1997 [1998]. Minsk-Moscow, January 1998.

Belarusian contribution/Annual report 1998 [1999] Further research and refinement of emission factors for heavy metals from industrial activities of the NIS countries (within the EMEP grid). Minsk - Moscow, January 1999.

Belarusian contribution/Annual report 1999 [2000]. Study for Evaluation of Emission Factors of Selected POPs from Main Activities of the NIS Countries. Minsk-Moscow, January 2000.

Berdowski J.J.M., Baas J, Bloos JP.J., Visschedijk A.J.H. and P.Y.J. Zandveld [1997]. The European Atmospheric Emission Inventory for Heavy Metals and Persistent Organic Pollutants. Umweltforschungsplan des Bundesministers fur Umwelt, Naturschutz und Reaktorsicherheit. Luftreinhaltung. Forschungbericht 104 02 672/03. TNO, Apeldoorn, The Netherlands.

Berdowski J.J.M., Veldt C., Baas J., Bloos J.P.J. and A.E.Klein [1995]. Technical Paper to the OSPARCOM-HELCOM-UNECE Emission Inventory of Heavy Metals and Persistent Organic Pollutants. TNO-report, TNO-MEP-R 95/247, Delft, the Netherlands.

Berdowski J.J.M., Pacyna J.M. and C.Veldt [1994]. Chapter 3: Emissions. In: The impact of atmospheric deposition of non-acidifying Pollutants on the Quality of European forest soil & the North Sea rep.R93/329 Main report of the ESQUAD project, RIVM rep.722401003, Van den Hout (ed.).IMW-TNO.

Breivik K., Sweetman A., Pacyna J.M. and K.C. Jones [2000]. Global emission inventory of PCBs with congener resolution. A first approach to present the historical atmospheric releases from intentionally produced PCBs. NILU.

Bremmer H.J.; Troost L.M; Kuipers G.; DeKoning J. and A.A. Sein [1994]. Emissions of dioxins in The Netherlands. National Institute of Public Health and Environmental Protection (RIVM) and Netherlands Organization for Applied Scientific Research (TNO). Report N.770501018.

Compilation of the database of POPs emission factors (PAH, HCB, PCB, dioxin/furan) for the countries of the Former USSR in coordination with national experts [1999] SRI Atmosphere report №2/33.

Dioxin and Furan Inventories/National and Regional Emissions of PCDD/PCDF. [1999] Geneva: UNEP Chemicals. 100 pp.

Eduljee G. and P. Dyke [1996] An Updated Inventory of Potential PCCD and PCDF Emission Sources in the UK. *Sci. Tot. Environ*. v.177, pp.303-321 p.

Kakareka S, V. Khomich, T. Kukharchyk, and V. Loginov et al. [1998] Heavy Metals Emission Factors Assessment for the NIS Countries. Minsk. 160 p.

Holoubek I., Caslavsky J., Nondek L., et. al. [1993]. Compilation of emission factors for persistent organic pollutants. A case study of emission estimates in the Czech and Slovak Republics.

Khudyakov I.F., Deroshkevich A.P. and S.V.Karelov [1987]. Metallurgy of secondary non-ferrous metals. Moscow, 528 p.

Kouprjakov J.P. [1995]. Shaft smelting of non-ferrous metal secondary raw materials. Moscow, 162 p.

Locating and Estimating Air Emissions from Sources of Polychlorinated Biphenyls (PCB) [1987]. US EPA-450/4-84-007n. May.

Pacyna J.M. et al. [1999]. Technical Report. Appendix 1. To the Executive Final Summary Report. Environmental Cycling of Selected Persistent Organic Pollutants (POPs) in the Baltic Region (POPCYCLING-Baltic project) Contract No ENV4-CT96-0214.

Parma Z., J. Vosta. J. Horejs, J.M. Pacyna and D. Thomas [1995] Atmospheric Emission Inventory Guidelines for Persistent Organic Pollutants (POPs). Prague, the Czech Republic, July.

PCB in the Russian Federation: Inventory and Proposals for Priority Remedial Actions [2000]. AMAP Report. ISBN 82-7971-008-6. Arctic Monitoring and Assessment Programme (AMAP), Oslo. Published by: Centre For International Projects (CIP), Moscow.

Reference book on emission factors of atmospheric pollutant for some manufactures-main sources of atmospheric pollution [1999] SRI Atmosphere, MSC-East. Saint-Petersburg. 108 p.

Quass U. and M. Fermann [1997] Identification of relevant industrial sources of dioxin and furans; quantification of emissions and evaluation of abatement technologies (The European Dioxin Inventory). Final Report, June 1997. 1997.

Shulyakovsky G.M. and Yu.A. Treger [1999] Abatement of dioxin and furan emissions. Report on Subregional Meeting of experts, Saint-Petersburg, 14-17 December.

Study for Evaluation of Emission Factors of Selected POPs from Main Activities of the NIS Countries. Belarusian Contribution into EMEP [1999]. Annual Report 1999. IPNRUE - MSC-East. Minsk - Moscow.

Technical Paper to the OSPARCOM-HELCOM-UNECE Emission Inventory [1995] TNO-report, TNO-MEP-R95/247.

The Environment in the NIS [1996]. International Statistical Committee of the NIS. M.

The protocol on persistent organic pollutants to the Convention of 1979 on Long-range Tranboundary Air Pollution in Europe and Annexes I, II or III to the Protocol [1998] UN, 193 pp.

Thomas V. and T.Spiro T. [1995] An estimation of dioxin emissions in the United States / Toxicological and *Environmental Chemistry*, No. 50. 1-37 pp.

Tsibulsky V.V., Yatsenko-Khmelevskaya M.A. [1996]. Estimation of heavy metals emission on the territory of Russia / SRI Atmosphere report. S-Peterburg.

Tysklind et al. [1989] PCDD and PCDF emissions from scrap metal smelting processes at a steel mill/ *Chemosphere*, Vol. 19, Nos. 1-6, pp. 705-710.

Umweltbundesamt [1996]. Determination of requirements to limit emissions of dioxins and furans. Report from the Working Group of the Subcommittee Air Technology of the Federal Government / Federal States Emissions Control Committee. Berlin, Germany.

USEPA [1987]. Locating and Estimating Air Emissions from Sources of Polychlorinated Biphenyls (PCB). US EPA-450/4-84-007n.

Annex A

THE CALCULATION RESULTS OF PCDD/F EMISSIONS FROM SOURCE CATEGORIES IN THE COUNTRIES

Table A.1. Annual emission of PCDD/Fs (g TEQ per year) in Azerbaijan

Source category	SNAP	PCDD/Fs		
		1990	1995	1997
Total	**000000**	**2.946**	**2.687**	**1.463**
Stationary fuel combustion	**01+02+03**	**0.891**	**1.095**	**0.969**
Combustion in energy production and energy transformation	**010000**	**0.577**	**0.758**	**0.648**
Fuel oil	01fo	0.576	0.758	0.648
Coal	01c	-	-	-
Peat	01p	-	-	-
Firewood	01w	-	-	-
Other liquid fuels	01olf	0.0	-	-
Other solid fuels	01osf	-	-	-
Combustion in commercial, institut., resident. sectors and agriculture, forestry, fishing	**020000**	**0.279**	**0.289**	**0.283**
Fuel oil	02fo	0.029	0.039	0.033
Coal	02c	-	-	-
Peat	02p	-	-	-
Firewood	02w	0.25	0.25	0.25
Other liquid fuels	02olf	-	-	-
Other solid fuels	02osf	-	-	-
Combustion in industry	**030000**	**0.035**	**0.048**	**0.038**
Fuel oil	03fo	0.031	0.043	0.036
Coal	03c	-	-	-
Peat	03p	-	-	-
Firewood	03w	-	-	-
Other liquid fuels	03olf	0.004	0.005	0.002
Other solid fuels	03osf	-	-	-
Production processes	**03&04**	**0.521**	**0.051**	**0.083**
Iron and steel industries		**0.321**	**0.011**	**0.022**
Sinter plants	030301	-	-	-
Coke oven furnaces	010406	0.045	0.001	0.012
Blast furnace	030203	-	-	-
Electric furnace steel plant	040207	0.081	0.002	0.005
Grey iron foundries	030303	0.195	0.008	0.005
Non-ferrous metal industries				
Aluminium production	040301	*	*	*
Primary copper production	030306	-	-	-
Secondary lead production	030307	-	-	-
Secondary copper production	030309	-	-	-
Secondary aluminium production	030310	-	-	-
Cement	030311	0.200	0.04	0.06
Lime	030312	-	-	-
Container glass and glass wool	030314&16	*	*	*
Asphalt concrete plants	030313	*	*	*
Proc. in organic chemical industr. (bulk production)	04050x	-	-	-
Processes in wood, paper pulp, food&drink industries & other industries	04060x	-	-	-
Solvent and other product use	**060000**			
Paint application	06010	*	*	*
Degreasing, dry cleaning and electronics & other use of solvent and related activities	0602&0604	*	*	*
Preservation of wood	060406	-	-	-
Use of PCB	06PCB	-	-	-
Road transport & Other mobile sources and machinery	**07+08**	**1.535**	**1.541**	**0.411**
Non-leaded gasoline	07gs	0.016	0.017	0.031
Leaded gasoline	07e	0.482	0.196	-
Diesel fuel	07+08d	1.037	1.328	0.380
Fuel oil	08fo	-	-	-
Other liquid fuels	07+08olf	-	-	-
Waste treatment and disposal	**090000**			
Incineration of domestic or municipal wastes	090201	-	-	-
Incineration of industrial wastes	090202	*	*	*
Incineration of hospital wastes	090207	*	*	*
Cremation	090901	-	-	-
Open burning of wastes	090907	**	**	**
Landfills	091004	*	*	*
Structure and other fires	09f	**	**	**
Agriculture	**100000**			
Stubble burning	100300	*	*	*
Use of pesticides	100600	*	*	*
Nature	**110000**			
Forest fires	110300	*	*	*

<< - >> - process (source) is not represented or insignificant;
* - there is evidence that this sector (process) is a source of emission;
** - there is evidence that this sector (process) is a significant source of emission.

Table A.2. Annual emission of PCDD/Fs (g TEQ per year) in Armenia

Source category	SNAP	PCDD/Fs		
		1990	1995	1997
Total	**000000**	**2.631**	**1.015**	**1.095**
Stationary fuel combustion	**01+02+03**	**1.715**	**0.545**	**0.592**
Combustion in energy production and energy transformation	**010000**	**0.374**	**0.009**	**0.069**
Fuel oil	01fo	0.374	0.009	0.069
Coal	01c	-	-	-
Peat	01p	-	-	-
Firewood	01w	-	-	-
Other liquid fuels	01olf	-	-	-
Other solid fuels	01osf	-	-	-
Combustion in commercial, institut., resident. sectors and agriculture, forestry, fishing	**020000**	**1.156**	**0.533**	**0.523**
Fuel oil	02fo	0.083	-	-
Coal	02c	0.923	0.01	-
Peat	02p	-	-	-
Firewood	02w	0.15	0.523[1]	0.523[1]
Other liquid fuels	02olf	-	-	-
Other solid fuels	02osf	-	-	-
Combustion in industry	**030000**	**0.185**	**0.003**	
Fuel oil	03fo	-	0.003	-
Coal	03c	0.185	-	-
Peat	03p	-	-	-
Firewood	03w	-	-	-
Other liquid fuels	03olf	-	-	-
Other solid fuels	03osf	-	-	-
Production processes	**03&04**	**0.300**	**0.048**	**0.060**
Iron and steel industries		**0.007**	**0.003**	**0.001**
Sinter plants	030301	-	-	-
Coke oven furnaces	010406	-	-	-
Blast furnace	030203	-	-	-
Electric furnace steel plant	040207	0.007	0.000	-
Grey iron foundries	030303	-	0.003	0.001
Non-ferrous metal industries				
Aluminium production	040301	-	-	-
Primary copper production	030306	-	-	-
Secondary lead production	030307	-	-	-
Secondary copper production	030309	-	-	-
Secondary aluminium production	030310	-	-	-
Cement	030311	0.293	0.045	0.059
Lime	030312	-	-	-
Container glass and glass wool	030314&16	*	*	*
Asphalt concrete plants	030313	*	*	*
Proc. in organic chemical industr. (bulk production)	04050x	-	-	-
Processes in wood, paper pulp, food&drink industries & other industries	04060x	-	-	-
Solvent and other product use	**060000**			
Paint application	06010	*	*	*
Degreasing, dry cleaning and electronics & other use of solvent and related activities	0602&0604	*	*	*
Preservation of wood	060406	-	-	-
Use of PCB	06PCB	-	-	-
Road transport & Other mobile sources and machinery	**07+08**	**0.616**	**0.422**	**0.443**
Non-leaded gasoline	07gs	0.008	0.004	0.008
Leaded gasoline	07e	0.246	0.048	0.065
Diesel fuel	07+08d	0.362	0.370	0.370
Fuel oil	08fo	-	-	-
Other liquid fuels	07+08olf	-	-	-
Waste treatment and disposal	**090000**			
Incineration of domestic or municipal wastes	090201	-	-	-
Incineration of industrial wastes	090202	*	*	*
Incineration of hospital wastes	090207	*	*	*
Cremation	090901	-	-	-
Open burning of wastes	090907	**	**	**
Landfills	091004	*	*	*
Structure and other fires	09f	**	**	**
Agriculture	**100000**			
Stubble burning	100300	*	*	*
Use of pesticides	100600	*	*	*
Nature	**110000**			
Forest fires	110300	*	*	*

[1] – greatly underestimated

<< - >> - process (source) is not represented or insignificant;

* - there is evidence that this sector (process) is a source of PCDD/F emission;

** - there is evidence that this sector (process) is a significant source of PCDD/F emission.

Table A.3. Annual emission of PCDD/Fs (g TEQ per year) in Belarus

Source category	SNAP	PCDD/Fs		
		1990	1995	1997
Total	**000000**	**22.303**	**13.860**	**16.402**
Stationary fuel combustion	**01+02+03**	**13.878**	**9.786**	**10.650**
Combustion in energy production and energy transformation	**010000**	**2.622**	**1.024**	**0.72**
Fuel oil	01fo	2.622	1.024	0.552
Coal	01c	-	-	0.050
Peat	01p	-	-	0.071
Firewood	01w	-	-	0.046
Other liquid fuels	01olf	-	-	0.001
Other solid fuels	01osf	-	-	-
Combustion in commercial, institut., resident. sectors and agriculture, forestry, fishing[1]	**020000**	**11.256**	**8.762**	**9.930**
Fuel oil	02fo	-	-	0.180
Coal	02c	3.242	1.051	0.644
Peat	02p	5.520	3.581	2.893
Firewood	02w	2.156	3.941	6.148
Other liquid fuels	02olf	0.121	0.113	0.064
Other solid fuels	02osf	0.217	0.076	0.001
Combustion in industry	**030000**			
Fuel oil	03fo			
Coal	03c			
Peat	03p			
Firewood	03w			
Other liquid fuels	03olf			
Other solid fuels	03osf			
Production processes	**03&04**	**4.48**	**2.169**	**3.288**
Iron and steel industries		**3.943**	**1.874**	**2.859**
Sinter plants	030301	-	-	-
Coke oven furnaces	010406	-	-	-
Blast furnace	030203	-	-	-
Electric furnace steel plant	040207	2.225	1.488	2.440
Grey iron foundries	030303	1.718	0.386	0.419
Non-ferrous metal industries		-	-	-
Aluminium production	040301	-	-	-
Primary copper production	030306	-	-	-
Secondary lead production	030307	-	-	-
Secondary copper production	030309	-	-	-
Secondary aluminium production	030310	-	-	-
Cement	030311	0.452	0.247	0.375
Lime	030312	0.085	0.035	0.043
Container glass and glass wool	030314&16	*	*	*
Asphalt concrete plants	030313	*	0.013	0.011
Proc. in organic chemical industr. (bulk production)	04050x	-	-	-
Processes in wood, paper pulp, food&drink industries & other industries	04060x	-	-	-
Solvent and other product use	**060000**	-	-	-
Paint application	06010	*	*	*
Degreasing, dry cleaning and electronics & other use of solvent and related activities	0602&0604	*	*	*
Preservation of wood	060406	-	-	-
Use of PCB	06PCB	-	-	-
Road transport & Other mobile sources and machinery	**07+08**	**3.924**	**1.894**	**2.453**
Non-leaded gasoline	07gs	-	0.042	0.091
Leaded gasoline	07e	0.944	0.112	-
Diesel fuel	07+08d	2.980	1.734	2.360
Fuel oil	08fo	-	-	-
Other liquid fuels	07+08olf	-	0.006	0.002
Waste treatment and disposal	**090000**	**0.021**	**0.011**	**0.011**
Incineration of domestic or municipal wastes	090201	0.01	-	-
Incineration of industrial wastes	090202	*	*	*
Incineration of hospital wastes	090207	*	*	*
Cremation	090901	0.011	0.011	0.011
Open burning of wastes	090907	**	**	**
Landfills	091004	*	*	*
Structure and other fires	09f	**	**	**
Agriculture	**100000**			
Stubble burning	100300	*	*	*
Use of pesticides	100600	*	*	*
Nature	**110000**			
Forest fires	110300	*	*	*

<< - >> - process (source) is not represented or insignificant;

[1] – including industrial combustion

* - there is evidence that this sector (process) is a source of PCDD/F emission;

** - there is evidence that this sector (process) is a significant source of PCDD/F emission.

Table A.4. Annual emission of PCDD/Fs (g TEQ per year) in Georgia

Source category	SNAP	PCDD/Fs		
		1990	1995	1997
Total	**000000**	**24.404**	**28.457**	**28.231**
Stationary fuel combustion	**01+02+03**	**4.000**	**27.795**	**27.770**
Combustion in energy production and energy transformation	**010000**	**0.824**	**0.228**	**0.238**
Fuel oil	01fo	0.587	0.199	0.209
Coal	01c	0.237	-	-
Peat	01p	-	-	-
Firewood	01w	-	0.029	0.029
Other liquid fuels	01olf	-	-	-
Other solid fuels	01osf	-	-	-
Combustion in commercial, institut., resident. sectors and agriculture, forestry, fishing	**020000**	**3.066**	**27.522**	**27.513**
Fuel oil	02fo	0.018	0.006	0.002
Coal	02c	0.029	0.016	0.011
Peat	02p	-	-	-
Firewood	02w	3	27.5	27.5
Other liquid fuels	02olf	0.019	0.0	0.0
Other solid fuels	02osf	-	-	-
Combustion in industry	**030000**	**0.111**	**0.045**	**0.019**
Fuel oil	03fo	0.071	0.024	0.008
Coal	03c	0.034	0.021	0.011
Peat	03p	-	-	-
Firewood	03w	-	-	-
Other liquid fuels	03olf	0.006	0.0	0.0
Other solid fuels	03osf	-	-	-
Production processes	**03&04**	**19.483**	**0.212**	**0.030**
Iron and steel industries		**19.226**	**0.200**	**0.010**
Sinter plants	030301	19.08	0.192	-
Coke oven furnaces	010406	0.091	0.003	-
Blast furnace	030203	0.016	0.001	0.0
Electric furnace steel plant	040207	0.038	0.001	0.001
Grey iron foundries	030303	-	0.003	0.009
Non-ferrous metal industries				
Aluminium production	040301	-	-	-
Primary copper production	030306	-	-	-
Secondary lead production	030307	-	-	-
Secondary copper production	030309	-	-	-
Secondary aluminium production	030310	-	-	-
Cement	030311	0.258	0.012	0.02
Lime	030312	-	-	-
Container glass and glass wool	030314&16	*	*	*
Asphalt concrete plants	030313	*	*	0.0
Proc. in organic chemical industr. (bulk production)	04050x	-	-	-
Processes in wood, paper pulp, food&drink industries & other industries	04060x	-	-	-
Solvent and other product use	**060000**			
Paint application	06010	*	*	*
Degreasing, dry cleaning and electronics & other use of solvent and related activities	0602&0604	*	*	*
Preservation of wood	060406	-	-	-
Use of PCB	06PCB	-	-	-
Road transport & Other mobile sources and machinery	**07+08**	**0.922**	**0.450**	**0.432**
Non-leaded gasoline	07gs	0.012	0.012	0.013
Leaded gasoline	07e	0.352	0.125	0.106
Diesel fuel	07+08d	0.558	0.313	0.313
Fuel oil	08fo	-	-	-
Other liquid fuels	07+08olf	-	-	-
Waste treatment and disposal	**090000**			
Incineration of domestic or municipal wastes	090201	-	-	-
Incineration of industrial wastes	090202	*	*	*
Incineration of hospital wastes	090207	*	*	*
Cremation	090901	-	-	-
Open burning of wastes	090907	**	**	**
Landfills	091004	*	*	*
Structure and other fires	09f	**	**	**
Agriculture	**100000**			
Stubble burning	100300	*	*	*
Use of pesticides	100600	*	*	*
Nature	**110000**			
Forest fires	110300	*	*	*

<< - >> - process (source) is not represented or insignificant;

* - there is evidence that this sector (process) is a source of PCDD/F emission;

** - there is evidence that this sector (process) is a significant source of PCDD/F emission.

Table A.5. Annual emission of PCDD/Fs (g TEQ per year) in Latvia

Source category	SNAP	PCDD/Fs		
		1990	1995	1997
Total	**000000**	**3.825**	**3.798**	**11.774**
Stationary fuel combustion	**01+02+03**	**2.890**	**3.452**	**11.377**
Combustion in energy production and energy transformation	**010000**	**0.398**	**0.239**	**0.325**
Fuel oil	01fo	0.243	0.117	0.107
Coal	01c	0.101	0.012	0.008
Peat	01p	0.034	0.058	0.061
Firewood	01w	0.007	0.051	0.148
Other liquid fuels	01olf	0.013	0.001	0.001
Other solid fuels	01osf	-	-	-
Combustion in commercial, institut., resident. sectors and agriculture, forestry, fishing	**020000**	**2.265**	**2.305**	**10.209**
Fuel oil	02fo	0.003	-	-
Coal	02c	0.680	0.100	0.150
Peat	02p	0.016	0.030	0.010
Firewood	02w	1.528	2.168	10.043
Other liquid fuels	02olf	0.038	0.007	0.006
Other solid fuels	02osf	-	-	-
Combustion in industry	**030000**	**0.227**	**0.908**	**0.843**
Fuel oil	03fo	0.038	0.045	0.060
Coal	03c	0.036	0.153	0.096
Peat	03p	0.119	0.045	0.034
Firewood	03w	0.020	0.566	0.629
Other liquid fuels	03olf	0.014	0.99	0.024
Other solid fuels	03osf	-	-	-
Production processes	**03&04**	**0.18**	**0.051**	**0.061**
Iron and steel industries		**0.019**	**0.007**	**0.006**
Sinter plants	030301	-	-	-
Coke oven furnaces	010406	-	-	-
Blast furnace	030203	-	-	-
Electric furnace steel plant	040207	0.019	0.007	0.006
Grey iron foundries	030303	-	-	-
Non-ferrous metal industries				**0.002**
Aluminium production	040301	-	-	-
Primary copper production	030306	-	-	-
Secondary lead production	030307	-	-	-
Secondary copper production	030309	-	-	-
Secondary aluminium production	030310	-	-	0.002
Cement	030311	0.149	0.041	0.049
Lime	030312	0.012	0.002	0.002
Container glass and glass wool	030314&16	*	*	*
Asphalt concrete plants	030313	*	0.001	0.002
Proc. in organic chemical industr. (bulk production)	04050x	-	-	-
Processes in wood, paper pulp, food&drink industries & other industries	04060x	-	-	-
Solvent and other product use	**060000**			
Paint application	06010	*	*	*
Degreasing, dry cleaning and electronics & other use of solvent and related activities	0602&0604	*	*	*
Preservation of wood	060406	-	-	-
Use of PCB	06PCB	-	-	-
Road transport & Other mobile sources and machinery	**07+08**	**0.751**	**0.291**	**0.337**
Non-leaded gasoline	07gs	0.002	0.011	0.015
Leaded gasoline	07e	0.289	0.093	0.037
Diesel fuel	07+08d	0.388	0.146	0.285
Fuel oil	08fo	0.069	0.041	-
Other liquid fuels	07+08olf	0.003	0.0	-
Waste treatment and disposal	**090000**	**0.004**	**0.004**	
Incineration of domestic or municipal wastes	090201	-	-	-
Incineration of industrial wastes	090202	*	*	*
Incineration of hospital wastes	090207	*	*	*
Cremation	090901	0.004	0.004	-
Open burning of wastes	090907	**	**	**
Landfills	091004	*	*	*
Structure and other fires	09f	**	**	**
Agriculture	**100000**			
Stubble burning	100300	*	*	*
Use of pesticides	100600	*	*	*
Nature	**110000**			
Forest fires	110300	*	*	*

<< - >> - process (source) is not represented or insignificant;

* - there is evidence that this sector (process) is a source of PCDD/F emission;

** - there is evidence that this sector (process) is a significant source of PCDD/F emission.

Table A.6. Annual emission of PCDD/Fs (g TEQ per year) in Lithuania

Source category	SNAP	PCDD/Fs		
		1990	1995	1997
Total	**000000**	**6.978**	**3.883**	**5.944**
Stationary fuel combustion	**01+02+03**	**5.350**	**3.310**	**5.231**
Combustion in energy production and energy transformation	**010000**	**0.533**	**0.283**	**0.222**
Fuel oil	01fo	0.533	0.283	0.210
Coal	01c	-	-	0.005
Peat	01p	-	-	0.003
Firewood	01w	-	-	0.003
Other liquid fuels	01olf	-	-	-
Other solid fuels	01osf	-	-	-
Combustion in commercial, institut., resident. sectors and agriculture, forestry, fishing	**020000**	**4.817**	**3.027**	**4.924**
Fuel oil	02fo	-	-	-
Coal	02c	3.130	0.872	0.557
Peat	02p	0.150	0.225	0.055
Firewood	02w	1.368	1.886	4.287
Other liquid fuels	02olf	0.169	0.044	0.025
Other solid fuels	02osf	-	-	-
Combustion in industry	**030000**	**-**	**-**	**0.086**
Fuel oil	03fo	-	-	-
Coal	03c	-	-	0.007
Peat	03p	-	-	0.009
Firewood	03w	-	-	0.007
Other liquid fuels	03olf	-	-	0.063
Other solid fuels	03osf	-	-	-
Production processes	**03&04**	**0.906**	**0.154**	**0.182**
Iron and steel industries		**0.226**	**0.034**	**0.042**
Sinter plants	030301	-	-	-
Coke oven furnaces	010406	-	-	-
Blast furnace	030203	-	-	-
Electric furnace steel plant	040207	0.014	-	-
Grey iron foundries	030303	0.212	0.034	0.042
Non-ferrous metal industries				
Aluminium production	040301	-	-	-
Primary copper production	030306	-	-	-
Secondary lead production	030307	-	-	-
Secondary copper production	030309	-	-	-
Secondary aluminium production	030310	-	-	-
Cement	030311	0.680	0.120	0.140
Lime	030312	-	-	-
Container glass and glass wool	030314&16	*	*	*
Asphalt concrete plants	030313	*	*	*
Proc. in organic chemical industr. (bulk production)	04050x	-	-	-
Processes in wood, paper pulp, food&drink industries & other industries	04060x	-	-	-
Solvent and other product use	**060000**			
Paint application	06010	*	*	*
Degreasing, dry cleaning and electronics & other use of solvent and related activities	0602&0604	*	*	*
Preservation of wood	060406	-	-	-
Use of PCB	06PCB	-	-	-
Road transport & Other mobile sources and machinery	**07+08**	**0.722**	**0.419**	**0.531**
Non-leaded gasoline	07gs	0.037	0.023	0.032
Leaded gasoline	07e	0.118	0.055	*
Diesel fuel	07+08d	0.285/0.282	0.215/0.126	0.407/0.092
Fuel oil	08fo	-	-	-
Other liquid fuels	07+08olf	-	-	-
Waste treatment and disposal	**090000**			
Incineration of domestic or municipal wastes	090201	-	-	-
Incineration of industrial wastes	090202	*	*	*
Incineration of hospital wastes	090207	*	*	*
Cremation	090901	-	-	-
Open burning of wastes	090907	**	**	**
Landfills	091004	*	*	*
Structure and other fires	09f	**	**	**
Agriculture	**100000**			
Stubble burning	100300	*	*	*
Use of pesticides	100600	*	*	*
Nature	**110000**			
Forest fires	110300	*	*	*

<< - >> - process (source) is not represented or insignificant;

* - there is evidence that this sector (process) is a source of PCDD/F emission;

** - there is evidence that this sector (process) is a significant source of PCDD/F emission.

Table A.7. Annual emission of PCDD/Fs (g TEQ per year) in Moldova

Source category	SNAP	PCDD/Fs		
		1990	1995	1997
Total	**000000**	**8.103**	**3.203**	**2.260**
Stationary fuel combustion	**01+02+03**	**5.427**	**2.393**	**1.478**
Combustion in energy production and energy transformation	**010000**	**0.957**	**0.273**	**0.141**
Fuel oil	01fo	0.424	0.066	0.051
Coal	01c	0.531	0.205	0.089
Peat	01p	-	-	-
Firewood	01w	0.0	0.0	0.0
Other liquid fuels	01olf	0.002	0.002	0.001
Other solid fuels	01osf	-	-	-
Combustion in commercial, institut., resident. sectors and agriculture, forestry, fishing	**020000**	**4.343**	**2.089**	**1.316**
Fuel oil	02fo	0.004	0.001	0.0
Coal	02c	4.025	1.590	0.692
Peat	02p	-	-	-
Firewood	02w	0.311	0.496	0.618
Other liquid fuels	02olf	0.003	0.002	0.006
Other solid fuels	02osf	-	-	-
Combustion in industry	**030000**	**0.127**	**0.031**	**0.021**
Fuel oil	03fo	0.070	0.011	0.009
Coal	03c	0.043	0.016	0.008
Peat	03p	-	-	-
Firewood	03w	0.008	0.002	0.002
Other liquid fuels	03olf	0.006	0.002	0.002
Other solid fuels	03osf	-	-	-
Production processes	**03&04**	**1.980**	**0.619**	**0.631**
Iron and steel industries		**1.499**	**0.605**	**0.606**
Sinter plants	030301	-	-	-
Coke oven furnaces	010406	-	-	-
Blast furnace	030203	-	-	-
Electric furnace steel plant	040207	1.424	0.601	0.601
Grey iron foundries	030303	0.075	0.004	0.005
Non-ferrous metal industries				
Aluminium production	040301	-	-	-
Primary copper production	030306	-	-	-
Secondary lead production	030307	-	-	-
Secondary copper production	030309	-	-	-
Secondary aluminium production	030310	-	-	-
Cement	030311	0.457	0.010	0.024
Lime	030312	0.016	0.001	-
Container glass and glass wool	030314&16	*	*	*
Asphalt concrete plants	030313	0.008	0.003	0.001
Proc. in organic chemical industr. (bulk production)	04050x	-	-	-
Processes in wood, paper pulp, food&drink industries & other industries	04060x	-	-	-
Solvent and other product use	**060000**			
Paint application	06010	*	*	*
Degreasing, dry cleaning and electronics & other use of solvent and related activities	0602&0604	*	*	*
Preservation of wood	060406	-	-	-
Use of PCB	06PCB	-	-	-
Road transport & Other mobile sources and machinery	**07+08**	**0.697**	**0.191**	**0.151**
Non-leaded gasoline	07gs	0.010	0.006	0.009
Leaded gasoline	07e	0.292	0.046	0.032
Diesel fuel	07+08d	0.395	0.139	0.110
Fuel oil	08fo	-	0.0	0.0
Other liquid fuels	07+08olf	-	-	-
Waste treatment and disposal	**090000**			
Incineration of domestic or municipal wastes	090201	-	-	-
Incineration of industrial wastes	090202	*	*	*
Incineration of hospital wastes	090207	*	*	*
Cremation	090901	-	-	-
Open burning of wastes	090907	**	**	**
Landfills	091004	*	*	*
Structure and other fires	09f	**	**	**
Agriculture	**100000**			
Stubble burning	100300	*	*	*
Use of pesticides	100600	*	*	*
Nature	**110000**			
Forest fires	110300	*	*	*

<< - >> - process (source) is not represented or insignificant;

* - there is evidence that this sector (process) is a source of PCDD/PCDF emission;

** - there is evidence that this sector (process) is a significant source of PCDD/PCDF emission.

Table A.8. Annual emission of PCDD/Fs (g TEQ per year) in European part of Russian Federation

Source category	SNAP	PCDD/Fs		
		1990	1995	1997
Total	**000000**	**669.178**	**472.876**	**441.205**
Stationary fuel combustion	**01+02+03**	**114.564**	**85.511**	**60.952**
Combustion in energy production and energy transformation	**010000**	**9.840**	**6.821**	**6.117**
Fuel oil	01fo	6.976	4.689	4.520
Coal	01c	2.863	2.132	1.598
Peat	01p	-	-	-
Firewood	01w	-	-	-
Other liquid fuels	01olf	-	-	-
Other solid fuels	01osf	-	-	-
Combustion in commercial, institut., resident. sectors and agriculture, forestry, fishing	**020000**	**53.701**	**37.028**	**27.547**
Fuel oil	02fo	-	0.436	0.371
Coal	02c	25.887	20.501	13.180
Peat	02p	1.623	0.794	0.692
Firewood	02w	26.191	15.150	13.137
Other liquid fuels	02olf	-	0.147	0.167
Other solid fuels	02osf	-	-	-
Combustion in industry	**030000**	**51.023**	**41.662**	**27.288**
Fuel oil	03fo	4.649	1.77	2.166
Coal	03c	42.972	29.224	18.049
Peat	03p	3.402	2.869	2.527
Firewood	03w	-	5.369	2.878
Other liquid fuels	03olf	-	2.430	1.668
Other solid fuels	03osf	-	-	-
Production processes	**03&04**	**494.146**	**369.238**	**367.682**
Iron and steel industries		**449.491**	**330.276**	**332.462**
Sinter plants	030301	428.064	317.873	320.796
Coke oven furnaces	010406	3.530	2.455	2.489
Blast furnace	030203	0.698	0.499	0.499
Electric furnace steel plant	040207	17.199	9.449	8.678
Grey iron foundries	030303	*	*	*
Non-ferrous metal industries		**33.163**	**33.273**	**30.713**
Aluminium production	040301	*	*	*
Primary copper production	030306	*	*	*
Secondary lead production	030307	0.940	0.650	0.690
Secondary copper production	030309	17.200	17.600	15.000
Secondary aluminium production	030310	15.023	15.023	15.023
Cement	030311	10.555	5.125	4.043
Lime	030312	0.942	0.564	0.464
Container glass and glass wool	030314&16	*	*	*
Asphalt concrete plants	030313	*	*	*
Proc. in organic chemical industr. (bulk production)	04050x	**	*	*
Processes in wood, paper pulp, food&drink industries & other industries	04060x	*	*	*
Solvent and other product use	**060000**			
Paint application	06010	*	*	*
Degreasing, dry cleaning and electronics & other use of solvent and related activities	0602&0604	*	*	*
Preservation of wood	060406	*	*	*
Use of PCB	06PCB	*	*	*
Road transport & Other mobile sources and machinery	**07+08**	**35.421**	**9.08**	**7.525**
Non-leaded gasoline	07gs	0.229	0.447	0.313
Leaded gasoline	07e	6.862	2.744	2.146
Diesel fuel	07+08d	28.330	5.889	5.066
Fuel oil	08fo	-	-	-
Other liquid fuels	07+08olf	-	-	-
Waste treatment and disposal	**090000**	**25.047**	**9.047**	**5.047**
Incineration of domestic or municipal wastes	090201	25.000	9.000	5.000
Incineration of industrial wastes	090202	**	**	**
Incineration of hospital wastes	090207	*	*	*
Cremation	090901	0.047	0.047	0.047
Open burning of wastes	090907	**	**	**
Landfills	091004	*	*	*
Structure and other fires	09f	**	**	**
Agriculture	**100000**			
Stubble burning	100300	*	*	*
Use of pesticides	100600	*	*	*
Nature	**110000**			
Forest fires	110300	**	**	**

<< - >> - process (source) is not represented or insignificant;

* - there is evidence that this sector (process) is a source of PCDD/F emission;

** - there is evidence that this sector (process) is a significant source of PCDD/F emission.

Table A.9. Annual emission of PCDD/Fs (g TEQ per year) in the Ukraine

Source category	SNAP	PCDD/Fs		
		1990	1995	1997
Total	**000000**	**1073.893**	**476.024**	**517.543**
Stationary fuel combustion	**01+02+03**	**83.035**	**38.513**	**34.272**
Combustion in energy production and energy transformation	**010000**	**12.311**	**10.23**	**13.046**
Fuel oil	01fo	2.928	1.176	0.673
Coal	01c	9.271	8.968	10.972
Peat	01p	0.034	0.029	0.078
Firewood	01w	0.007	0.016	0.022
Other liquid fuels	01olf	0.069	0.018	0.026
Other solid fuels	01osf	0.002	0.023	1.275
Combustion in commercial. institut., resident. sectors and agriculture, forestry, fishing	**020000**	**65.137**	**21.238**	**19.689**
Fuel oil	02fo	0.193	-	0.013
Coal	02c	57.468	17.107	14.213
Peat	02p	0.143	0.076	0.087
Firewood	02w	5.330	3.912	4.636
Other liquid fuels	02olf	1.363	0.080	0.666
Other solid fuels	02osf	0.640	0.063	0.074
Combustion in industry	**030000**	**5.587**	**7.045**	**1.537**
Fuel oil	03fo	0.924	0.378	0.080
Coal	03c	3.944	5.379	1.109
Peat	03p	0.211	0.053	0.188
Firewood	03w	0.055	0.281	0.047
Other liquid fuels	03olf	0.453	0.954	0.113
Other solid fuels	03osf	-	-	-
Production processes	**03&04**	**956.035**	**416.168**	**464.960**
Iron and steel industries		**938.711**	**402.738**	**452.064**
Sinter plants	030301	913.897	394.168	443.609
Coke oven furnaces	010406	8.666	3.953	4.097
Blast furnace	030203	1.185	0.475	0.544
Electric furnace steel plant	040207	7.254	2.537	2.343
Grey iron foundries	030303	7.709	1.605	1.471
Non-ferrous metal industries		**12.1**	**11.6**	**11.6**
Aluminium production	040301	*	*	*
Primary copper production	030306	-	-	-
Secondary lead production	030307	1.3	0.8	0.8
Secondary copper production	030309	-	-	-
Secondary aluminium production	030310	10.8	10.8	10.8
Cement	030311	4.546	1.525	1.020
Lime	030312	0.678	0.305	0.276
Container glass and glass wool	030314&16	*	*	*
Asphalt concrete plants	030313	*	*	*
Proc. in organic chemical industr. (bulk production)	04050x	*	*	*
Processes in wood, paper pulp, food&drink industries & other industries	04060x	*	*	*
Solvent and other product use	**060000**			
Paint application	06010	*	*	*
Degreasing, dry cleaning and electronics & other use of solvent and related activities	0602&0604	*	*	*
Preservation of wood	060406	-	-	-
Use of PCB	06PCB	*	-	-
Road transport & Other mobile sources and machinery	**07+08**	**9.137**	**3.587**	**2.656**
Non-leaded gasoline	07gs	0.281	0.149	0.143
Leaded gasoline	07e	2.808	0.496	0.234
Diesel fuel	07+08d	5.763	2.942	2.209
Fuel oil	08fo	0.091	-	0.015
Other liquid fuels	07+08olf	0.194	-	0.055
Waste treatment and disposal	**090000**	**25.687**	**17.756**	**15.655**
Incineration of domestic or municipal wastes	090201	25.665	17.701	15.633
Incineration of industrial wastes	090202	**	**	**
Incineration of hospital wastes	090207	*	*	*
Cremation	090901	0.022	0.055	0.022
Open burning of wastes	090907	**	**	**
Landfills	091004	*	*	*
Structure and other fires	09f	**	**	**
Agriculture	**100000**			
Stubble burning	100300	*	*	*
Use of pesticides	100600	*	*	*
Nature	**110000**			
Forest fires	110300	*	*	*

<< - >> - process (source) is not represented or insignificant;
* - there is evidence that this sector (process) is a source of PCDD/F emission;
** - there is evidence that this sector (process) is a significant source of PCDD/F emission.

Table A.10. Annual emission of PCDD/Fs (g TEQ per year) in Estonia

Source category	SNAP	PCDD/Fs		
		1990	1995	1997
Total	**000000**	**8.575**	**6.406**	**10.127**
Stationary fuel combustion	**01+02+03**	**7.814**	**5.981**	**9.770**
Combustion in energy production and energy transformation	**010000**	**4.869**	**2.701**	**2.779**
Fuel oil	01fo	0.275	0.069	0.063
Coal	01c	0.024	0.014	0.009
Peat	01p	0.023	0.041	0.043
Firewood	01w	0.005	0.067	0.089
Other liquid fuels	01olf	0.002	0.001	0.0
Other solid fuels	01osf	4.540	2.509	2.575
Combustion in commercial, institut., resident. sectors and agriculture, forestry, fishing	**020000**	**2.028**	**2.935**	**6.639**
Fuel oil	02fo	0.001	-	-
Coal	02c	0.130	0.018	0.115
Peat	02p	0.513	0.19	0.158
Firewood	02w	1.384	2.712	6.355
Other liquid fuels	02olf	0.0	0.014	0.011
Other solid fuels	02osf	-	-	-
Combustion in industry	**030000**	**0.917**	**0.346**	**0.352**
Fuel oil	03fo	0.013	0.002	0.002
Coal	03c	0.122	0.001	0.006
Peat	03p	-	0.002	0.002
Firewood	03w	0.011	0.010	0.008
Other liquid fuels	03olf	0.031	0.003	0.007
Other solid fuels	03osf	0.74	0.328	0.327
Production processes	**03&04**	**0.202**	**0.084**	**0.085**
Iron and steel industries				
Sinter plants	030301	-	-	-
Coke oven furnaces	010406	-	-	-
Blast furnace	030203	-	-	-
Electric furnace steel plant	040207	-	-	-
Grey iron foundries	030303	-	-	-
Non-ferrous metal industries				
Aluminium production	040301	-	-	-
Primary copper production	030306	-	-	-
Secondary lead production	030307	-	-	-
Secondary copper production	030309	-	-	-
Secondary aluminium production	030310	-	-	-
Cement	030311	0.188	0.083	0.085
Lime	030312	0.014	0.001	-
Container glass and glass wool	030314&16	*	*	*
Asphalt concrete plants	030313	*	*	*
Proc. in organic chemical industr. (bulk production)	04050x	-	-	-
Processes in wood, paper pulp, food&drink industries & other industries	04060x	-	-	-
Solvent and other product use	**060000**			
Paint application	06010	*	*	*
Degreasing, dry cleaning and electronics & other use of solvent and related activities	0602&0604	*	*	*
Preservation of wood	060406	-	-	-
Use of PCB	06PCB	-	-	-
Road transport & Other mobile sources and machinery	**07+08**	**0.559**	**0.341**	**0.272**
Non-leaded gasoline	07gs	0.001	0.008	0.015
Leaded gasoline	07e	0.248	0.066	0.037
Diesel fuel	07+08d	0.299	0.257	0.221
Fuel oil	08fo	0.011	0.01	-
Other liquid fuels	07+08olf	-	-	-
Waste treatment and disposal	**090000**			
Incineration of domestic or municipal wastes	090201	-	-	-
Incineration of industrial wastes	090202	*	*	*
Incineration of hospital wastes	090207	*	*	*
Cremation	090901	-	-	-
Open burning of wastes	090907	**	**	**
Landfills	091004	*	*	*
Structure and other fires	09f	**	**	**
Agriculture	**100000**			
Stubble burning	100300	*	*	*
Use of pesticides	100600	*	*	*
Nature	**110000**			
Forest fires	110300	*	*	*

<< - >> - process (source) is not represented or insignificant;

* - there is evidence that this sector (process) is a source of PCDD/F emission;

** - there is evidence that this sector (process) is a significant source of PCDD/F emission.