Figure 4.36. Arctic Ocean watershed, and catchment areas of the largest Arctic rivers (AMAP, 1998).

The Yenisey is one of the world's ten largest rivers, with a catchment area of 2.59 million km^2 (world ranking: 7) and mean long-term annual runoff of 603 km^3 (world ranking – 5) (GRDC, 1994). Its basin incorporates the East-Siberian economic region, parts of which, particularly those located in the upper and central parts of the Yenisey basin, are heavily industrialized. Industrial enterprises within these areas include non-ferrous metallurgy, pulp and paper manufacture, chemical industries, and mining, etc., which are recognized as significant sources of PTS emissions and discharges.

The catchment area of the Pechora river comprises 0.325 million km^2 (world ranking – 46), with a mean long-term annual runoff of 141 km^3 (world ranking: 30). The Pechora river basin, including the catchments of its primary and secondary tributaries the Vorkuta, Bol'shaya Inta, Kolva, Izhma and Ukhta rivers, contain areas rich in mineral resources, with associated oil, gas and coal extraction activities.

4.3.2. Objectives and methodology of the study

The objective of this study was to estimate PTS fluxes in the flows of the Pechora and Yenisey rivers to areas inhabited by indigenous peoples. Calculations of PTS loads in the lower reaches of the Pechora and Yenisey rivers used a range of data, included hydrometric measurements at the closing cross-sections of the Roshydromet basic hydrological network (in the area of Oksino settlement on the Pechora River and Igarka settlement on the Yenisey River), and at the lowermost cross-sections in the delta apexes, upstream of the rivers' main branching points (in the vicinity of Andeg settlement, on both the Large and Small Pechora rivers, and of Ust'-Port settlement, on the Yenisey River) (Figures 4.37 and 4.38). In addition, data were obtained from analysis of pooled water and suspended matter samples collected during periods of hydrological observations.

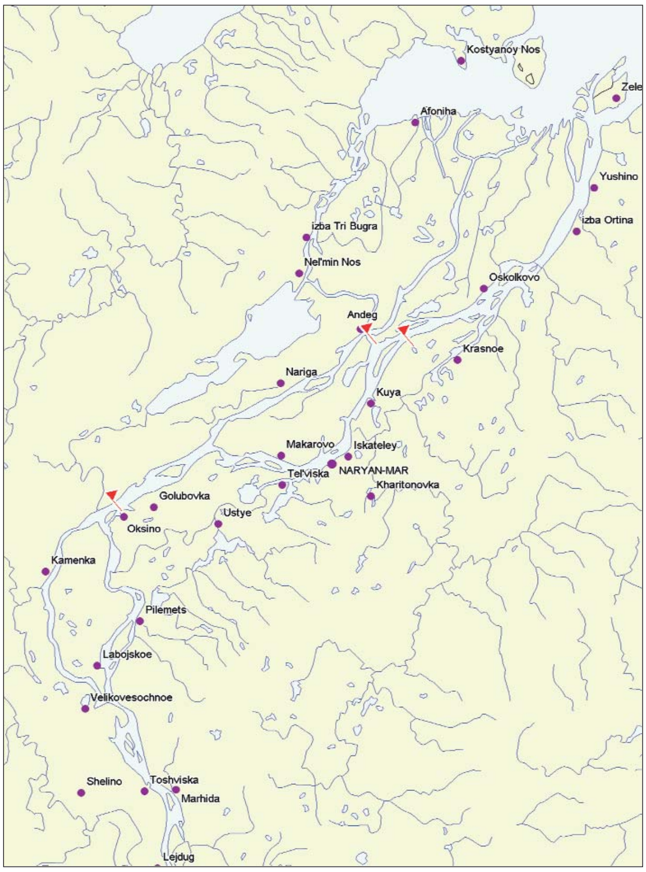


Figure 4.37. Location of hydrometric cross-sections on the Pechora river.

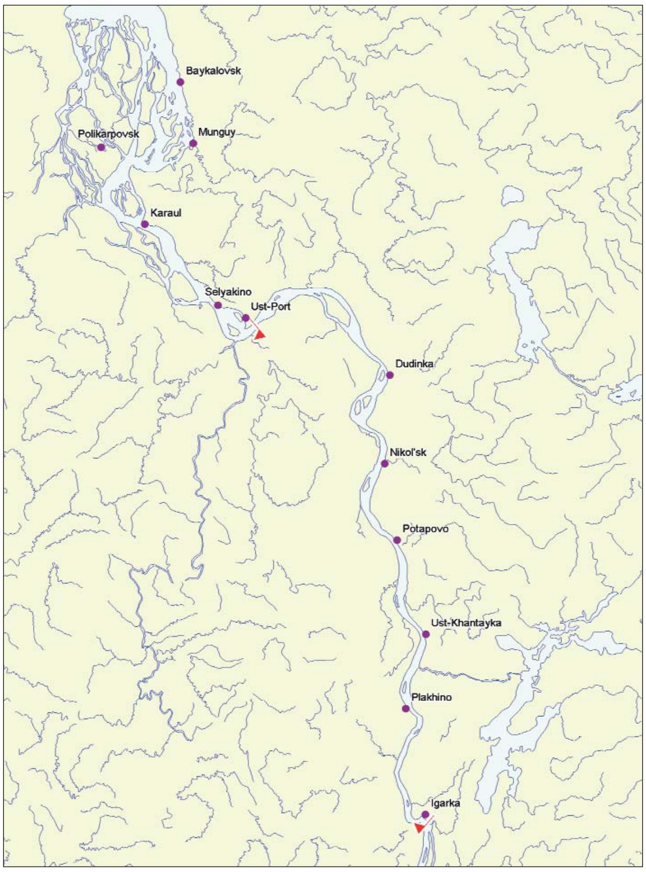


Figure 4.38. Location of hydrometric cross-sections on the Yenisey river.

Hydrometric measurements and water sampling at each of the cross-sections were carried out according to internationally accepted methodologies (GEMS, 1991; Chapman, 1996) during four typical hydrological water regime phases: during the spring flood fall period (late-June to early-July), during the summer low water period (late-July to early-August), before ice formation during the period of rain-fed floods (late-September to October), and during the winter low water period (March to April).

During each field survey period, measurements of flow velocity at various sampling points in the channel profile were made every 6 hours, for 3 days. Water level observations were conducted every 2 hours. Water sampling was carried out twice during the first observation day and once a day during the next two days (a total of 4 single samples for each sampling point). The volume of each pooled sample was not less than 20 litres.

Initial data for each water regime phase included:

- For the Pechora river at the closing cross-section near Oksino settlement (see Figure 4.39):
  - 15 flow velocity measurements (3 horizontal levels on each of 5 vertical profiles);
  - measurement of the channel profile;
  - 36 measurements of the river water level;
  - analytical data on PTS concentrations in 11 pooled water and 11 pooled suspended matter samples collected over a 3-day period in 11 cross-section segments;
  - suspended matter concentrations for samples taken at the flow velocity measurement points, in 11 pooled water samples, collected over a 3-day period in 11 cross-section segments.

- For the Large and Small Pechora rivers at the downstream cross-sections near Andeg settlement (see Figures 4.40 and 4.41):
  - 12 flow velocity measurements (3 horizontal levels on each of 4 vertical profiles, in both rivers);
  - measurement of the channel profile;
  - 36 measurements of the river water level;
  - analytical data on PTS concentrations in 3 pooled water samples and 3 pooled suspended matter samples from the surface, middle and near-bottom horizons collected over a 3-day period;
  - suspended matter concentrations in 3 pooled water samples collected over a 3-day period from the surface, middle and near-bottom horizons.

- For the Yenisey river at the closing cross-section near Igarka settlement (see Figure 4.42):
  - 15 flow velocity measurements (3 horizontal levels on each of 5 vertical profiles);
  - measurement of the channel profile;
  - 36 measurements of the river water level;
  - analytical data on PTS concentrations in 11 pooled water samples and 11 pooled suspended matter samples collected over a 3-day period in 11 cross-section segments;
  - suspended matter concentrations for the flow velocity measurement points in 11 pooled water samples, collected over a 3-day period from 11 cross-section segments.

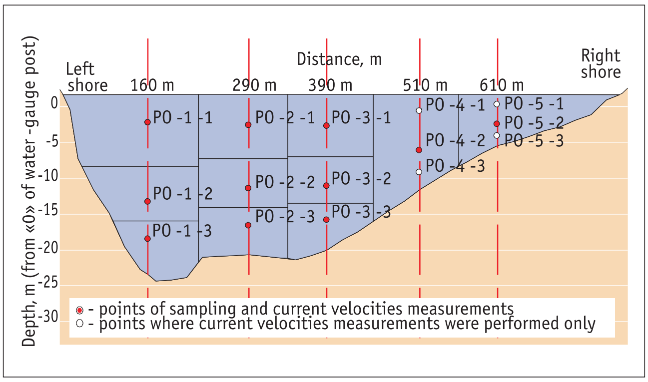


Figure 4.39. Channel profile and sampling/measurement points on the Large Pechora river at the closing cross-section near Oksino settlement.

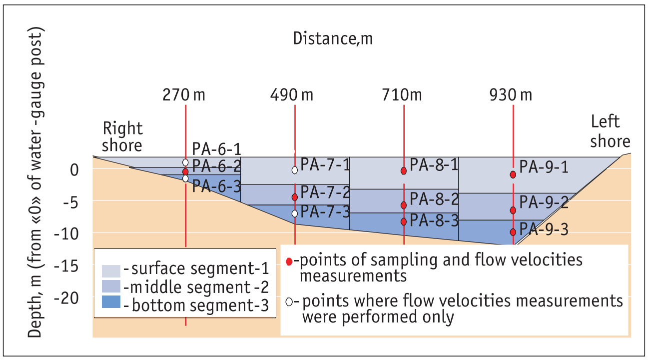


Figure 4.40. Channel profile and sampling/measurement points on the Large Pechora river at the downstream cross-section near Andeg settlement.

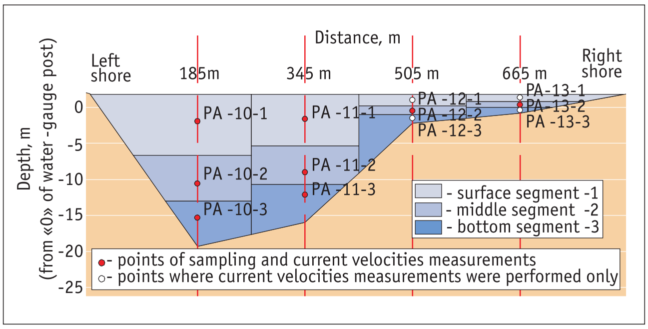


Figure 4.41. Channel profile and sampling/measurement points on the Small Pechora river at the downstream cross-section near Andeg settlement.

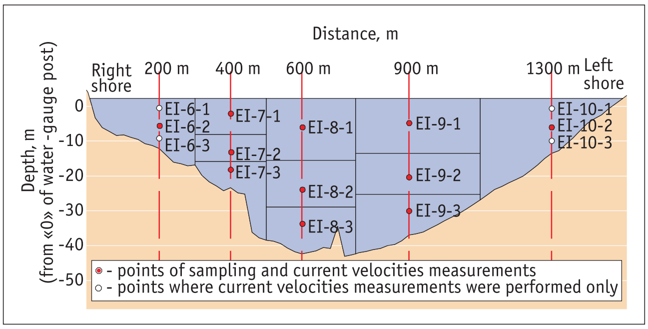


Figure 4.42. Channel profile and sampling/measurement points on the Yenisey river at the closing cross-section near Igarka settlement.

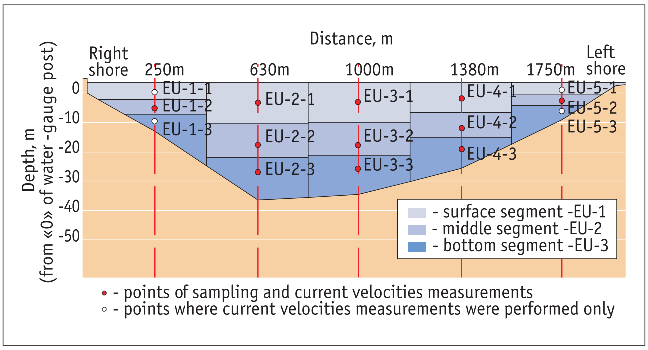


Figure 4.43. Channel profile and sampling/measurement points on the Yenisey river at the downstream cross-section near Ust'-Port.

- For the Yenisey river at the downstream cross-section near Ust'-Port settlement (see Figure 4.43):
  - 15 flow velocity measurements (3 horizontal levels on each of 5 vertical profiles);
  - measurement of the channel profile;
  - 36 measurements of the river water level;
  - analytical data on PTS concentrations for 3 pooled water samples and 3 pooled suspended matter samples from the surface, middle and near-bottom horizons collected over a 3-day period;
  - suspended matter concentrations in 3 pooled water samples collected over a 3-day period from the surface, middle and near-bottom horizons.

During the winter low water period, ice thickness was also measured at each of the cross-sections.

For calculations of mean monthly and annual PTS fluxes through the closing and downstream cross-sections for the year in which the observations were made, operational data consisting of water discharge measurements at river cross-sections in the area of Oksino and Igarka settlements were used. These data were provided by the Northern (Pechora river) and Central Siberian (Yenisey river) Territorial Branches of Roshydromet.

In order to calculate mean monthly and annual PTS fluxes through the closing cross-sections of the rivers for a year with ‘average’ runoff, and to assist in the preparation of a brief review of the inter-annual variability in water runoff via the Pechora and Yenisey rivers, published hydrographical data from 1932-1998, obtained from the Roshydromet hydrological network, were used.

Calculation of mean daily PTS fluxes over the 3-day observation periods was undertaken in several stages:

1. evaluation of the river channel profiles at the cross-sections where hydrometric measurements were taken;
2. division of the cross-sectional area into segments, for calculation of partial discharges and PTS fluxes;
3. calculation of the partial mean daily water and suspended matter discharges (for each segment identified) and total water and suspended matter discharges (for the whole cross-section) during each of the typical water regime phases;
4. calculation of partial and total mean daily fluxes of PTS in dissolved form during the typical water regime phases;
5. calculation of partial and total mean daily fluxes of PTS in suspended matter during the typical water regime phases.

The river channel profiles used in the hydrometric measurement cross-sections were evaluated on the basis of depth measurements and water level observations. Depth measurements (at various points across the channel) were taken once, prior to the start of the 3-day observation period. Water level observations were then made every two hours for three days. To model the channel profile, an averaged single value for water level above the original gauging station datum was applied across the river cross section. Thus, 16 profiles were evaluated (one for each of the four cross-sections in each of the four water regime phases) on the basis of average ‘effective’ cross-sectional areas during the 3-day observational periods. Ice thickness was taken into account in the construction of the channel profile during the winter low water period.

The cross-section areas were subdivided into segments corresponding to the points of flow velocity measurements and sampling. The profile schemes for each cross-section showing segments are presented in Figures 4.39 to 4.43. The numbers of segments coincides with the number of observations points.

In order to calculate partial and total mean daily PTS fluxes in dissolved and suspended form during the typical water regime phases, the following assumptions were made:

- At the closing cross-section, within a given segment, the PTS concentrations in water and suspended matter do not vary over the time period being represented, and are equal to the measured concentration at the corresponding observation point.
- At the downstream cross-section, within the combined segments identified, the PTS concentrations in water and suspended matter do not vary over the time period being represented, and are equal to the measured concentrations in the corresponding pooled samples.
- Any PTS that were either not found in any of the samples during the entire observation period, or were found in less than 10% of the total number of samples collected at both the closing and the more downstream cross-sections of a river, were excluded from PTS flux calculations for the given hydrological phase.
- Edge effects are not taken into account.

An assessment of mean monthly PTS flux (μ_y) in dissolved and suspended form was made according to the calculation method proposed by E.M.L. Beal (Frazer and Wilson, 1981).

$$\mu_y = \mu_x \frac{m_y}{m_x} \frac{\left(1 + \frac{1}{n}\frac{S_{xy}}{m_y m_x}\right)}{\left(1 + \frac{1}{n}\frac{S_x^2}{m_x^2}\right)} \qquad (4.1)$$

where:

μ_x – mean daily water discharge for the given month (L/day);

m_y – mean daily flux of the substance under consideration in the dissolved or suspended forms (kg/day), obtained for a 3-day observation period;

m_x – mean daily water discharge (L/day), obtained for a 3-day observation period;

n – number of observation days in a month (using our assumptions – three).

$$S_{xy} = \frac{\sum_{i=1}^{n} X_i Y_i - n \cdot m_y \cdot m_x}{n-1} \qquad S_x^2 = \frac{\sum_{i=1}^{n} X_i^2 - n \cdot m_x^2}{n-1}$$

and:

X_i, Y_i – values of the water discharge and flux of the substance under consideration for each specific day when measurements were conducted.

In our case $Y_i = m_y$ and $X_i = m_x$, as the concentration of suspended matter and PTS concentrations were determined from a single integral sample collected during the 3-day observation period and the water discharges were calculated on the basis of the average flow velocity for a 3-day period.

In this case, equation (1) above for the calculation of mean monthly PTS flux can be simplified to:

$$\mu_y = \mu_x \frac{m_y}{m_x} \qquad (4.2)$$

In applying this, the following assumptions were adopted:

- Values of my and mx were assumed to be constant for the months which fall within each hydrological season: i.e., May-July (spring flood); August-September (summer low water period); October (period before the onset of ice formation); November-April (winter low water period).
- The ratio of the PTS fluxes in dissolved and particulate associated phases is constant inside the cross-section and during the hydrological season represented.
- The ratio of the PTS fluxes in dissolved and particulate associated phases during the spring freshet is assumed to be equal to the ratio during periods of low discharge.

As mentioned above, mean monthly water discharges at the closing cross-sections of the Pechora and Yenisey rivers (near Oksino settlement and Igarka, respectively) for both the observation year and an 'average' water discharge year, for use in the calculations, were provided by Roshydromet. For the two downstream cross-sections, similar data were not available. Consequently, the following assumptions were adopted for calculation purposes:

Congener	**Form**	**R. Pechora (at Oksino)**		**R. Yenisey (at Igarka)**	
		2001-2002	**Long-term**	**2001-2002**	**Long-term**
CB28	Dissolved	115	122	125	107
	Suspended	639	678	609	520
	Total	**754**	**800**	**734**	**627**
CB31	Dissolved	93	99	102	87
	Suspended	692	734	727	621
	Total	**785**	**833**	**829**	**708**
CB52	Dissolved	187	198	146	125
	Suspended	274	291	465	398
	Total	**461**	**489**	**611**	**523**
CB99	Dissolved	10	11	324	277
	Suspended	85	90	232	198
	Total	**95**	**101**	**556**	**475**
CB101	Dissolved	5	5	214	183
	Suspended	49	52	36	31
	Total	**54**	**57**	**250**	**214**
CB105	Dissolved	13	14	243	208
	Suspended	48	51	48	41
	Total	**61**	**65**	**291**	**249**
CB118	Dissolved	12	13	75	64
	Suspended	8	8	349	298
	Total	20	21	424	362
CB128	Dissolved	0	0	118	101
	Suspended	1	1	51	44
	Total	**1**	**1**	**169**	**145**
CB138	Dissolved	10	11	102	87
	Suspended	27	29	265	227
	Total	**37**	**40**	**367**	**314**
CB153	Dissolved	3	3	1	1
	Suspended	0	0	58	50
	Total	**3**	**3**	**59**	**51**
CB156	Dissolved	2	2	0	0
	Suspended	0	0	34	29
	Total	**2**	**2**	**34**	**29**
CB170	Dissolved	0	0	2	2
	Suspended	0	0	2	2
	Total	**0**	**0**	**4**	**4**
CB183	Dissolved	6	6	9	8
	Suspended	0	0	55	47
	Total	**6**	**6**	**64**	**55**
CB187	Dissolved	3	3	0	0
	Suspended	4	4	0	0
	Total	**7**	**7**	**0**	**0**
Σ PCB	Dissolved	456	484	1460	1250
	Suspended	1830	1940	2930	2510
	Total	**2280**	**2420**	**4390**	**3760**

Table 4.12. PCB flux (kg/y) at the closing cross-sections of the Roshydromet network, calculated for the period of observations (2001-2002), and for the long-term mean annual water discharge.

- For the Pechora, mean monthly water discharges at the Andeg cross-section were assumed to be equal to the discharges at the Oksino cross-section.
- For the Yenisey, mean monthly water discharges at the Ust'-Port cross-section were assumed to be 3% higher than the discharges at the Igarka cross-section.

Analytical studies covered the whole range of PTS included within the project scope, with the exception of dioxins and brominated compounds, which were excluded due to their extremely low levels in abiotic freshwater environments. However, analysis of samples collected during field work also showed that levels of toxaphene compounds in all samples from the Pechora and Yenisey were lower than effective detection limits (0.05 ng/L for water, and 0.01 ng/mg for suspended matter), therefore toxaphene was also excluded from the assessment of fluxes.

4.3.3. Overview of the assessment results

PCB

Estimated PCB fluxes via the Pechora and Yenisey rivers are presented in Table 4.12. It is worth noting that the estimated fluxes of specific PCB congeners through both the closing cross-sections of the regular hydrometric network and the downstream cross-sections are very similar (Figure 4.44). Based on this information, the overview of assessment results for other contaminant groups, below, focuses mainly on fluxes in the closing cross-sections of the rivers.

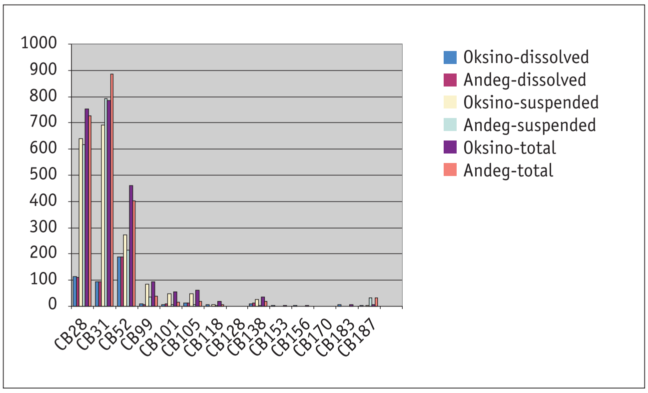
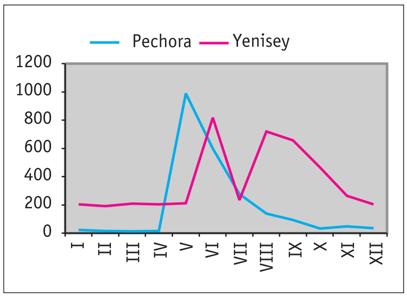


Figure 4.44. Estimated fluxes (kg/y) of PCB congeners at the closing (Oksino) and downstream (Andeg) cross-sections of the Pechora river.

The total PCB flux in the Pechora river consists almost entirely of tri- and tetra-chlorobiphenyls. Fluxes of the heavier PCB congeners are negligible. This is consistent with information presented to the OSPAR Commission by Sweden (Axelman, 1998).

The structure of PCB fluxes in the Yenisey river are more complex. As expected, peak PCB fluxes in both rivers coincide with springtime peaks in water discharge, which occur later in the lower Yenisey than in the lower Pechora. However, flux values for the Yenisey river also exhibit a distinct second peak in the late summer-autumn period (Figure 4.45).

Figure 4.45. Monthly fluxes (kg) of PCB in the Pechora and Yenisey rivers.



Two possible explanations for the second peak are:

- instrumental/procedural errors during analysis of the samples;
- accidental PCB release from some unknown pollution source.

Although it is difficult to make a definite conclusion regarding the cause of this peak appearance, the following information should be noted:

- the peak was observed not only during the summer low water period, when it was detected for the first time, but also during the period before ice formation in October (Figure 4.62);
- the peak is due to increased fluxes in PCB congeners associated with suspended matter, with dissolved forms showing practically unchanged fluxes;
- compared to the spring flood peak, which, as in the case of the Pechora, is a result of fluxes of tri- and tetra-chlorobiphenyls, the second flux peak has a higher contribution of penta- and hexa-chlorobiphenyls, particularly CB118 and CB138 (Figure 4.46).

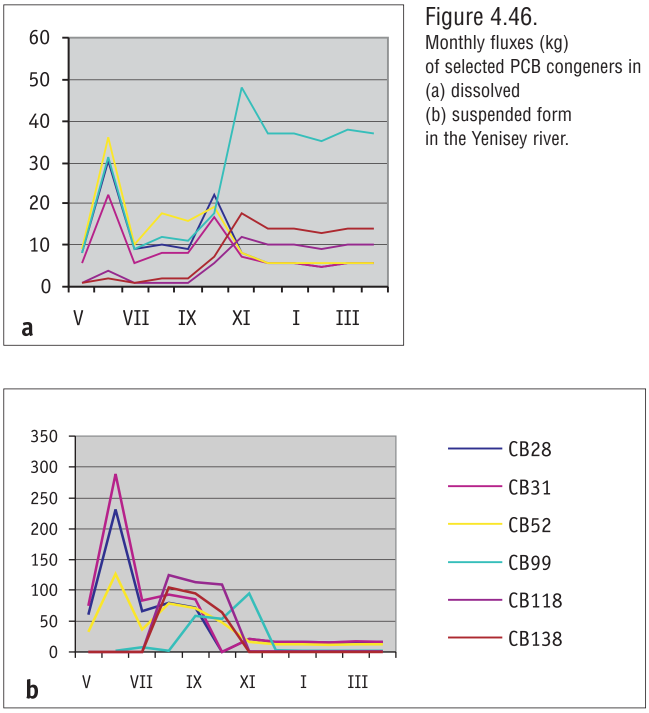


Figure 4.46. Monthly fluxes (kg) of selected PCB congeners in
(a) dissolved
(b) suspended form
in the Yenisey river.

Compound	Form	Pechora		Yenisey	
		2001-2002	Long-term	2001-2002	Long-term
1234-TeCBz	Dissolved	6.6	7	0	0
	Suspended	2.4	2.5	16	12
	Total	**9**	**9.5**	**16**	**12.7**
1235-TeCBz	Dissolved	0	0	0	0
	Suspended	0	0	0	0
	Total	**0**	**0**	**0**	**0**
1245-TeCBz	Dissolved	8.8	9.7	138	112
	Suspended	5.9	6.3	170	131
	Total	**14.7**	**16**	**308**	**242**
QCB (PeCBz)	Dissolved	8.7	9.4	29.7	24.7
	Suspended	59.7	65.1	189	171
	Total	**68.4**	**74.5**	**218**	**196**
HCB (HxCBz)	Dissolved	73.8	79.1	200	175
	Suspended	143	155	161	139
	Total	**217**	**235**	**362**	**314**
ΣPCBz	Dissolved	97.9	105	368	311
	Suspended	211	229	536	454
	Total	**309**	**335**	**904**	**765**

Table 4.13. Fluxes of polychlorinated benzenes (kg/y) in flows of the Pechora and Yenisey rivers, calculated for the period of observations (2001-2002), and for the long-term mean annual water discharge.

This evidence, whilst indirect, argues for the likely explanation being an accidental PCB release from a non-identified local source. However, in case of a short-term release, estimation of the annual flux based of this data can be overestimated.

Polychlorinated benzenes

Estimates of annual fluxes of polychlorinated benzenes (PCBz) in the flows of the Pechora and Yenisey rivers are presented in Table 4.13. As expected, hexachlorobenzene (HCB) is the main compound in this contaminant group, with relatively high fluxes in both rivers. Although tetra-chlorinated benzenes (TeCBz) have occasionally been found in both water and suspended matter of both rivers, their concentrations were close to detection levels, and as such they cannot be considered contaminants that pose a significant threat to either the aquatic environment or humans. Seasonal distribution of fluxes exhibit the a typical pattern of a peak during the spring flood period (Figure 4.47).

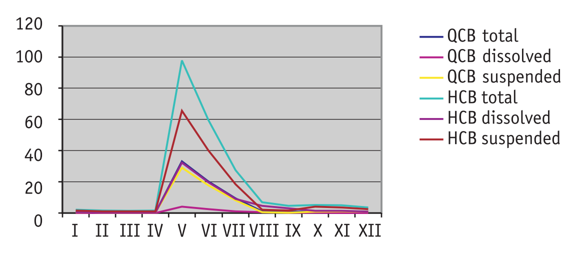


Figure 4.47. Monthly fluxes (kg) of QCB and HCB in the Pechora river.

Contaminant	Form	Pechora		Yenisey	
		Oksino	Andeg	Igarka	Ust-Port
α -HCH	Dissolved	98.4	157	71.6	60.2
	Suspended	85.4	351	699	271
	Total	**184**	**509**	**771**	**210**
β -HCH	Dissolved	14.8	34.5	16.4	16.9
	Suspended	71.6	158	161	0
	Total	**86.4**	**192**	**177.6**	**16.9**
γ -HCH	Dissolved	109	190	109	47.2
	Suspended	159	721	751	218
	Total	**267**	**912**	**859**	**265**
Σ HCH	Dissolved	222	382	197	123
	Suspended	316	1230	1610	488
	Total	**537**	**1610**	**1810**	**612**

Table 4.14. Fluxes of HCH compounds (kg/y) in flows of the Pechora and Yenisey rivers for 2001-2002.

Organochlorine pesticides and their metabolites

(a) Hexachlorocyclohexane (HCH)

Data on HCH fluxes in the Pechora and Yenisey rivers are presented in Table 4.14. For both rivers, total HCH fluxes are dominated by α- and γ-HCH isomers, with γ-HCH the most prevalent. However, the two rivers do not show consistent trends between the closing cross-sections of the regular observation network and the more downstream cross-sections, established close to areas inhabited by indigenous population. Fluxes of all HCH compounds increase downstream in the Pechora river, while the Yenisey shows the opposite trend. A possible explanation is that the downstream section of the Pechora rivers shows the impact of local HCH usage, while HCH fluxes in the lower Yenisey river are the result of long-range transport alone, and thus the downstream section of the river has lower loads due to self-purification processes in the aquatic environment. It should be noted however that in case of short-term environmental releases annual fluxes can be overestimated.

Contaminant	Form	Pechora		Yenisey	
		Oksino	Andeg	Igarka	Ust-Port
o,p'-DDT	Dissolved	18.0	20.7	93.2	115
	Suspended	55.9	476	417	93.1
	Total	**73.9**	**497**	**511**	**209**
p,p'-DDT	Dissolved	33.8	90.8	247	200
	Suspended	119	855	835	238
	Total	**153**	**945**	**1080**	**438**
Σ DDT	Dissolved	51.8	112	340	315
	Suspended	175	1440	1250	331
	Total	**227**	**1554**	**1590**	**646**
o,p'-DDE	Dissolved	5.5	3.7	10.9	8.7
	Suspended	30.2	59.2	155	73.2
	Total	**35.7**	**62.9**	**166**	**81.9**
p,p'-DDE	Dissolved	14.7	21.2	46.4	30.8
	Suspended	75.6	93.7	354	137
	Total	**90.3**	**115**	**400**	**168**
Σ DDE	Dissolved	20.2	24.9	57.3	39.5
	Suspended	106	153	509	210
	Total	**126**	**178**	**566**	**250**
o,p'-DDD	Dissolved	20.2	13.3	127.3	68.0
	Suspended	30.1	45.3	24.5	6.5
	Total	**50.3**	**58.6**	**151.8**	**74.5**
p,p'-DDD	Dissolved	5.6	~0	333.0	229.7
	Suspended	0.5	94.9	84.8	~0
	Total	**6.1**	**94.9**	**418**	**230**
Σ DDD	Dissolved	25.8	13.3	460	297
	Suspended	30.6	140	109	6.5
	Total	**56.4**	**154**	**570**	**303**
Σ DDTs	Dissolved	97.8	146	857	652
	Suspended	311	1740	1870	548
	Total	**409**	**1880**	**2730**	**1200**
DDE:DDT ratio	Dissolved	0.39	0.22	0.17	0.13
	Suspended	0.6	0.11	0.41	0.63
	Total	**0.55**	**0.12**	**0.36**	**0.39**

Table 4.15. Fluxes of DDT compounds (kg/y) in flows of the Pechora and Yenisey rivers for 2001-2002.

(b) DDTs

Fluxes of DDTs in flows of the Pechora and Yenisey rivers show similar trends as for HCHs (Table 4.15), with a strong increase in concentrations between the Oksino and Andeg cross-sections of the Pechora, and a decrease between the Igarka and Ust'-Port cross-sections of the Yenisey. This can be explained by a large local input of DDT into the lower part of Pechora, particularly during the spring flood period (Figure 4.48), whereas in the Yenisey, the contamination is the result of long-range transport of contaminants in the Yenisey, with fluxes decreasing downstream due to self-purification. This conclusion is supported by the significant change seen in the composition of the total DDTs flux at the downstream Andeg cross-section when compared to Oksino. At Andeg, the proportion of the DDT

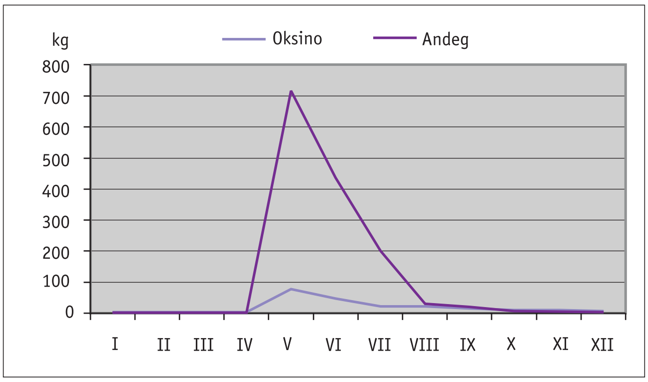
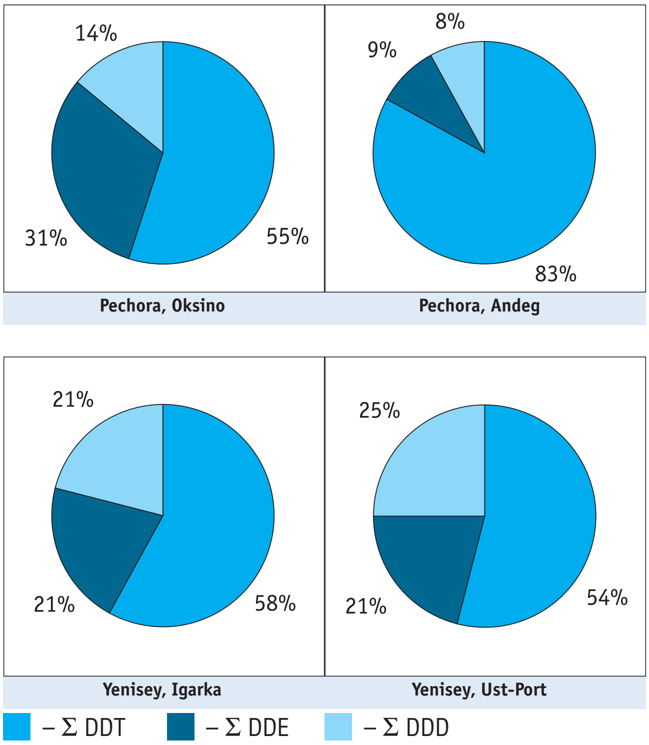


Figure 4.48. Monthly fluxes (kg) of DDT in the Pechora river.

component is far greater (Figure 4.49). Considering that the absolute value of Σ DDD, which is a dechlorinated DDT analog in the technical DDT mixture (AMAP, 1998), also shows an almost three-fold increase, it is reasonable to assume that the DDT flux increase is due to fresh local input of DDT. For the Yenisey river, the Σ DDT flux composition did not alter between the two cross-sections. In this case, like in case of HCH, annual fluxes can be overestimated.

It should be noted that the increase in DDT flux at the Andeg cross-section is mostly determined by an increase in its suspended form. Data quality can be verified from the comparability of data obtained for the suspended matter flux in different layers of the Andeg cross-section (Figure 4.50). The ratio of *o,p'*-DDT to *p,p'*-DDT in the surface, middle and bottom layers of the river flow remains constant, however, the surface layer shows lower levels of DDT when compared to the middle and bottom layers.



Pechora, Oksino
Pechora, Andeg
Yenisey, Igarka
Yenisey, Ust-Port

Figure 4.49. Composition of total DDT fluxes in the Pechora and Yenisey rivers.

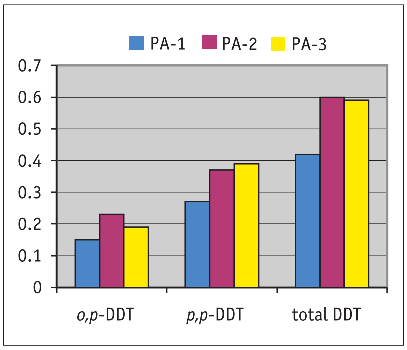


Figure 4.50. DDT concentrations (ng/mg) in suspended matter of the Pechora river at the Andeg cross-section (PA-1: surface layer, PA-2: middle layer, PA-3: bottom layer) (see Figures 4.40 and 4.49).

(c) Other chlorinated pesticides

Other chlorinated pesticides included in the priority list of PTS considered in the project were either found only at levels below detection limits, or had fluxes that would not be expected to have any noticeable impact on the health of indigenous human populations (Table 4.16).

Contaminant	Form	Pechora		Yenisey	
		Oksino	Andeg	Igarka	Ust-Port
Heptachlor	Dissolved	11.9	21.2	7.0	1.1
	Suspended	0.5	0	2.7	0
	Total	**12.4**	**21.2**	**9.7**	**1.1**
Heptachlorepoxide	Dissolved	0	0	0	0
	Suspended	0.9	0	1.5	0
	Total	**0.9**	**0**	**1.5**	**0**
***Cis*-chlordane**	Dissolved	0	0	0	0
	Suspended	0	0	0	0
	Total	**0**	**0**	**0**	**0**
***Trans*-chlordane**	Dissolved	6.6	17.4	117	99
	Suspended	0.5	0	0.3	0
	Total	**7.1**	**17.4**	**118**	**99**
***Cis*-nonachlor**	Dissolved	0	0	0	0
	Suspended	0	0	0	0
	Total	**0**	**0**	**0**	**0**
Trans-nonachlor	Dissolved	10.3	19.5	7.2	0
	Suspended	1.3	0	7.9	0
	Total	**11.6**	**19.4**	**15.1**	**0**
Photomirex	Dissolved	0	0	0	0
	Suspended	0	0	0	0
	Total	**0**	**0**	**0**	**0**
Mirex	Dissolved	0	0	0	0
	Suspended	2.6	3.1	0	0
	Total	**2.6**	**3.1**	**0**	**0**

Table 4.16. Fluxes of other chlorinated pesticides (kg/y) in flows of the Pechora and Yenisey rivers for 2001-2002.

Polycyclic aromatic hydrocarbons (PAHs)

The list of PAHs included in the scope of the preliminary assessment of riverine fluxes included 20 compounds. Annual fluxes of 10 PAHs in the Pechora and Yenisey are presented in Figures 4.51 and 4.52, respectively. However, fluxes of several PAHs could not be assessed, as their concentrations in water and suspended matter in both rivers were below detection limits. These were:
acenaphthene, benzo[*a*]anthracene,
benzo[*b*]fluoranthene, benzo[*e*]pyrene, perylene,
benzo[*k*]fluoranthene, benzo[*a*]pyrene,
dibenzo[*a,h*]anthraceneindeno[1,2,3-*c,d*]pyrene,
and benzo[*ghi*]perylene.

In both rivers, PAH fluxes are dominated by the more soluble 2-cyclic PAHs (naphthalene, 2-methylnaphthalene, biphenyl) and, to certain extent, 3-cyclic PAHs (fluorene, phenanthrene). At the downstream Ust'-Port cross-section of the Yenisey river, PAH fluxes are significantly lower. This confirms an absence of additional PAH sources between the two cross-sections along this part of the river. However, fluxes of some PAHs at the downstream Andeg cross-section of the Pechora river are significantly higher than at the upstream Oksino cross-section. This is true not only for 2- and 3-cyclic PAHs, such as 2-methylnaphthalene, fluorene and phenanthrene, but also for the heavier PAHs (fluoranthene and pyrene). Increase in fluxes of these less readily transported 4-cyclic PAHs provides additional evidence of local pollution sources between the Oksino and Andeg cross-sections of the Pechora river.

Contaminant	Form	Pechora		Yenisey	
		Oksino	Andeg	Igarka	Ust-Port
Lead	Dissolved	89.2	77.1	624	375
	Suspended	77.2	24.4	114	535
	Total	**166**	**101**	**738**	**911**
Cadmium	Dissolved	6.77	3.31	124	122
	Suspended	22.05	9.90	4.34	26.98
	Total	**28.8**	**13.2**	**129**	**149**
Mercury	Dissolved	1.02	0.472	0	0
	Suspended	1.82	1.75	2.79	9.10
	Total	**2.84**	**2.22**	**2.79**	**9.10**

Table 4.17. Fluxes of heavy metals (t/y) in flows of the Pechora and Yenisey rivers for 2001-2002.

Heavy metals.

Data on annual fluxes of heavy metals that were included in the study (lead, cadmium, and mercury) are presented in Table 4.17.

(a) Lead

The intra-annual distribution of lead fluxes in flows of the Pechora and Yenisey rivers are presented in Figures 4.53 and 4.54. For both rivers, peaks of lead fluxes coincide with the peak of the spring flood. It is noticeable that the composition and annual distribution of lead flux in the Yenisey river has a more complicated pattern than that of the Pechora river. During low-water periods, and particularly during the ice cover season, lead flux at both the Igarka and Ust'-Port cross-sections is dominated by the dissolved form of the metal, with levels almost twice as high at the upstream cross-section. However, during the flood period, the flux at the Ust'-Port cross-section is significantly higher than at Igarka, and is mostly due to suspended forms of lead.

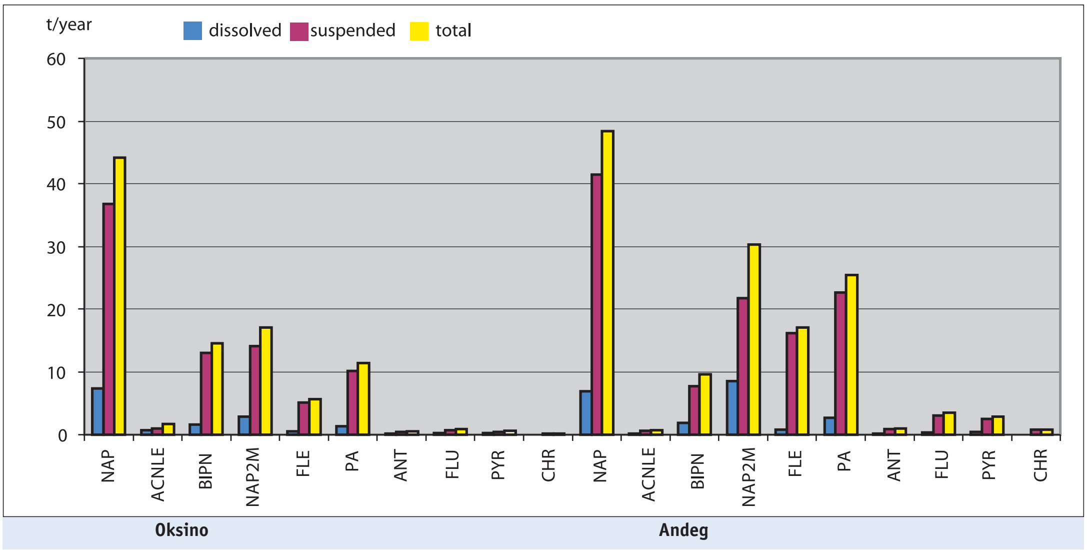


Figure 4.51. Estimated fluxes (t/y) of PAHs in the flow of the Pechora river.

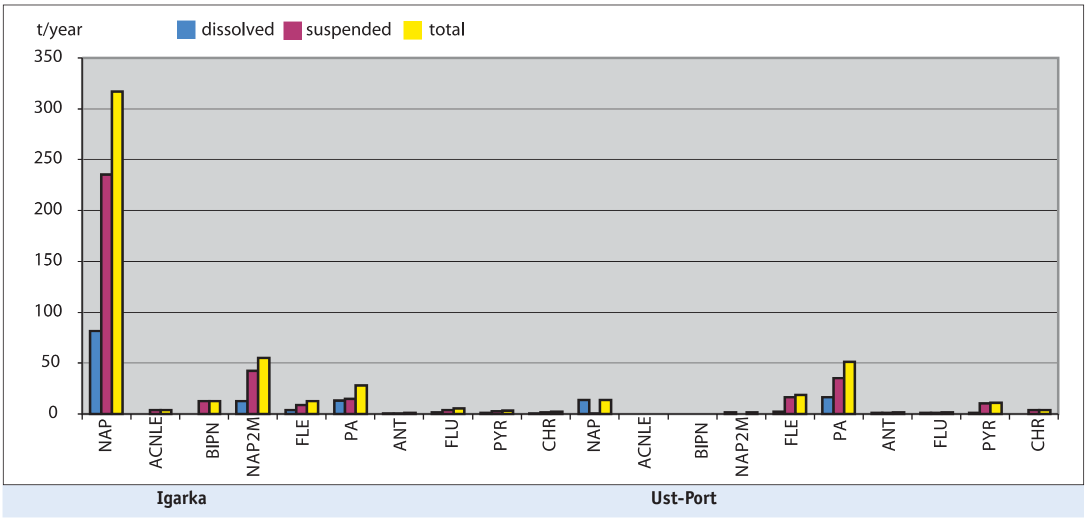


Figure 4.52. Estimated fluxes (t/y) of PAHs in the flow of the Yenisey river.

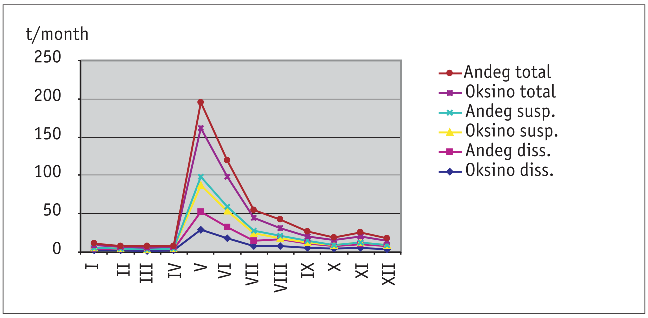


Figure 4.53. Monthly fluxes (t) of lead in the Pechora river.

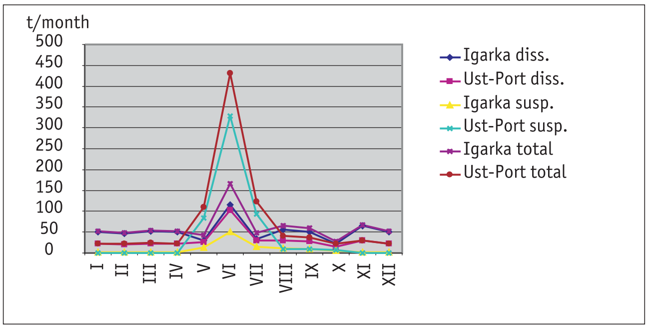


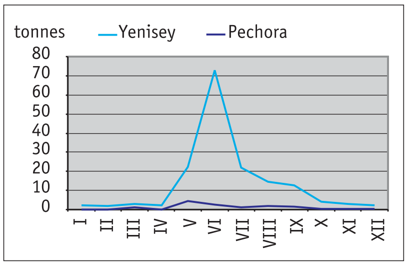
Figure 4.54. Monthly fluxes (t) of lead in the Yenisey river.

This suggests that during the ice cover season, lead flux is almost totally determined by long-range transport of the more mobile dissolved form of lead, from industrialized regions in the central part of the Yenisey basin; whereas, during the flood period, lead flux is dominated by local runoff from the area between Igarka and Ust'-Port, which can be significantly affected by the Norilsk industrial region.

(b) Cadmium

Compared to the other PTS, the difference in cadmium fluxes seen in the flows of the Pechora and Yenisey rivers is much more pronounced (Figure 4.55). It is also notable that the composition of cadmium fluxes in the two rivers are different (Figures 4.56 and 4.57). The Pechora river flux has a much greater proportion of the suspended form of cadmium, particularly during the spring flood period. During the ice cover season, this difference is not so noticeable. This could be explained by the higher sediment load of the Pechora, compared to the Yenisey.

Figure 4.55. Monthly fluxes (t) of (dissolved+suspended) cadmium in the Pechora and Yenisey rivers.



(c) Mercury

In general, the intra-annual distribution of mercury fluxes in the Pechora and Yenisey correspond to the respective river hydrographs, with the highest fluxes during the spring flood period (Figures 4.58 and 4.59). The Yenisey river mercury flux almost totally consists of suspended forms of the metal. The composition of the mercury flux of the Pechora river is more complicated, and differs between the Oksino and Andeg cross-sections (Figure 4.60). Total flux at the upstream Oksino cross-section is higher relative to that at Andeg (Figure 4.61). During the spring flood period, suspended forms of mercury are dominant in the flux, particularly at

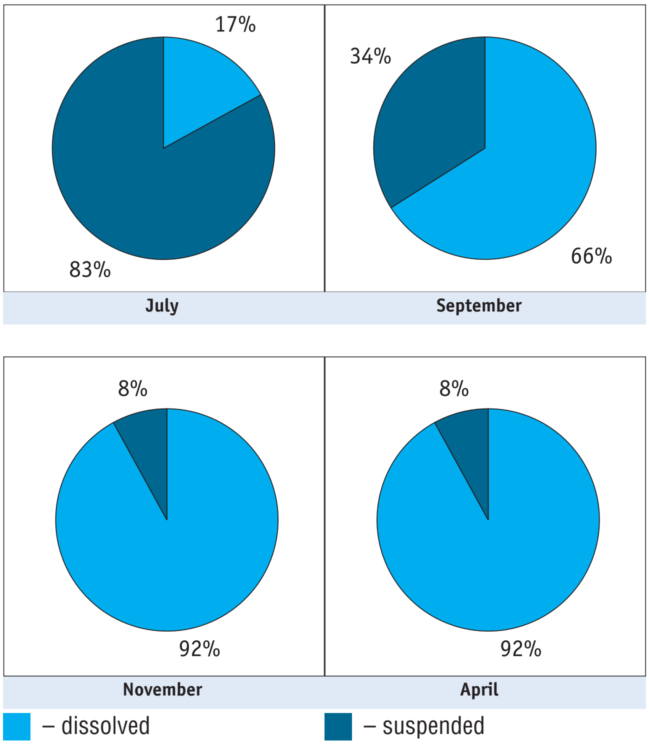


Figure 4.56. Seasonal changes in the ratio of dissolved and suspended fluxes of cadmium in the Pechora river flow.

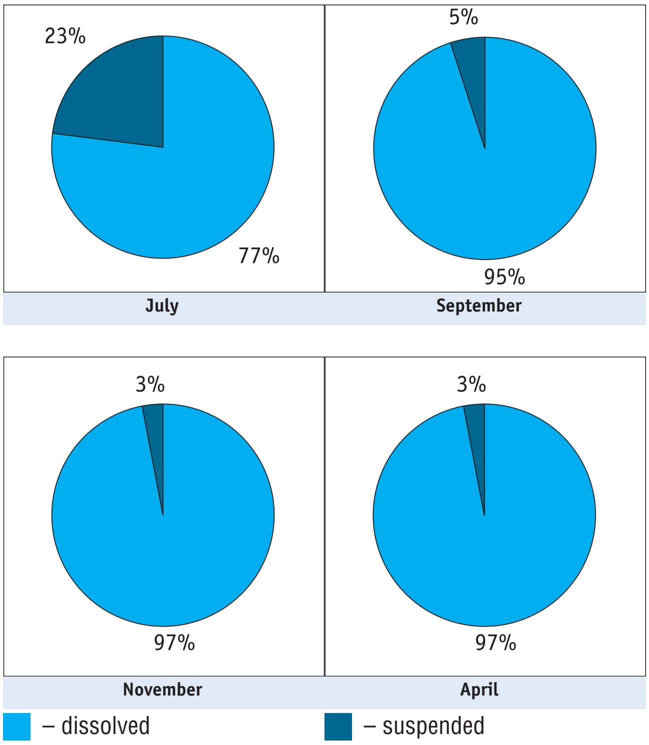


Figure 4.57. Seasonal changes in the ratio of dissolved and suspended fluxes of cadmium in the Yenisey river flow.

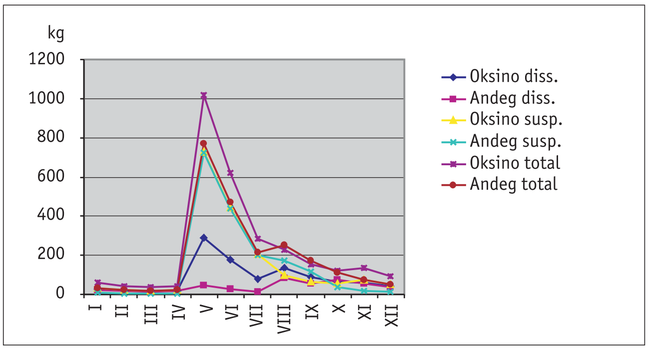
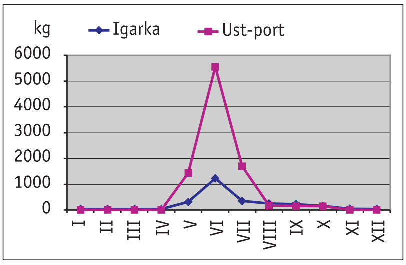


Figure 4.58. Monthly fluxes (kg) of mercury in the Pechora river.

Figure 4.59. Monthly fluxes (kg) of mercury in the Yenisey river.



Andeg. During low water periods, the dissolved proportion of the total mercury flux is larger, amounting to 74% of the total at Andeg during the ice cover season. It should be also noted that during this period, the dissolved flux at these two cross-sections is fairly constant (17-20 kg), while suspended flux is noticeably lower at Andeg than at Oksino (Figure 4.61); this can be explained by sedimentation processes.

The significant difference in the composition of mercury fluxes in the Pechora and Yenisey rivers may be explained by differences in their water composition. Concentrations of total organic matter in the Pechora are almost twice as high as those in the Yenisey, reaching 13-15 mg/L Total Organic Carbon (TOC), 98% of which is in dissolved form (Kimstach *et al.*, 1998). As TOC in natural waters is mostly represented by humic and fulvic acids, which form strong complexes with mercury, the trends in the Pechora mercury fluxes are understandable.

4.3.4. Conclusions

1. In general, PTS fluxes in the Pechora and Yenisey river flows correspond to seasonal river discharges. Highest fluxes usually coincide with spring peak discharges.

2. Among the chlorinated persistent organic pollutants, the highest fluxes are observed for PCBs, HCH and DDTs. The amounts of these contaminants transported by river flows to areas inhabited by indigenous peoples are such that they could contribute to risks to human health.

3. Levels of other chlorinated organic pollutants are either below detection limits, or their fluxes are not sufficiently high to represent a significant risk to the indigenous population.

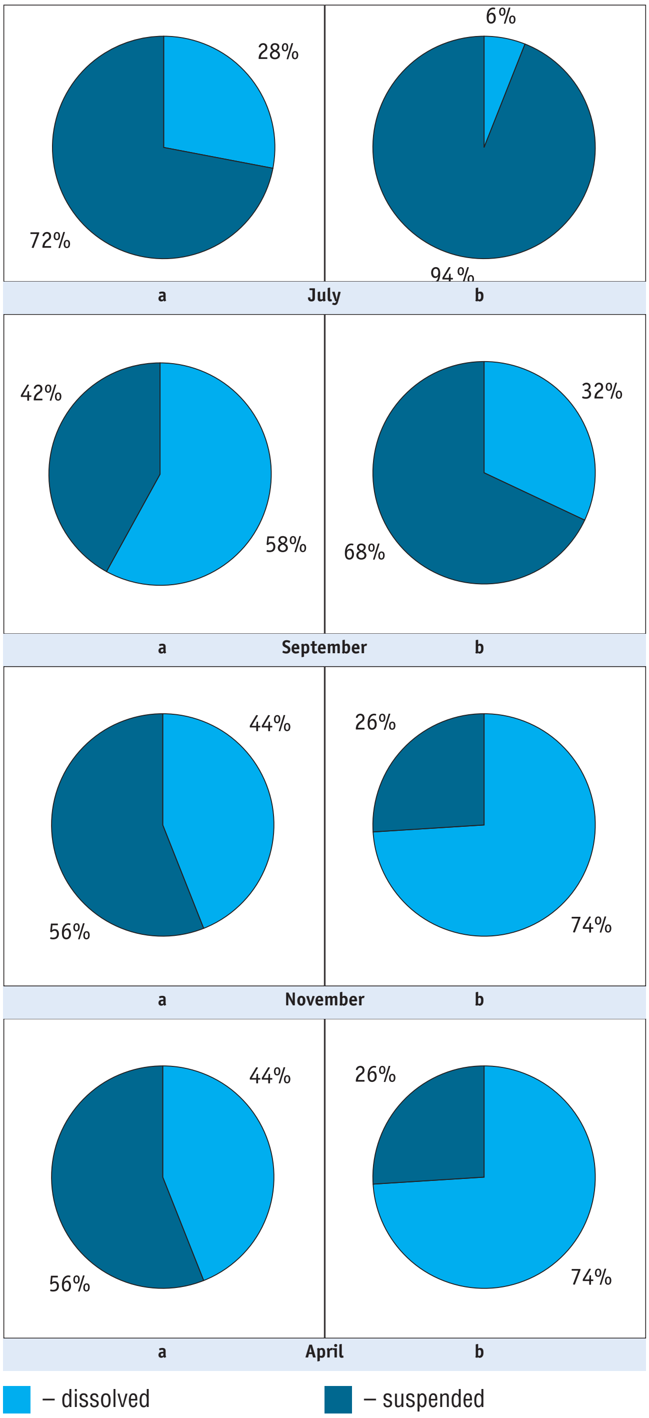


Figure 4.60. Ratio of dissolved and suspended fluxes of mercury at (a) the Oksino and (b) the Andeg cross-sections of the Pechora river

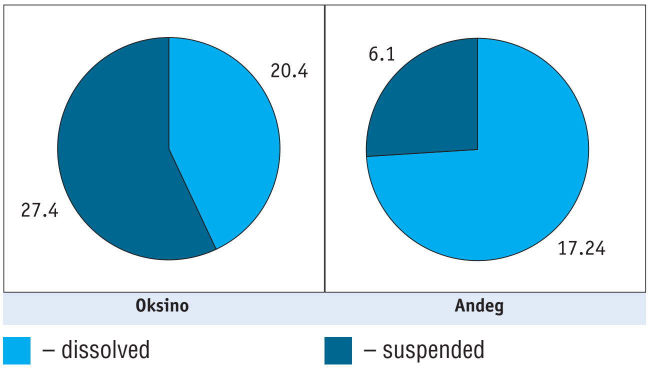


Figure 4.61. Mercury fluxes (kg) at two cross-sections in the Pechora river in April 2002

4. PCB fluxes are mostly in the form of tri- and tetrachlorobiphenyls. Fluxes of the heavier PCB congeners are practically negligible.

5. HCH and DDT fluxes in the Yenisey river flow are the result of long-range transport. In the Pechora river, local sources may contribute to the fluxes of HCH and DDT in the lower reaches of the river. DDE to DDT ratios indicates that the increased DDT flux in the lower part of the river may be caused by fresh use of this pesticide. However, taking into account possible short-term environmental release of these substances, their annual fluxes can be overestimated.

6. Fluxes of polycyclic aromatic hydrocarbons (PAHs) in both rivers consist mostly of 2- and 3-cyclic compounds. In addition to contamination through long-range transport, the lower reaches of the Pechora river may also be affected by local sources of PAHs, which contribute some heavier compounds.

7. Fluxes of heavy metals (lead, cadmium and mercury) in the flow of the Yenisey river, are the result of local contamination, in addition to contamination from long-range transport, particularly during the spring flood period. This can be explained by the influence of pollution from the Norilsk industrial complex.

4.4. Local pollution sources in the vicinities of indigenous communities

4.4.1. Introduction

The main objectives of undertaking an assessment of local pollution sources were to determine their role in general environmental pollution, in the contamination of traditional food products and, accordingly, to determine their influence on human health. For inventory purposes, ‘local sources’ were taken to mean sources within an approximate maximum distance of 100 km of sites of residence of indigenous peoples. Specific boundaries for inventory zones, however, were defined more exactly in each case by taking account of local conditions (dominating winds, river flows and the scale of regional sources, etc.). As some of the pilot study areas within the project are affected by pollution which originates from large industrial complexes located in their vicinity, the pollution source inventory included such towns as Apatity, Monchegorsk, Olenegorsk, Revda, and Kirovsk (in Murmansk Oblast); Nar’yan-Mar (in the Nenets AO); Norilsk (located in the Taymir AO, but under the administrative authority of Krasnoyarsk Krai); and Anadyr (in the Chukotka AO).

The assessment was based on official data relating to PTS emissions, obtained from the various administrative territories and regions, representatives of the Russian Association of Indigenous People of the North (RAIPON), and also from expert estimates of PTS release resulting from use of organic fuel (as this information is not included in official statistical data on PTS emissions). This latter source of atmospheric PTS is important for pollutants such as heavy metals, PAHs, and dioxins. It should be mentioned that in Russia, dioxin emissions have not been recorded and, among PAHs, only benzo[*a*]pyrene emissions are recorded.

Under the study, expert estimates were made for emissions of the following PTS: lead, cadmium, mercury, benzo[*a*]pyrene, benzo[*k*]fluoranthene, indeno[1,2,3-*c,d*]pyrene, and dioxins. These estimates were made using statistical data relating to consumption of the various kinds of fuels and associated emission factors (for the amount of contaminants released to the atmosphere per tonne of a specific fuel). Emission factors were determined either in accordance with existing Russian methodology, or by adapting Western European emissions factors to take account of Russian technologies.

Statistical data were provided by the State statistic offices of the relevant administrative territories of the Russian Federation, environmental protection authorities, and reports by the Russian Federation’s State Committee for Statistics (Goskomstat).

Regional Branches (Committees) of the Russian Federation’s Ministry of Natural Resources were responsible for the initial collection and processing of data and information. The inventory of pollution sources was based upon the following sources of information:

- State Statistic Reports on emissions of gaseous pollutants discharges of waste waters, and solid waste from industrial, municipal and agricultural enterprises and transport;
- Ecological passports of industrial enterprises;
- Reports on environmental protection activities of the local environmental protection authorities, sanitary-epidemiological control services, agricultural administrative authorities, and other information sources (Murmansk, 1991-2000; Murmansk, 1996-2000; Murmansk, 2001; Murmansk, 1994-2000; Nenets, 1998; Nenets, 1999; Nenets, 2001);
- Annual reports and reviews of Federal Ministries and Departments (MNR, 2001; Roshydromet, 1995-2000);
- Other relevant official sources and literature.

It is necessary to mention, however, that there was variation in the completeness and volume of information provided by the various regions for the inventory, due to different technical, organizational, and other aspects of the relevant local services. Due to this, a certain amount of data are derived from expert estimates.

City/District (Rayon)	Total	SO_2	NO_x	CO	Dust
Murmansk	26.8	19.6	2.8	2.2	1.7
Apatity	21.9	12.0	3.9	0.2	5.8
Kirovsk	11.5	6.7	2.1	1.1	1.4
Kandalaksha	22.8	5.4	0.6	7.2	8.2
Monchegorsk	58.1	43.9	1.2	3.8	7.8
Olenegorsk	12.4	4.4	1.0	26	3.9
Severomorsk	10.2	6.4	0.6	2.3	0.7
Kovdorsky District	7.7	3.8	0.5	1.9	1.4
Kolsky District	5.0	2.3	0.3	1.7	0.7
Lovozersky District	2.0	1.3	0.2	0.3	0.1
Pechengsky District	137.9	124.4	0.6	2.2	10.6
Total emissions in Murmansk Oblast	332.5	240.1	14.7	29.8	43.7
Total emissions in inventory area	105.9	61.6	8.4	8.0	19.0
Percentage of the Oblast's emissions occurring in the inventory area	31.8	25.7	57.1	26.8	43.5

Table 4.18. Industrial air emissions of major contaminants in the cities and districts of the Murmansk Oblast in 2002, thousand tonnes (NEFCO, 2003).

City/District	Enterprise	Total emissions	% in city/district
Apatity	Apatity heat and power plant	18.5	84
	'Apatit' JSC	3.5	16
Kirovsk	'Apatit' JSC	11.5	99.7
Monchegorsk	'Severonickel' NCS	51.8	89.2
Olenegorsk	'Olcon'JSC	10.9	87.9
Lovozersky District	Revda heat and power plant	0.8	40
	'Lovozero GOC' JSC	0.3	15

Table 4.19. Total air emissions of pollutants (thousand tonnes) from major industrial pollution sources in the inventory area in Murmansk Oblast, 2002, and their percentage contribution to emissions from the corresponding cities/districts.

Enterprise	Total discharge	Biodegradable organic substances	Suspended matter	SO_4^{2-}	Cl^-	Ni	Cu
'Severonickel' NCS	14.7	48.7	364	38780	6800	10.9	2.1
Lovozero GOC	13.6	21.0	200	82	76	-	-
'Apatit' JSC	145.5	288	514	8694	909	-	-

Table 4.20. Wastewater discharges (million m3) from selected large industrial enterprises in 2002, and associated discharges (tonnes) (NEFCO, 2002).

4.4.2. Murmansk Oblast

4.4.2.1. General description

The inventory of PTS sources covered the territory within a radius of at least 100 km of the settlement of Lovozero. It includes the cities of Monchegorsk, Olenegorsk, Apatity, Kirovsk, and Revda.

Murmansk Oblast is one of the largest and most economically developed regions of Russia's European North. Almost the entire territory lies to the North of the Arctic Circle. The population amounts to 958,400 residents, of whom 91.7% are urban and 8.3% percent are rural. The northern indigenous peoples, mostly Saami, amount to 0.2% of the total population.

The economy of Murmansk Oblast is mainly oriented towards the extraction and reprocessing of natural resources. The region produces 100% of Russia's apatite concentrate, 12% of iron-ore concentrate, 14% of refined copper, 43% of nickel, and 14% of fish foodstuffs. Concerning production industries, 90% of the gross regional product is created by primary industrial enterprises.

Estimates of emissions of general air pollutants (SO_2, NO_x, CO, and dust) from industries in the region are presented in Table 4.18. Although these pollutants are not representative of any specific PTS, they do characterize levels of general environmental pollution, and thus are related to pollution impacts on human health. As shown, industrial enterprises located in the vicinity of the study area, which is densely populated by the Saami people, emit a significant part of the total industrial air emissions in Murmansk Oblast, particularly NO_x and dust.

Mining and processing plants provide the basis for the economies of the majority of the regions large towns and cities where a third of the Oblast's population live. These include the Nickel and Copper Combined Smelter JSC GMK Pechenganikel, in the city of Zapolyarny and the town of Nikel; the Iron Ore Concentration Plant JSC Olkon, in the city of Olenegorsk; the Nickel and Copper Combined Smelter JSC Severonikel, in the city of Monche-gorsk; the Mining Plant Apaptit JSC, in the cities of Kirovsk and Apatity; the Iron Ore Kovdor Mining and Concentration Plant JSC, and the Concentration Plant Kovdorslyuda JSC, in the city of Kovdor; and the rare metals extraction and concentration plant Sevredmet JSC, in the settlement of Revda. The contributions made by the large enterprises located in the inventory area to total air emissions in the corresponding city/district are presented in Table 4.19.

Surface water bodies located close to settlements and industrial complexes have a high degree of pollution, as determined by their acidification (pH) and levels of fluorine (F), aluminium (Al), iron (Fe), and manganese (Mn), which all exceed maximum permissible concentrations. Data on wastewater discharges from the selected large industrial enterprises in the survey area are presented in Table 4.20.

Monchegorsk area

A zone of 'extremely unfavorable environmental pollution' lies within the area influenced by the cities of Monchegorsk and Olenegorsk. This zone occupies an area of about 1400 km², and has the form of an ellipse with the city of Monchegorsk at its epicenter and its long axis extending 48-50 km to the south (due to the prevailing wind direction). In the north, the zone extends as far as the city of Olenegorsk, incorporating the urban agglomeration, and in the south, it extends to Viteguba. The Monchegorsk area is characterized by extreme levels of annual deposition of nickel (Ni) and copper (Cu) (115.9 and 136.5 kg/km^2, respectively). Cadmium levels in the surface geological horizon in this area are five times higher than the background level for the region. These figures confirm the high environmental impact of the Monchegorsk 'Severonickel' combined smelter.

Kirovsk – Apatity

This area is located within the limits of the Khibiny Massif, which is a natural geochemical anomaly with respect to the vast number elements and the unique deposits of apatite and nepheline ores. 'Apatit' JSC, which processes and enriches deposits of apatite and nepheline ores, is considered as the main pollution source for this area. The plant is one of the world's biggest manufacturers of raw phosphate used in the production of mineral fertilizers. 'Apatit' JSC is a huge mining and chemical complex which currently includes four mines, a concentration plant, railway facilities, an automobile workshop, and about thirty other service workshops.

Since opening, the 'Apatit' plant has extracted and transported more than 1.4 x 10^9 tonnes of ore to the concentration plant, and produced about 520 million tonnes of apatite and more than 52 million tonnes of nepheline concentrates. The concentrates also contain fluorine, strontium oxide, and rare-earth elements, which may be separated as individual products during processing. Nepheline concentrate is used as a raw material for producing alumina, and in the glass and ceramic industries. It is also used as a raw material for producing soda, potash, cement, and other products.

Lovozero – Revda

This area is located in a zone of heavy metal contamination created by the 'Severonickel' combined smelter. The largest local pollution source is the rare metals combined enterprise JSC 'Lovozero GOC' (formerly known as – 'Sevredmet'), located in the settlement of Revda. The enterprise consists of two mines (Karnasurt and Umbozero) and two concentration plants. Tailings and rocks left after drifting and stripping are stockpiled in surface dumps and storage sites. Mining and drainage waters are discharged into surface water bodies.

The river with the highest anthropogenic load is the Sergevan, which receives untreated and poorly-treated mining, filtration, and domestic wastewaters from the Karnasurt mine and concentration plant. Fluorine, sulphates, and nitrates are typical constituents of the mining waters. Environmental and geochemical mapping of the northern part of the Lovozero Massif which was carried out between 1993 and 1996, (Lipov, 1997), depicted areas classed as extremely hazardous (125 km^2), hazardous (200 km^2), moderately hazardous (240 km^2) and acceptable (435 km^2) with respect to pollution of soils. The total area of polluted land amounted to 565 km^2. With increasing distance from the industrial pollution sources and the Lovozero Massif (an ore-rich feature, which itself creates a natural geochemical anomaly), a drastic reduction in the content of all polluting substances in soils, with the exception of sulphur, can be observed. Sulphur content in soils has a patchy occurrence, with localised 'hotspots', usually seen in remote places, far from the sources of gas and dust emissions.

As in the case of soils, the highest pollution levels in mineral bottom sediments of water bodies are observed in the area of the Lovozero Massif and its spurs, where the main mining and concentration plants are located. Similar to soils, the maximum levels of toxic elements (for the same group of main pollutants) found in bottom sediments generally correspond to the level of emissions. Contrary to its distribution in soils, however, maximum concentrations of sulphur are found in the bottom sediments of water courses in urban areas.

4.4.2.2. Inventory of PTS pollution sources

Pesticides

According to data provided by the Murmansk Territorial Station for Plant Protection, chlorinated pesticides that are the main subject of the PTS inventory have not been used, and are not currently used, in Murmansk Oblast. Other types of pesticides used over the last twenty years, according to the information available from this office, are shown in Table 4.21. The quantity of pesticides used on open ground varies from tens to a few hundred kilograms in weight, because the area of agricultural land is limited.

Enterprise	Pesticide	Amount used, kg	Treated area, hectares
Sovkhoz 'Industria', Apatity	Prometrin	3340	668
	Zenkor	70	100
	Fosulene	42	7
	Syrtin	500	100
	Licoprop	500	125
	Likmin	531	161
	Lontrel	90	90
	Bazargan	248	161
	Ramrod	50	5
Sovkhoz 'Monchegorsky', Monchegorsk	Licoprop	724	181
	Likmin	540	180
	Bazargan	370	185
	Ramrod	180	18
	Prometrin	24	9
Sovkhoz 'Tundra', Lovozero	Licoprop	80	20
	Likmin	60	20
Sovkhoz 'Revda', Revda	Licoprop	520	130
	Likmin	270	90
	Bazargan	184	92
POSVIR, Apatity	Prometrin	390	78

Table 4.21. Use of pesticides in 1990-2000 in the Murmansk Oblast inventory area, data from the Murmansk Territorial Station for Plant Protection.

Such agricultural enterprises as ‘Industria’, ‘Revda’, and ‘Monchegorsky’ and “POSVIR”, store pesticides in standard or customized warehouses, which are registered by the sanitary and epidemiological surveillance bodies. The agricultural enterprise ‘Tundra’ has received one-off permissions for delivery and use of plant protection chemicals.

It should be noted that the table contains data on herbicides only, and that no other types of pesticides, particularly insecticides, are included. It is, therefore, likely that the data and information provided by the regional authorities responsible for pesticide use and handling is incomplete.

According to the Regional Veterinary Medicine Administration (pers. comm.: letter no. 38/482 of 08.04.2003), the pesticide ‘Etacyde’ was used in the 1960-1970s on reindeer farms in the Murmansk region to treat the animals against subcutaneous reindeer gadflies. From the early-1980s until the present, the pesticide ‘Ivomex’ has been used. According to the information received, there has been no treatment used against blood-sucking insects.

A tentative (but not comprehensive) inventory of stocks of obsolete pesticides in Murmansk Oblast, has identified a number of stocks in the study area (Table 4.22). It should be noted that this information also lacks data on stocks of chlorinated pesticides, except one enterprise in the city of Murmansk.

Location	Total	Chlori-nated	Phosphorus-based	Mercury-based	Other	Poor state
Apatity	714	-	278	-	436	138
Tuloma, Kolsky District	995	-	-	-	995	-
Polyarnye Zori	7584	-	-	-	7584	-
Murmansk	195	13	75	-	107	-
Kirovsk	77	-	74	-	3	-
Murmashi, Apatitsky District	53	-	-	-	53	-
Total in Murmansk Oblast	9623	13	427	-	9183	138
Total in the inventroy area	8428	-	352	-	8076	138

Table 4.22. Stocks of obsolete pesticides in the Murmansk Oblast, kg. (in bold letters - the inventory area)

Polychlorinated biphenyls (PCBs)

There is no statistical registration or control of PCB release to the environment. Therefore, for the inventory of possible PCB pollution sources, all enterprises in the cities and villages mentioned above, plus the enterprises of the regional energy company ‘Kolenergo’ JSC were canvassed. According to data provided by these enterprises, the total number of power transformers in the survey area is 1590, including 1458 in operation and 132 in reserve. However, most of them are filled with the following mineral oils: T-1500, Tkp, Tk, T-750, GOST 982-56, GOST 10121-76, TP-22, and OMTI, which, according to available information, contain no synthetic PCB additives. The PCB-containing transformer fluid ‘Sovtol’ (total amount: 35.92 t) is used only in 13 transformers of the TNZ type at ‘Apatit’ JSC. The inventory did not find any other enterprises within Murmansk Oblast that use PCB-containing fluids in any type of electric equipment.

At the same time, it is notable that of the 180000 t of PCB that was produced in the former USSR/Russia, 53000 t were in the form of the product ‘Sovol’ that was used in the production of varnish and paint (37000 t) and lubricants (10000 t). In addition, ca. 5500 t were used by defence-related industrial enterprises for unknown purposes (AMAP, 2000) and tracing the fate of these PCB-containing products has proved problematic. In view of the fact that Murmansk Oblast is known to have a high concentration of defence-related activities, particularly in previous decades, it might reasonably be assumed that a considerable proportion of these products were used here, and probably contributed to PCB contamination of the area.

Dioxins and Furans

Data on emissions of dioxins and furans from industrial enterprises are not included in the state statistical reporting system, and therefore there is no information on their contribution to pollution of the survey area. Some enterprises, such as the combined nickel smelter ‘Severonikel’ are likely to be sources of dioxins, but there is no information available to confirm this assumption. Overall, there are a number of dioxin sources that are likely to affect the survey area (Table 4.23).

Dioxin sources	Emission factors (TEQ)
Incineration of domestic waste	38.2 ng/kg
Incineration of medical waste	589 ng/kg
Automobile transport: **- leaded gasoline** **- diesel fuel** **- unleaded gasoline**	 45 pg/km 172 pg/km 1,5 pg/kg
Incineration of waste water residues	6.94 ng/kg d.w.
Cremation	17 μg/body
Burning of spent tires	0.282 ng/kg
Domestic burning of wood fuel	2 ng/kg
Cement kilns **- with incineration of hazardous wastes** **- without incineration of hazardous wastes**	 1.04 - 28.58 ng/kg cement 0.27 ng/kg cement
Coal re-activation	1.2 ng/kg
Smoking	0.43 - 2.9 pg/cigarette
Natural fires	2 ng/kg of biomass
Ferrous metallurgy	0.55 - 4.14 ng/kg agglomerate
Copper recycling	3.6 - 16600 ng/kg scrap
Aluminum recycling	21.1 ng/kg scrap
Open air burning of domestic waste	140 ng/kg
Industrial coal combustion	0.6 ng/kg
Domestic coal heating	6 ng/kg
Accidental fires	~66.5 μg/fire
Steel production	1.26 ng/kg raw materials
Asphalt production	14 ng/t

Table 4.23. Main sources of dioxin formation and emissions (Kluyev *et al*., 2001).

Polyaromatic hydrocarbons (PAHs)

Of the large group of PAH compounds, only emissions of benzo[*a*]pyrene are documented. No instrumental control measurements of benzo[*a*]pyrene emissions are carried out, however. Emissions have therefore been estimated for heat and power plants using fossil fuels; metallurgical plants ('Severonikel' JSC, 'Olcon' JSC); and mining enterprises ('Apatit' JSC, 'Sevredmet' JSC).

In general, the two major PAH pollution sources are fossil fuel, including raw oil, combustion, and the incomplete incineration of organic materials such as wood, coal and oil. Usually, the heavier the fuel source, the higher the PAH content.

The main anthropogenic sources of PAH are:

- production of acetylene from raw gas;
- pyrolysis of wood, producing charcoal, tar and soot;
- pyrolysis of kerosene, producing benzene, toluene and other organic solvents;
- electrolytic aluminum production with graphite electrodes;
- coke production;
- coal gasification;
- production of synthetic alcohol;
- oil-cracking.

Large amounts of PAH can also be formed as a result of:

- incineration of industrial and domestic wastes;
- forest fires;
- energy production based on the incineration of fossil fuel;
- motor vehicles.

Benzo[*a*]pyrene emission data for the inventory area (Table 4.24), clearly show that information on emissions from industrial enterprises, even based on estimates, is extremely scarce.

Mercury

Intentional use of mercury in industrial production within Murmansk Oblast has not been documented. However, mercury-containing devices, luminescent lamps in particular, are widely used and contribute to environmental contamination, due to the lack of environmentally sound waste handling. Mercury-containing wastes (mostly discarded luminescent lamps), are the main contributors to wastes of the highest hazard class (31.7 t in 2001. There are two enterprises involved in the treatment of spent luminescent lamps:

- 'Rick-market' Ltd (Kolsky Distrikt), a new installation with environmentally sound recovery of mercury wastes;
- 'Ecord' Ltd (Kirovsk), an outdated installation that entered into operation in 1994. According to environmental protection authorities, this plant, although utilizing a proportion of lamps from Murmansk Oblast, actually contributes itself to mercury contamination of the environment. It should be stressed that this enterprise is located within the survey area.

Re-cycling of other equipment and instruments containing mercury, as well as of metallic mercury itself, is not systematically organized. Also, the two plants mentioned above only treat used lamps from industrial enterprises and not from the wider community.

Another significant source of mercury contamination is the mobilisation of mercury impurities within different industrial activities. According to expert estimates, the annual mobilization of mercury impurities within the Russian Federation comprises 83% of the annual intentional use of this metal. However, the amount of mercury released to the air through mobilisation is six times greater than that from intentional use (COWI, 2004).

Nickel and copper production are among the most important sources of mercury mobilisation. As one of the largest producers of primary nickel in the Russian Federation, the 'Severonickel' combined smelter (with annual production of 103000 t of nickel and 132700 t of copper in 2001) is located in Monchegorsk, it must be considered as a significant source of mercury contamination in the area. The average content of mercury in the sulphide copper-and-nickel ore that is used in this smelter is 1 mg/kg (Fedorchuk, 1983). However, this level can vary depending on the origin of the ore, from 0.05-0.11 mg/kg in ore from the Monchegorsk deposit to 2.78 mg/kg in ore from the Nittis-Kumuzhie (Kola peninsula) deposit. It should be noted that, in recent decades, the 'Severonickel' combined smelter has also used ore from different deposits, including those on the Taymir peninsula. Given this, the average content of 1 mg/kg provided above may be considered as a fair estimate. Expert estimates carried out within the ACAP project 'Assessment of Mercury Releases from the Russian Federation' concluded that mercury emissions from the 'Severonickel' combined smelter were 0.18-0.22 t in 2001. In addition, a further 0.075–0.111 t was accumulated in captured dust (COWI, 2004).

Table 4.24.
Trends in emissions of benzo[a]pyrene to the atmosphere in the Murmansk Oblast inventory area.

City/district	Emission, kg									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Kirovsk	29	27	na	na	na	na	9	na	na	na
Monchegorsk	na	na	na	na	na	na	14	22	19	27
Olenegorsk	6	9	na	na	na	na	na	7	6	4
Revda	na	na	na	na	na	na	na	3	na	10
Apatity	300	na	na	1	na	na	na	na	na	na
Lovozero District	na	na	na	na	na	na	na	5	1	3

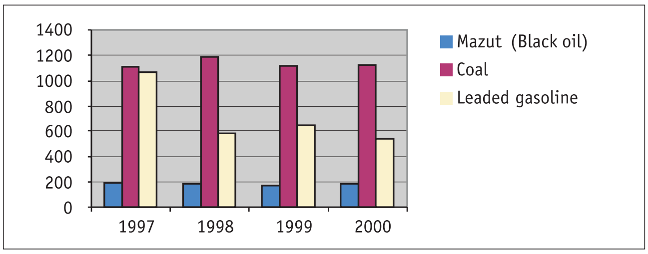


Figure 4.62. Trends in lead emissions from the combustion of fossil fuels in the Lovozero area, kg.

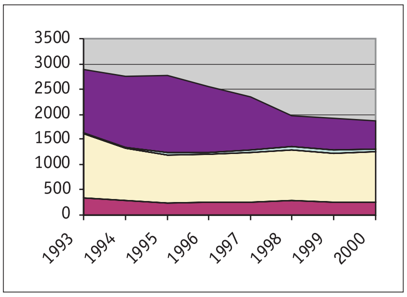


Figure 4.63. Contribution of different branches of economic activity to total lead emissions through the use of fossil fuels in the Lovozero area, kg.

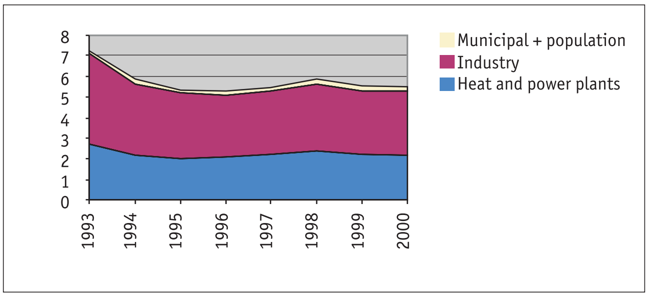


Figure. 4.64. Contribution of different branches of the economy to total mercury emissions through fossil fuel combustion in the Lovozero area, kg.

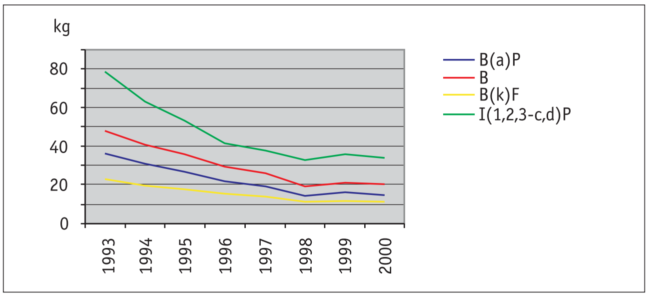


Figure 4.65. Mobilization of PAH compounds (benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]flouranthene, and indeno[1,2,3-c,d]pyrene) through the combustion of organic fuel in the Lovozero area.

4.4.2.3. PTS mobilization from combustion of fossil fuels

Official statistical data exists on the consumption of fossil fuels in Murmansk Oblast as a whole, but there are no data on organic fuel consumption in the survey area itself. According to statistics, about 23% of the total population of the Murmansk Oblast live in the survey area, and in order to estimate emissions from fossil fuel consumption it was therefore decided to assume that use of fuel is proportional to the share of the population. For calculation of dioxin and lead emissions from gasoline combustion, it was assumed that consumption of leaded gasoline in the survey area comprised about 20% of total gasoline consumption within the Oblast.

Lead

Coal combustion is considered a major contributor to lead emissions, along with the combustion of other fossil fuels. (Figure 4.62). In the middle of the 1990s, contributions from coal and gasoline combustion were comparable. However, in the late-1990s, due to the reduction in the use of leaded gasoline, coal became the dominant source of lead emissions. Total emissions from the combustion of fossil fuels in the area have decreased in recent years, mainly due to the reduction in emissions from motor vehicles (Figure 4.63).

Mercury

Mercury mobilization due to the use of fossil fuels is mostly determined by fuel combustion in industrial sectors and energy plants (heat and power plants, HPP). Fuel consumption by municipal services and the general population comprises only a minor part of total emissions (Figure 4.64). It should be noted that mercury emissions from this source have not changed significantly during recent years.

The role played by fossil fuel combustion in total mercury contamination arising from local sources, is significantly less than that due to mercury mobilization through nickel and copper production at the 'Severonickel' combined smelter (not more than 3%). However, given that domestic use of organic fuel, particularly coal, often contributes to the contamination of the indoor environment, its significance in terms of human intake may be much greater.

Polyaromatic hydrocarbons (PAHs)

Estimates of PAH mobilization through the use of organic fuel in the Lovozero area were made using methods similar to those for heavy metals (Figure 4.65).

PAH releases have gradually decreased since the early-1990s, possibly due to changes in the fuel types used. However, after 1998, the amount of PAH released stabilized, possibly due to the recovery of economy after the 1997 crisis.

Dioxins

The trend in dioxin emissions with organic fuel combustion in the Lovozero area is presented in Figure 4.66, which shows a decline during the early-1990s, but little change in emission levels since the mid-1990s.

Industrial enterprises are the main source of dioxin pollution from organic fuel in the Lovozero area according to Figure 4.67. However, it should be noted

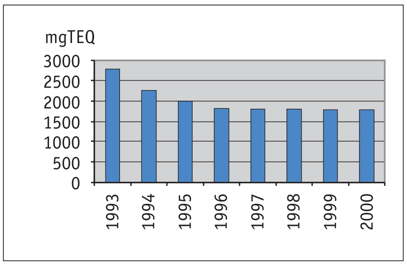


Figure 4.66. Dioxin emission trend in the Lovozero area from organic fuel combustion.