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Review and application of Russian and Norwegian methods for measuring and estimating riverine inputs of heavy metals to the Barents Sea

River Mezen (photo: A. Yakovlev)

Norwegian Institute for Water Research
– an institute in the Environmental Research Alliance of Norway

REPORT

Main Office
Gaustadalléen 21
NO-0349 Oslo, Norway
Phone (47) 22 18 51 00
Telefax (47) 22 18 52 00
Internet: www.niva.no

Regional Office, Sørlandet
Jon Lilletuns vei 3
NO-4879 Grimstad, Norway
Phone (47) 22 18 51 00
Telefax (47) 37 04 45 13

Regional Office, Østlandet
Sandvikaveien 59
NO-2312 Ottestad, Norway
Phone (47) 22 18 51 00
Telefax (47) 62 57 66 53

Regional Office, Vestlandet
Thormøhlens gate 53 D
NO-5006 Bergen Norway
Phone (47) 22 18 51 00
Telefax (47) 55 31 22 14

Regional Office Central
Høgskoleringen 9
NO-7034 Trondheim
Phone (47) 22 18 51 00
Telefax (47) 73 54 63 87

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Ø. Kaste, I.J. Allan, K. Austnes, *Guttorm Christensen (Akvaplan-NIVA)*, A.B. Christiansen, *Anna Chultsova (IO-RAS)*, T. Høgåsen, *Nikolay Kashulin (INEP)*, *Tatyana Kashulina (INEP)*, *Grigory Khomenko (IO-RAS)*, L.B. Skancke, J.R. Selvik, E. Yakushev.	Monitoring	Free
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Abstract

This report presents the results from the Norwegian-Russian collaboration project NordRID project, which was carried out from December 2011 to December 2013. Four institutions have been involved; INEP and IO RAS from the Russian side and Akvaplan-NIVA and NIVA from the Norwegian side. The main purpose of the project has been to review Russian and Norwegian methods for measuring and estimating riverine inputs of heavy metals to the Barents Sea. The report gives an overview of the most common methods applied for monitoring and calculating riverine inputs of heavy metals. INEP and IO-RAS have provided both meta-data and to some extent also real data for a number of rivers draining from the Kola and Arkhangelsk area, respectively. Two pilot studies with passive sampling techniques were performed as part of the project; one with DGTs (Diffusion Gradient in Thin-films) for detection of metals, and one with passive samplers for detection of hydrophobic contaminants. Two bilateral project meetings/workshops have been carried out during the project (at Svanhovd and in Oslo). The report contains recommendations for future work based on the studies and experiences made from the project.

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Øyvind Kaste
Project Manager

Atle Hindar
Manager Region South

Claus Beier
Research Director

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Preface

The NordRID project "Review and application of Russian and Norwegian methods for measuring and estimating riverine inputs of heavy metals to the Barents Sea" has been carried out during a two-year period between December 2011 and December 2013. It has been funded under the Norwegian-Russian environmental cooperation programme, by the Norwegian Ministry of Foreign Affairs and administered by the Norwegian Ministry of the Environment (contact person: Ingrid Lillehagen).

NIVA has coordinated the project, with Institute of the North Industrial Ecology Problems (INEP) - Laboratory of Aquatic Ecosystems, P.P.Shirshov Institute of Oceanology of the Russian Academy of Sciences (IO RAS) and Akvaplan-NIVA (APN) as main partners. The project team has included:

INEP: Nikolay Kashulin and Tatyana Kashulina
IO-RAS: Anna Chultsova and Grigory Khomenko
APN: Guttorm Christensen
NIVA: Kari Austnes, Evgeniy Yakushev, John Rune Selvik, Tore Høgåsen, Ian Allan, Øyvind Garmo, Anne B. Christiansen, Liv Bente Skancke, and Øyvind Kaste

Thanks to the funding institutions and all project participants for their valuable contributions to the project! Thanks also to Dr. Atle Hindar for carrying out quality assurance of the report

Oslo, January 2014

Øyvind Kaste

Contents

Summary

The management plan for the marine environment in the Barents Sea and the Lofoten area, and the Norwegian Marine Pollution Monitoring Programme (alternating between Norway's three main ocean areas) have revealed a number of gaps in our knowledge related to discharges of environmental hazardous substances to the Barents Sea. One gap is the lack of available data on riverine inputs from the Russian side of the Barents Sea, which represents a major uncertainty in the modelling of concentrations and fluxes of contaminants to the marine environment. This represents the starting point for the Norwegian-Russian collaboration project NordRID project, which aims at:

- Reviewing and discussing Russian and Norwegian methods for measuring and calculating riverine inputs of heavy metals to the Barents Sea
- Getting an overview of the most important datasets on riverine inputs from Norway and Russia to the Barents Sea
- Demonstrating passive sampling as a possible technique for estimating fluxes of heavy metals and persistent organic compounds in rivers
- Demonstrating how source-apportion models can provide estimates of riverine inputs from un-monitored catchments
- Improving the Norwegian-Russian cooperation in the Barents Region by bringing together key research institutes from both sides of the border

The report provides an overview of the most common methods applied for monitoring and calculating riverine inputs of heavy metals. In Norway this is based on the RID principles of the OSPAR (OSlo-PARis) Convention for the Protection of the Marine Environment of the North-East Atlantic (www.ospar.org). The Norwegian RID programme uses three methods to record loads from land to the sea: monitoring of concentrations in river water; monitoring of direct discharges from point sources; and modelling/estimating loads from unmonitored areas. In Russia, element concentrations in rivers are analysed by standardised methods, and with respect to the heavy metals Hg, Pb, Cd, Cu, Zn, Cr, Ni and As, both IO-RAS (Arkhangelsk) and INEP (Murmansk) apply atomic absorption spectrometry or ICP-MS as the main analytical instruments.

The Barents Sea receives riverine inputs from a land area of approximately 56000 km^2 on the Norwegian side and approximately 931000 km^2 on the Russian side. The main currents travel from west to east, and the Russian river inputs therefore enter the Barents Sea "downstream" of the Norwegian coastal area. The currents, however, follow a circular pathway west of Novaja Semlja and return to the south before approaching Svalbard. INEP and IO-RAS have provided both meta-data (catchment characteristics, availability of hydrological and chemical data, references to reports, etc.) and to some extent also real data for a number of rivers draining from the Kola and Arkhangelsk area, respectively.

Two pilot studies with passive sampling techniques were performed as part of the project; one with DGTs (Diffusion Gradient in Thin-films) for detection of metals, and one with passive samplers for detection of hydrophobic contaminants. The first pilot study was performed in three rivers located in Pasvik, around Nikel, and in the Arkhangelsk area. The main purpose of the pilot study was to demonstrate the methods and the possibilities they offer in terms of integrating metal concentrations in rivers over longer or shorter periods. Another purpose was that each institute should get experience with deploying DGTs in the field, analyse them in the lab, and calculate the integrated metal concentrations in their rivers.

Passive sampling for detection of hydrophobic contaminants in the Pasvik river showed that most compounds of interest were detected and quantified in the freely dissolved phase. As expected, highest

PAH concentrations were found for the least hydrophobic substances while hydrophobic contaminants were well below 1 ng L^{-1}. Concentrations of low molecular weight PAHs were significantly lower in the River Pasvik than in the Alna or Glomma rivers in south-eastern Norway (part of the RID programme). Less difference could be observed for the higher molecular weight PAHs. PCB concentrations were in the low pg L^{-1} range or below. PCB concentrations were found to be lower than those measured with silicone samplers in the Alna River a relatively polluted stream that runs through Oslo.

Good communication and good knowledge of each institute's infrastructure and working practices is essential for achieving an effective trans-national cooperation in the Barents Region, which in turn is needed for an integrated and knowledge-based management of the Barents Sea. In bilateral collaboration projects like NordRID, project meetings and workshops are an important arena for exchanging knowledge, experiences and data. An example is exchange of experiences with modelling tools as the TEOTIL model (which is briefly described in chapter 5 of this report). Two bilateral project meetings/workshops have been carried out during the project:

- 18-20 June 2012: Scientific workshop, Pasvik
- 21-22 October 2013: Final meeting, Oslo

Recommendations for future work: The review of Russian and Norwegian methods for measuring heavy metals and other water quality determinants show that the approaches are quite similar and the detection limits are generally low and comparable for most variables. Hence, there is a very good basis for exchanging data and for development of more integrated monitoring activities in main rivers draining to the Barents Sea. Access to existing data from Russian rivers can be a challenge, however, due to restrictions set by different data-owners. An improved access to historical data would be extremely valuable as basis for future monitoring and assessments. Implementation of novel monitoring techniques, including real-time measurements and use of time-integrative passive sampling techniques (cf. pilot studies performed in this project) is highly recommended. The latter can be especially relevant in remote areas, due to relatively low cost and the abilities to detect and quantify heavy metals as well as organic contaminants, which is a major environmental concern in arctic regions.

1. Introduction

1.1 Background

In March 2006 the Norwegian Government presented a comprehensive management plan for the marine environment in the Barents Sea and the marine areas outside Lofoten (Report to the Norwegian Parliament; Stortingsmelding 8, 2005-2006). The management plan emphasised that all activities in the area should be managed within a framework that ensures that the overall environmental impact does not exceed the carrying capacity of ecosystems. Distinct environmental quality targets were defined and a more coordinated and systematic marine monitoring programme was initiated; e.g. Green et al. (2010, 2013). This particular programme calculated and modelled annual fluxes of environmental hazardous substances, oil and radioactive substances from all known sources on land and offshore. The monitoring programme alternates between three ocean areas, and started with the Barents Sea in 2009. The report for the Barents Sea 2009 pointed out a number of knowledge gaps (Green et al. 2010). Lack of data on riverine inputs from the Russian side of the Barents Sea represents an uncertainty in the modelling of concentrations and fluxes of environmental hazardous substances in the marine area. Inputs from the Norwegian mainland are currently monitored by the RID-OSPAR programme (Riverine inputs and direct discharges to Norwegian coastal waters) and the TEOTIL programme (Theoretical calculation of phosphorus and nitrogen inputs in Norway), both led by NIVA on commission from the Norwegian Environment Agency (Skarbøvik et al. 2012; Tjomsland et al. 2010).

1.2 Objectives

The starting point for the NordRID project is the need for a close Norwegian-Russian collaboration to get a better overview of the total inputs of environmental hazardous substances to the Barents Sea. The main objectives of the project are:

- Review and discuss Russian and Norwegian methods for measuring and calculating riverine inputs of heavy metals to the Barents Sea (other contaminants are considered if applicable)
- Get an overview of the most important datasets on riverine inputs from Norway and Russia to the Barents Sea
- Demonstrate passive sampling techniques (for heavy metals and persistent organic compounds) at selected Norwegian and Russian case study sites
- Demonstrate how source-apportion, coefficient-based models (like TEOTIL) can provide estimates of riverine inputs from un-monitored catchments
- Improve Norwegian-Russian cooperation in the Barents Region by bringing together key research institutes from both sides of the border and thereby contribute to more knowledge-based management of the Barents Sea.

1.3 Links to bilateral collaboration programmes

The NordRID project has contributed to the working programmes for Norwegian-Russian environmental cooperation (2011-2012, and 2013-2015) and is directly linked to “Protection of the marine environment” and the activity HAV-4 “Inputs of pollution to the Barents Sea”. The project addresses both sub-tasks of HAV4: “Review of Russian and Norwegian methods for calculating inputs from various sources to the Barents Sea” and “Pilot project in a Norwegian and a Russian river for testing identified methods for calculating inputs of pollutants”. The activities are supportive of the main objective of “Protection of the marine environment” as regards assembling the necessary knowledge base for preserving the clean, rich ecosystem of the Barents Sea. The project will also contribute with data and knowledge to the “Pasvik programme” (DGS-1).

2. Methods for monitoring and calculating riverine inputs to the sea

The analytical methods applied at the laboratories at NIVA, INEP and IO-RAS are presented in more detail in Appendix A1, A2 and A3, respectively. Appendix A4 contains a more extensive description of analytical methods applied at IO RAS

2.1 Heavy metals

The methods for analysing heavy metals are quite similar at the three institutes. NIVA applies ICP-MS, IO-RAS uses Atomic Absorption Spectrometry (AAS), whereas INEP applies three different instruments depending on the detection limits required (AAS, ICP-EOS, ICP-MS). A comparison of detection limits are given in Table 1. The table shows that INEP and NIVA have low and relatively similar detection limits when using ICP-MS. INEP has the lowest detection limits for copper, zinc and arsenic.

Table 1. Detection limits for analyses of heavy metals at NIVA, IO-RAS, and INEP.

	Unit	NIVA_ICP-MS	IO-RAS_AAS	INEP_AAS	INEP_ICP-EOS	INEP_ICP-MS
Lead (Pb)	µg/L	0.005	2	0.5	1	0.005
Cadmium (Cd)	µg/L	0.005	0.2-0.3	0.05	0.1	0.005
Copper (Cu)	µg/L	0.01	0.4-0.6	0.2	0.5	0.005
Zinc (Zn)	µg/L	0.05	0.2-0.3	0.1	0.2	0.03
Arsenic (As)	µg/L	0.05	0.05	0.5	0.3	0.01
Chromium (Cr)	µg/L	0.1	1.5-2	0.2	0.2	0.1
Nickel (Ni)	µg/L	0.05	3	0.5	0.4	0.05
Mercury (Hg)	ng/L	1	6	-	-	-

2.2 Other components

Also when it comes to other standard water quality parameters, the analytic methods and detection limits are quite similar (Table 2). Altogether, the simple review of analytical methods and detection limits for heavy metals and other chemical determinants shows an excellent basis for integrated monitoring activities and data exchange and comparison across the border.

Table 2. Detection limits for analyses of other standard parameters at NIVA, IO-RAS, and INEP.

	Unit	NIVA	IO-RAS	INEP
pH		0.01	0.01	0.01
Conductivity	mS/m	0.05	0.01	0.05
Suspended particulate matter (SPM)	mg/L	0.1	3	0.1
Total Organic Carbon (TOC)	mg C/L	0.1	-	-
Total phosphorus	µg P/L	1	0.01*	2
Orthophosphate (PO4-P)	µg P/L	1	0.01*	2
Total nitrogen	µg N/L	10	-	10
Nitrate (NO3-N)	µgN/L	1	0.01*	5
Ammonium (NH4-N)	µg N/L	2	-	2
Silicate (SiO2)	mg SiO2/L	0.02	0.1	5
* mg/L				

2.3 Automatic sampling and continuous measurements

Some experiences at NIVA

NIVA has long experience with automated sampling techniques and continuous monitoring of water quality. Automated sampling (time-integrated or flow-proportional) is most commonly used within research projects or for short-term campaigns (episode studies). An example is the CLUE project (Stuanes et al. 2008), where a number of small headwater streams were instrumented with a tipping-bucket system for flow measurements, data loggers and ISCO automated water samplers (Figure 1a).

Figure 1. a) ISCO water sampler, b) TinyTag temperature logger

In 2013, new sampling techniques were implemented in the RID-OSPAR programme (cf. presentation by Kari Austnes at the NordRID final meeting; Appendix D):

- Basic parameters:
  - Continuous measurements of pH, conductivity, turbidity and temperature in three rivers
  - TinyTag loggers for continuous temperature measurements installed in all remaining min rivers (Figure 1b)

- Organic contaminants (three rivers):
  - Passive samplers (dissolved): PBDE, HBCDD, PCB, PAH
  - Centrifuge (particles): PBDE, HBCDD, PCB, PFC, TBBPA, BPA, SCCP, MCCP, PAH
  - Bottle samples: Siloxanes

Heavy metals:
- Ag (all rivers)
- DGT: Pb, Cd, Cu, Ni, Zn, Ag (six rivers)

Pilot studies with passive samplers for heavy metals and organic contaminants from this project are described in Chapter 4.

Continuous monitoring performed by IO-RAS
IO-RAS has experience with e.g., SeaGuard RCM SW (AANDERAA), a multi-parameter instrument that can be deployed both in the sea and in freshwater. Sensors applied by IO-RAS: Temperature, conductivity, pressure, turbidity, oxygen, speed and direction of water.

Figure 2. Continuous monitoring of pH, conductivity, turbidity and temperature in a RID river (photo: NIVA).

3. Review of existing data

3.1 Some characteristic features of the Barents Sea.

Barents Sea has a mean depth of 230 m. There are three main bodies of water: warm Atlantic water with high salinity, cold Arctic water from the north and warm coastal water with less salinity. Main circulation patterns in surface waters Figure 3 are dominated by a northbound flow of warm water along the coast and on the west side of Bear Island and Svalbard. A branch of this stream follows the coast past the North Cape and along the west coast of Novaya Zemlya in the Russian part of the Barents Sea. It is a cold southbound flow on the eastern side of Svalbard. The ice front in February is normally located on the western side of Svalbard, south of Bear Island and west of Novaya Zemlya.

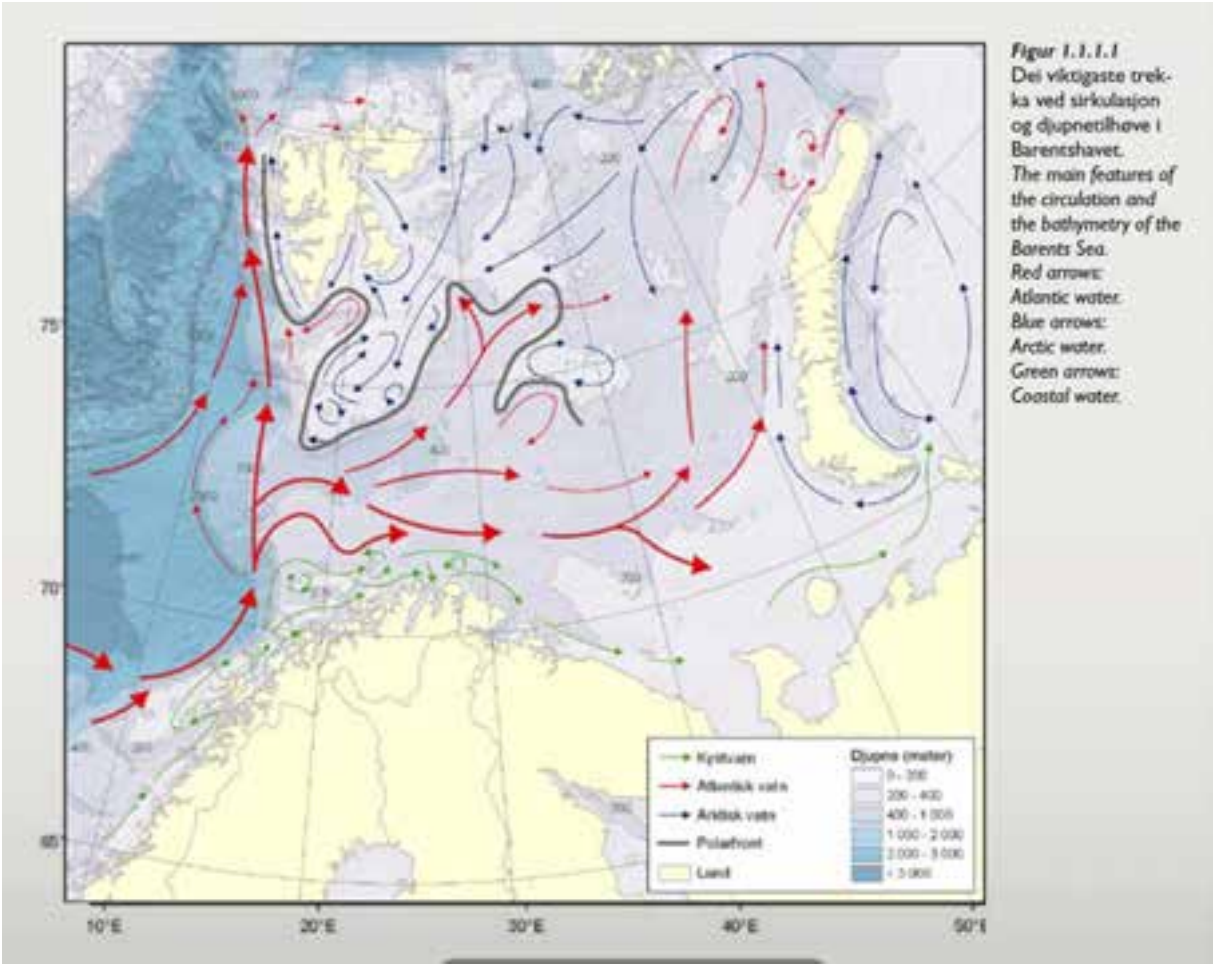

Figure 3. Circulation patterns of surface waters in the Barents Sea (from IMR).

The temperature of the Barents Sea has increased in recent years, and in several years since 2000 it has been ice-free in summer (Sunnanå et al. 2010). Changes in climate can theoretically affect the distribution and dispersion of pollutants and also lead to bioaccumulation of potential harmful substances. Changes in temperature can affect the distribution of pollutants between different media or phases as air, particles, and water (Smith and McLachlan 2006, Macdonald et al. 2005). This will affect the bioavailability of these chemicals. Climate change may also affect the transport of contaminants between geographical regions, by changes in transport routes and volumes in water and air with different pollution levels (Macdonald et al. 2005).

Elevated precipitation amounts in the future may also lead to increased leaching of contaminants from land to sea (Ruus et al. 2010). Increased levels of CO_2 in the atmosphere also promote ocean acidification, with potentially huge negative environmental impacts (Orr et al. 2005). Although the overall pollution load is low in the Barents Sea, human activities can still put seafood safety under pressure (Sunnanå et al. 2010).

3.2 Norwegian rivers draining to the Barents Sea

The Norwegian rivers draining to the Barents Sea are shown in Figure 4. Main catchment characteristics (position at outlet, catchment size, mean flow, land use, population) and availability of hydrological and hydrochemical data are given in **Appendix B1**. Altogether, the Norwegian rivers listed in Appedix B1 and B2 comprise a total catchment area of approximately 56000 km^2. The most common land cover types are mountainous open landscapes, with scattered forests.

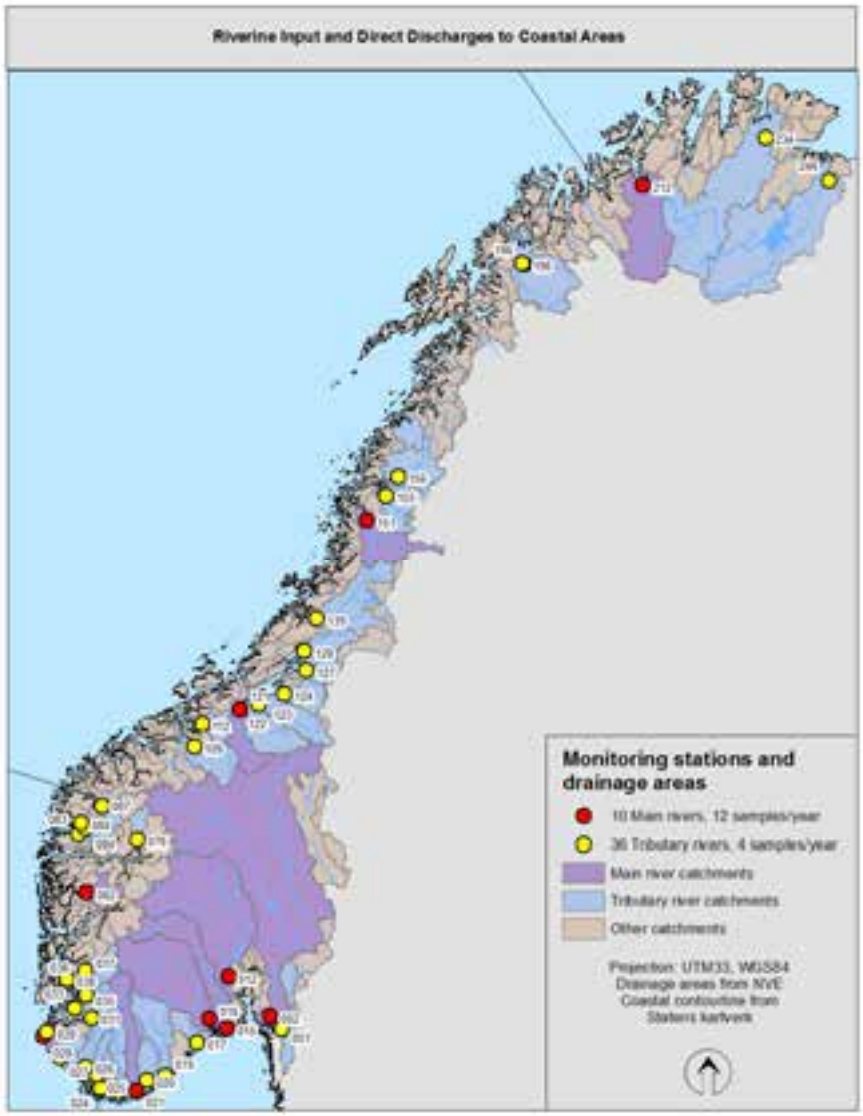

Figure 4. Rivers included in the Norwegian monitoring programme on riverine discharges (RID). Rivers draining to the Barents Sea: 196 Barduelva, 212 Altaelva, 234 Tana, 246 Pasvikselva.

Figure 5 displays mean concentrations (1990-2011) of heavy metals (Cu, Cd, Cr, Ni, Zn, Hg, Pb) and general water quality parameters as total organic carbon (TOC) and suspended particulate matter (SPM). All data (Appendix B2) are collected as part of the RID programme (Skarbøvik et al. 2012). In the Barents Sea region the RID programme includes one main river (Alta; monthly sampling) and three rivers with less extensive sampling (Barduelva/Målselv, Tana and Pasvik; sampled quarterly). The remaining rivers included in Appendix B2 have less frequent data, mostly obtained before 2003.

The concentrations of heavy metals are generally low (Figure 5), but there is a clear increase in Cu and Ni concentrations close to the Russian border (especially in the Pasvik river and Grense Jakobselv). The concentrations of TOC and SPM are moderate, indicating relatively low loads of organic matter and particles to the Barents Sea. Barduelva and Målselv had the highest SPM-concentrations (6-7 mg/L).

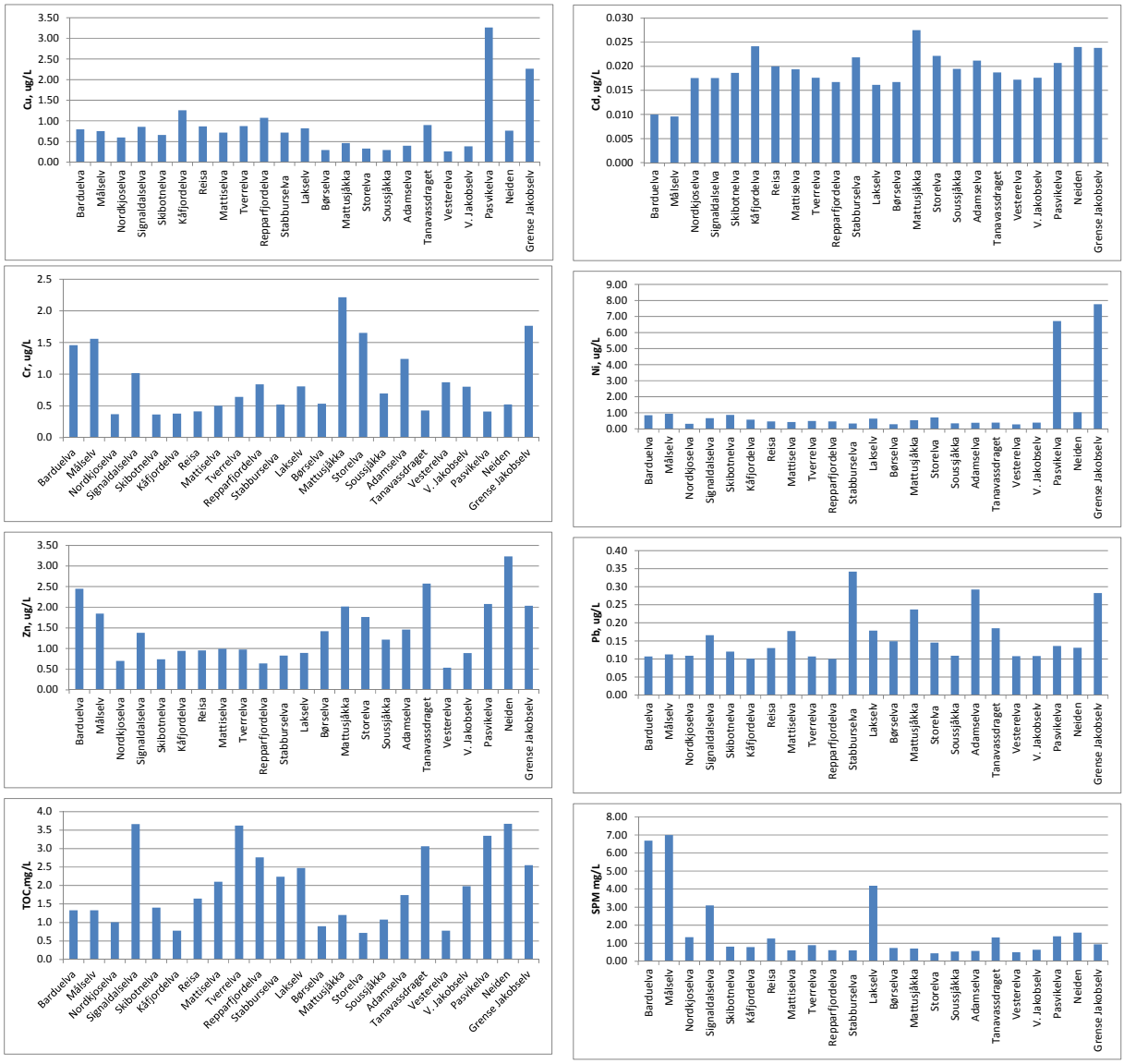

Figure 5. Mean concentrations (1990-2011) of heavy metals (Cu, Cd, Cr, Ni, Zn, Pb), total organic carbon (TOC) and suspended particulate matter (SPM). Data from the RID programme (Skarbøvik et al. 2012).

Figure 6. Pasvik river, looking downstream from the RID monitoring station (photo: E. Pettersen)

3.3 Russian rivers draining to the Barents Sea.

The Russian rivers draining to the Barents Sea are shown in Figure 7. Main catchment characteristics (position at outlet, catchment size, mean flow, land use, population) and availability of hydrological and hydrochemical data are given in **Appendix B2**. Altogether, the Russian rivers comprise a total catchment area of approximately 931000 km^2 (~16 times larger than the contributing area on the Norwegian side) (Figure 7). Land cover distribution varies among the catchments (cf **Appendix B3**), the main types being tundra, grassland, bogs, taiga, forests and agricultural land.

Figure 7. Large Russian rivers draining to the Barents Sea (from Brittain et al. 2008)

Hydrology

Typical for rivers in the Barents region is that water flow is strongly affected by snow accumulation and melting. Snow melt often contributes more than 50% of the total annual runoff. The rest comes from rainfall during summer and autumn, of which the autumn period contributes the most. Runoff through the soils is extremely poor because of the permafrost. The presence of permafrost creates

special conditions for the hydrological regime of rivers. Frozen ground promotes increased surface runoff during snowmelt and rainfall, and it also prevents soil runoff during the cold period.

The hydrological regime of rivers is characterized by low flow during winter, high spring floods and generally low flow during the summer-autumn period, interrupted by rain floods. The main part of the runoff occurs in the spring, on average 70-80% of the annual volume. In comparison, the summer and autumn period on average contributes with 15-25%, and the winter period 1.5-1.6% of the annual runoff. The spring flood in rivers of the region normally begins around 5 to 10 May, with the maximum usually occurring in the end of May. The average duration of the spring flood in small and medium rivers is 1.5-2 months. The total volume of the spring flood is 160 mm on average, and it often increases the river water level by 1.5 to 3.7 m. Average dates for termination of the spring flood are 20-25 June.

The summer-autumn low-water period generally occurs during the second half of June and normally lasts for 60-70 days. The total runoff volume during this period often is 10-30 mm. In some years, rain peaks during summer or autumn can promote floods larger than the spring flood in small and medium-sized rivers. The greatest rain floods are usually observed in August and October. Rises in river water level by rainfall can be in the range from 0.3 to 1.5 m. Rivers in this area is heavily affected by ice formation. In late autumn the ice regime is characterized by formation of cake ice and sludge. The first river ice formations usually appear in the end of October. Several rivers are affected by ice drift during spring. During dry and cold winters some streams might dry up and freeze completely.

A

B

C

Figure 8. A) Northern Dvina river near the city of Arkhangelsk (photo: G. Khomenko), B) River Mezen (photo: A. Yakovlev), C) River Pinega (photo: A. Yakovlev).

Water quality
Chemical composition of surface waters in the Arkhangelsk region is affected by a severe climate, low solar radiation (especially in winter), waterlogging, and the presence of permafrost. The water quality is usually controlled by the hydrocarbonate system, although low weathering and mineralization rates give moderate concentrations of base cations as calcium. Most rivers have a large influence of humic compounds and particles. The average annual water turbidity (measured as suspended particulate matter) is often in the range of 25-50 mg/l. Oxygen saturation of water in the ice-free period ranges between 75-95%, with typical concentrations 7-12 mg/l. During summer, the concentration of oxygen is often reduced to 7-8 mg/l.

In winter, the oxygen content of surface waters decrease, some places to values around 2-3 mg/L. The low oxygen content of the water is caused by decomposition of a high content of organic matter during the long ice-period. The biological oxygen demand (as BOD5-values) is often in the range of 1.0-3.5 mg O_2/l). The highest BOD5 values are observed in spring and summer, due to melt water with high content of organic compounds and generally high activity of biological processes. The total concentration of oxidable organic and mineral substances is measured as COD (chemical oxygen demand, with typical values around 20-40 mg O_2/l). Maximum COD-values are observed in spring when the soils are washed with water from melted snow.

The water acidity is controlled by dissolved humic acids. But in summer (24 hours with daylight) primary production during mass development of Cyanobacteria can raise pH up to 9.0.

The main anions are hydro-carbonates, with concentrations in the range 5.9 - 135 mg/L, followed by chloride ions (0,9-30.0 mg/L) and sulphate ions (0,08-4,1 mg/L). The cation composition is dominated by calcium, and only in rare cases sodium ions.

The highest nutrient concentrations occur during the winter, whereas a minimum occurs in the vegetation period. The concentration of silica varies in the range of 0.5-0.6 mg/l, phosphate-phosphorus 0-0.1 mg/l, ammonium nitrogen 0.05-0.04 mg/l, nitrite nitrogen 0-0.01 mg/l, and nitrate nitrogen 0-0.3 mg/l. For mineral nutrients the general tendency is an increase during low flow, when the groundwater influence is highest. Enrichment with iron is common in areas which drain wetlands. A significant amount of organic substances, including humic and fulvic acids form organometallic complexes with iron.

Water quality of small lakes and streams in the Norwegian, Finnish and Russian border area
Results from the trilateral Pasvik monitoring programme for water bodies in the border area of Norway, Finland and Russia are reported by Puro-Tahvanainen et al. (2011). The data obtained confirms the ongoing pollution of river and water systems: “Copper (Cu), nickel (Ni) and sulphates are the main pollution components. The highest levels were observed close to the smelters. The most polluted water source of the basin is the River Kolosjoki, as it directly receives the sewage discharge from the smelters. The concentrations of metals and sulphates in the River Pasvik are higher downstream from the Kuetsjarvi Lake. There has been no decrease in the concentrations of pollutants in Pasvik watercourse over the last 10 years.

Ongoing recovery from acidification has been evident in the small lakes of the Jarfjord and Vätsäri areas during the 2000s. The buffering capacity of these lakes has improved and the pH has increased. The reason for this recovery is reduced sulphate deposition, which is also reflected in reduced water concentrations. However, concentrations of some metals, especially Ni and Cu, have increased during the 2000s. Ni concentrations have increased in all three areas, and Cu concentrations in the Pechenganickel and Jarfjord areas, closer to the smelters. Emission levels of Ni and Cu did not fall during the 2000s. In fact, the emission levels of Ni compounds even increased compared to the 1990s”.

3.4 Relevant projects

The following tables include some examples of projects related to rivers and lakes draining to the Barents Sea.

NIVA

Name of project	Sites	Duration	References
Riverine inputs and direct discharges to Norwegian coastal waters	Bardu river, Alta river, Tana river, Pasvik river	1990-	Skarbøvik et al. (2012)
Monitoring long-range transboundary air pollution. Effects	Dalelva (Jarfjord), small lakes on the Jarfjord plateau	1989-	Schartau et al. (2012)
National lake survey, part 2: Sediments. Pollution of metals, PAH and PCB	25 lakes in Eastern Finnmark	2004 – 2006	Rognerud et al. (2008)

IO RAS

Name of project	Sites	Duration	References
Grant RFBR 08-05-98814- r_north_a «The study of accumulation of nutrients in the ice and snow of the delta Northern Dvina River».	Northern Dvina River	2008-2009	1-4
Assessment of the role of different-scale physical and chemical processes in the formation of the characteristic features of ecosystems estuarine areas of the rivers of the White sea basin.	Northern Dvina River. Small rivers Onega peninsula: Nizhma, Känd, Tamtsa, Lopshenga.	2010-2012	5-8

References:
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2. Chultsova (2009)
3. Chultsova and Skibinski (2009)
4. Chultsova (2009)
5. Kotova et al. (2012)
6. Chultsova (2010)
7. Khomenko and Leshchyov (2010)
8. Khomenko (2010)

INEP

Name of project	Sites	Duration	References
KO370- Trilateral cooperation on environmental challenges in the joint border area (TEC 2012-2014)	Pasvik river	2012-2014	
State of the Environment in the Norwegian, Finnish and Russian Border Area.	Pasvik river	2003-2006	*)
Heavy metals from the Nikel area. Investigations in Kolosjoki river 1995, Kola peninsula, Russia.	Kolosjoki river	1995	Traaen et al. (1996)
Pasvik River Watercourse, Barents Region:Pollution Impacts and Ecological Responses. Investigations in 1993	Pasvik river	1993	Moiseenko et al. (1994)
Pasvik Water Quality Report. Environmental Monitoring Programme in the Norwegian, Finnish and Russian Border Area	Pasvik river	2007-	Puro-Tahvanainen et al. (2011)
Pollution impact on freshwater communities in the border region between Russia and Norway	border region between Russia and Norway	1990-1996	Nøst et al. (1997)

***)** http://www.pasvikmonitoring.org/eng/index.html

4. Results from pilot studies with passive samplers

4.1 DGTs for detection of metals

Principles
The Diffusion Gradient in Thin-films (DGT) technique (Davison and Zhang 1994; Zhang and Davison 1995) is based on a simple device that accumulates metals in situ, over time in a Na resin gel. These samplers bind metals in an ion exchange sorbent packed behind a filter and a diffusion gel and have been successfully applied to a wide range of environmental monitoring scenarios (Warnken et al. 2007). More information on the technique can be found in Røyset et al. (2012) and references therein.

Methodology (field and lab)
At the Svanvik workshop (Appendix D1) it was agreed to carry out a simple pilot study with DGTs deployed in three rivers located in the Pasvik, Nikel and Arkhangelsk area. The suggested design of the pilot study is given below.

DGT pilot study – suggested procedure:

Study sites (one site per river)	1) Pasvik river (responsible: NIVA/Akvaplan-NIVA) 2) Stream near Nikel (responsible: INEP) 3) River/stream near Arkhangelsk (responsible: IO RAS)
DGT deployment	Two (parallel) DGTs deployed at each sampling event (please store DGTs cold before as well as after deployment)
Field procedure	See attached document from NIVAs lab. (Note: Remember to fill out the registration form with water temperature, flow velocity, etc.)
Exposure period	One week (3-5 days at heavily polluted sites)
Sampling rounds	Four consecutive rounds á one week (i.e., 8 DGTs per round)
Manual samples	Water samples (0.5 L) should be taken at each sampling site – before and after each DGT deployment.
Storage	DGTs and water samples should be stored cold (4^{o}C) until analysis
Analysis	One set of DGTs (4 pieces) and the water samples are analysed at the local laboratory. The parallel set of DGTs (4 pieces) is shipped to NIVA for analysis (remember to attach the field registration form). Both DGTs and water samples are analyzed by ICP-MS for the following constituents: Cu, Ni, Cr, Cd, Pb, and Zn.
Correction of DGT concentrations	Average concentrations of DGT-labile metal species through exposure period can be calculated by a simple formula. NIVA can help with this calculation if the following data are provided: metal concentration in the DGT-gel, water temperature and flow velocity before and after exposure of the DGT.

Calculation
If diffusion through the diffusion gel is known, the concentration of labile metal compounds in water (Cv) is calculated on the basis of the concentration in the ion exchanger (M), the sampling period (t) and the diffusion coefficient (D).

$$C_V = \frac{M \cdot \Delta g}{D \cdot A \cdot t}$$

Δg: thickness of the diffusion membrane
A: area of the sampling window

The diffusion coefficient varies with temperature and therefore must be measured for different temperatures. An overview of diffusion coefficients for different temperatures is given for various metals on http://www.dgresearch.com/.

Results
Figure 9 and

Table 3 displays heavy metal concentrations at the sites that were selected for the pilot studies. The data show high Ni and Cu concentrations in the Kolosjoki river (near Nikel), and relatively high levels of Cr, Pb and Zn in River Pinega in the Arkhangelsk area.

The results from the pilot study with metal DGTs are displayed in Appendix C (on the Norwegian side the smaller Karpelva river was studied instead of the larger Pasvik river). The main purpose of the pilot study was to demonstrate the methods and the possibilities it offers in terms of integrating metal concentrations in rivers over longer or shorter periods. Another purpose was that each institute should get an experience with both deploying DGTs in the field, analyse them in the lab, and calculate the integrated metal concentrations (Cv) based on the equation above. Hence, the main focus in this round with metal DGTs was more on the methodology than on the actual results.

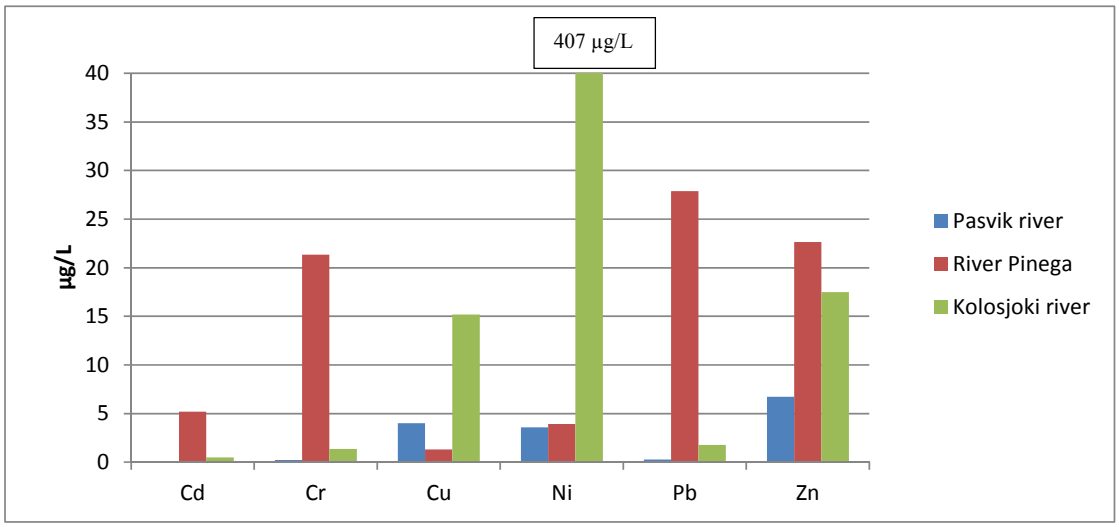

Figure 9. Concentrations of heavy metals in the Pasvik river (Norwegian side, sampled 3 May 2012), River Pinega (Arkhangelsk area, sampled 31 August 2012) and the Kolosjoki river (near Nikel, 22 August 2012. Samples are analysed at NIVA (Pasvik), IO-RAS (Pinega) and INEP (Kolosjoki)

Table 3. Same data as in Figure 9 showed in table format.

Site	Date	Cd	Cr	Cu	Ni	Pb	Zn
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Pasvik river	03/05/2012	0.02	0.20	4.03	3.58	0.27	6.72
River Pinega	31/08/2012	5.19	21.35	1.29	3.92	27.88	22.66
Kolosjoki river	22/08/2012	0.47	1.35	15.18	407	1.79	17.50

4.2 Passive samplers for detection of hydrophobic contaminants

Principle of passive sampling for hydrophobic contaminants
Passive sampling is based on the diffusive movement of substances from the environmental matrix being sampled into a polymeric device (initially free of the compounds of interest) in which contaminants absorb. For the passive sampling of hydrophobic compounds the best known sampler is the SemiPermeable Membrane Device (SPMD) comprising a low density polyethylene membrane containing a triolein lipid phase (Huckins et al., 2006). Nowadays, single phase polymeric samplers constructed from material such as low density polyethylene or silicone rubber as a result of their robustness (Allan et al., 2009, Allan et al., 2010, Allan et al., 2011). At equilibrium, the mass of a chemical absorbed in the sampling device can be translated into a freely dissolved contaminant concentration in the water the device was exposed to through K_{sw}, the sampler-water partition coefficient. Passive sampling techniques that allow to derive freely dissolved contaminant concentrations have been the subject of much development over the last two decades (Vrana et al., 2005). For hydrophobic contaminants with $\log K_{ow}$ (Octanol-Water Partition Coefficient) > 5-6, polymeric samplers have a large capacity. For typical deployment periods of a few weeks, equilibrium between the sampler and water will not be attained for these chemicals. Uptake in the linear mode (i.e. far from equilibrium) is therefore time-integrative for the deployment period in water. The resulting time-integrated freely dissolved concentration can be estimated if *in situ* sampling rates, R_s, equivalent amount of water sampled per unit of time (L d^{-1}) are known. Sampling rates can be estimated from the dissipation of performance reference compounds (PRC), analogues of compounds of interest (but not present in the environment) spiked into the samplers prior to exposure (Booij et al., 1998, Huckins et al., 2002).

Methodology (field and lab)
Samplers, similar to those used for the RID programme 2013 and made of AlteSil silicone rubber (1000 cm^2 and 30 g, strips 100 cm long and 2.5 cm wide) were prepared in the NIVA laboratory following standard procedures. In short, the silicone rubber samplers were placed in a Soxhlet extractor for 24 hour cleaning using ethyl acetate. Samplers were then left to dry before further cleaning with methanol. PRCs (deuterated PAHs) were spiked into the samplers using a methanol-water solution (Booij et al., 2002).

Onced spiked with PRCs, samplers were kept in the freezer at -20 °C until deployment. Replicate samplers were deployed in the Pasvik River using SPMD canisters and samplers mounted on spider holders. A control sampler was used to assess potential contamination of the samplers during preparation and deployment procedures and to assess initial PRC concentrations. The deployment duration was 70 days.

Once back in the laboratory, the surface of samplers was thoroughly cleaned to remove any fouling before extraction with pentane (twice 200 mL over 48 hours). Extract were combined and reduced. The solvent was changed to dichloromethane before clean-up by gel permeation chromatography. The extract was then reduced and analysed by gas chromatography-mass spectrometry for polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and other chlorinated organics.

Field and laboratory procedures have been described elsewhere (e.g. Allan et al., 2010, Allan and Ranneklev 2011).

Results from the Pasvik river

Freely dissolved concentrations were calculated using the boundary-layer controlled uptake model given in Rusina et al. (2010) and using the non-linear least square method to estimate sampling rates as a function of $logK_{sw}$ (Booij and Smedes, 2010). Polymer-water partition coefficients were not corrected for temperature. Sampling rates for substances with a $logK_{ow}$ of 5.2 were estimated to be 5.8 and 6.5 L d^{-1} for the two replicate devices. The standard error on the sampling rate estimation was below 20% for each of the samplers. Estimates of freely dissolved concentrations of PAHs and chlorinated organics are given in Table 1 and Table 5, respectively. For PAHs, concentrations range from 1.9 ng L^{-1} for phenanthrene to 0.01 ng L^{-1} for benzo[ghi]perylene. Freely dissolved PeCB and HCB concentrations were 6.7 and 27 pg L^{-1} respectively. Concentrations for PCB congeners were 4 pg L^{-1} for CB28 down to below limits of detection with LODs close to 1 pg L^{-1}.

Table 4. Freely dissolved concentrations of polycyclic aromatic hydrocarbons in the Pasvik River measured using silicone rubber passive sampling devices.

Substance	$LogK_{sw}$*	C_w (ng L^{-1})	Relative percent difference
Naphthalene	3.03	0.24	5.0
Acenaphthylene	3.26	0.13	2.9
Acenaphthene	3.62	0.25	6.0
Fluorene	3.79	0.39	1.2
Dibenzothiophene	3.54	0.19	4.3
Phenanthrene	4.11	1.9	8.0
Anthracene	4.21	0.047	20
Fluoranthene	4.62	1.3	12
Pyrene	4.68	0.25	13
Benz[a]anthracene	5.32	0.033	12
Chrysene	5.25	0.054	17
benzo[b&j]fluoranthene	5.74	0.13	12
Benzo[k]fluoranthene	5.74	0.024	16
Benzo[e]pyrene	5.7	0.041	12
Benzo[a]pyrene	5.69	0.0054	18
Perylene	5.7	0.013	23
Indeno[1,2,3-cd]pyrene	6.06	0.015	8.2
Dibenzo[ah]anthracene	6.24	0.0020	5.9
Benzo[ghi]perylene	6.02	0.010	16

*For silicone rubber (Smedes et al., 2009)

Table 5. Freely dissolved concentrations of polychlorinated biphenyls, pentachlorobenzene (PeCB) and hexachlorobenzene (HCB) in the Pasvik River measured using silicone rubber passive sampling devices.

Substance	$LogK_{sw}$*	C_w (pg L^{-1})	Relative percent difference
PeCB	4.5	6.7	4.6
HCB	5.06	27.0	11.5
CB28	5.53	4.0	12
CB52	5.80	1.2**	-
CB101	6.28	2.5	44

CB118	6.42	1.1	27
CB105	6.42	1.2	29
CB153	6.72	< 1.0	-
CB138	6.77	1.1	12
CB156	6.72	< 1.0	-
CB180	6.99	< 1.1	-
CB209	8.51	< 1.5	-

*For silicone rubber (Smedes et al., 2009)
**One measurement above limits of detection

Discussion

Most compounds of interest were detected and quantified in the freely dissolved phase in the Pasvik River. As expected, highest PAH concentrations were found for the least hydrophobic substances while those with $\log K_{ow}$ over 5-6 were well below 1 ng L^{-1}. Concentrations of low molecular weight PAHs were significantly lower in the River Pasvik than in the Aln or Glomma (Table 6). Less difference could be observed for the higher molecular weight PAHs.

PCB concentrations were in the low pg L^{-1} range or below. PCB concentrations were found to be lower than those measured with silicone samplers in the Alna River a relatively polluted stream that runs through Oslo (Allan et al. 2011; Allan et al., 2013).

Table 6. Comparison of freely dissolved concentrations of PAHs measured with silicone samplers in the Rivers Alna, Glomma and Pasvik.

Substance	C_{free} (ng L^{-1})		
	Pasvik	Glomma	Alna
Acenaphthylene	0.13	0.26	0.78
Acenaphthene	0.25	1.6	2.1
Fluorene	0.39	1.2	3.6
Dibenzothiophene	0.19	0.17	4.1
Phenanthrene	1.9	3.2	13.7
Anthracene	0.047	0.13	3.3
Fluoranthene	1.3	0.59	5.4
Pyrene	0.25	0.33	7.3
Benz[a]anthracene	0.033	0.024	0.31
Chrysene	0.054	0.033	0.36
benzo[b&j]fluoranthene	0.13	0.034	0.13
Benzo[k]fluoranthene	0.024	<0.01	0.042
Benzo[e]pyrene	0.041	0.018	0.12
Benzo[a]pyrene	0.0054	<0.01	0.042
Perylene	0.013	0.037	0.017
Indeno[1,2,3-cd]pyrene	0.015	<0.01	0.012
Dibenzo[ah]anthracene	0.002	<0.01	<0.005
Benzo[ghi]perylene	0.01	<0.01	0.022

5. Source-apportionment models as tools to estimate riverine inputs

5.1 The TEOTIL model

The TEOTIL model has been developed to quantify the nutrient loads to the sea from land-based sources in Norway based on available regional statistical information (Tjomsland and Bratli 1996, Bratli and Tjomsland 1996, Selvik et al. 2006). The data are reported annually as part of Norway's commitments to OSPAR (Skarbøvik et al. 2012). TEOTIL is an export model which calculates the transport of nitrogen and phosphorus out of a catchment.

TEOTIL includes both point sources and diffuse sources of N and P (Figure 10). Point sources are industry, waste-water treatment plants, and human population (sparse population and dense population). The diffuse sources of N and P are included by specifying land-cover types, each of which is given an empirical nutrient loss coefficient. Agricultural areas include grazed land and cultivated land. The model includes in-lake but not in-stream retention. The TEOTIL calculations are based on REGINE hydrological units (small sub-catchments). These are linked in drainage networks and scaled up to the river basin.

TEOTIL starts with the definition of the drainage system; which describes the course of the water from REGINE field to REGINE field. Next, the lakes are assigned to the corresponding REGINE fields and the retention time of the lakes is calculated. Area specific N and P coefficients are uploaded, and the mass fluxes are calculated. These calculations are based on individual REGINE fields and then accumulated downstream.

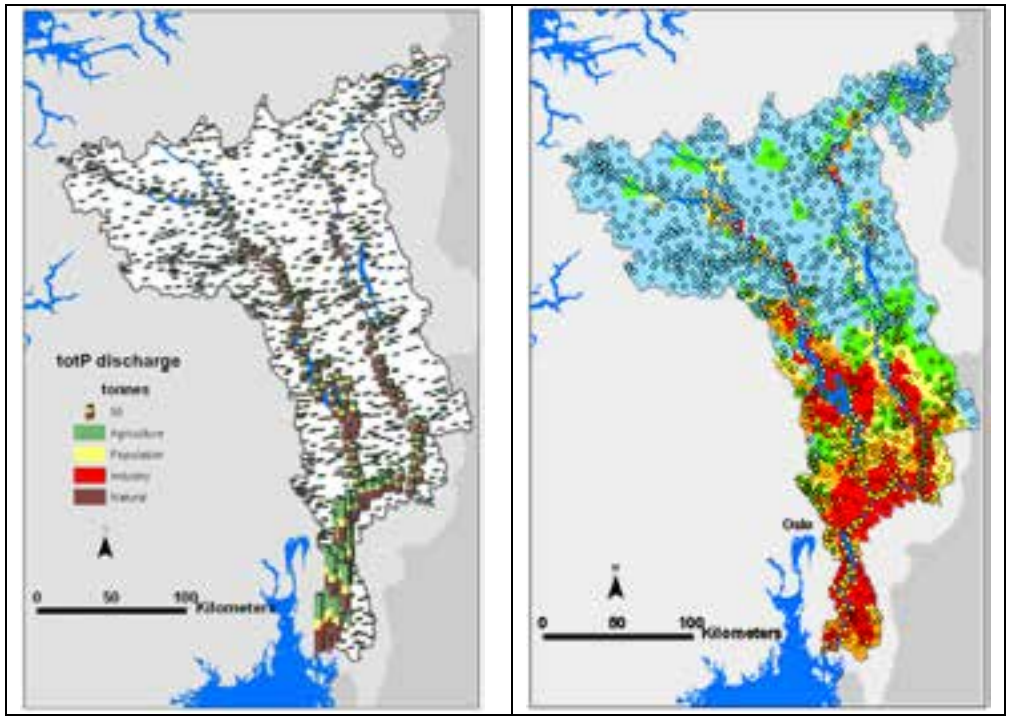

Figure 10. Results from the TEOTIL model displayed on maps. Example from the Glomma river in eastern Norway (Tjomsland et al. 2010).

5.2 Application of the TEOTIL model within the RID programme

Within the Norwegian RID programme (Skarbøvik et al. 2012) the TEOTIL model has been utilised for pollution load compilations of nitrogen and phosphorus in unmonitored catchments or groups of unmonitored catchments (in order to estimate the total N and P load from the entire Norwegian mainland). The point source estimates are based on national statistical information on sewage, industrial effluents, and aquaculture (fish farming). Nutrient loads from diffuse sources (agricultural land and natural runoff from forest and mountain areas) are modelled by a coefficient approach (Selvik et al., 2006). Area specific export coefficients for nutrients have been estimated for agricultural land in different geographical regions. The coefficients are based on empirical data from agricultural monitoring fields in Norway and are adjusted annually by Bioforsk based on reported changes in agricultural practice (national statistics). For forest and mountain areas, concentration coefficients for different area types and geographical regions have been estimated based on monitoring data from reference sites. The annual loads of natural runoff vary from year to year depending on the annual discharge.

So far, the TEOTIL model has been applied on N and P export only. Other elements might be included in future versions of the model (e.g. heavy metals), but this will require further developments of the model and extensive testing against measured data.

6. Meetings/workshops and further work

Project meetings / workshops
An important element in the project has been to maintain and further develop the Norwegian-Russian cooperation in the Barents Region by bringing together key research institutes from both sides of the border. The best way to achieve this is through project meetings/workshops, where the researchers involved can share competences, experiences and data that can improve our common understanding and thereby contribute to a better and more knowledge-based management of the rivers discharging into the Barents Sea.

Two bilateral project meetings/workshops have been carried out during the project:

- 18-20 June 2012: Scientific workshop, Pasvik
- 21-22 October : Final meeting, Oslo

The workshop programmes are displayed in Appendix D and E, respectively. Presentations held at the workshops are stored electronically at NIVA, and pdf-files can be made available on request.

Recommendations for future work
The review of Russian and Norwegian methods for measuring heavy metals and other water quality determinants show that the approaches are quite similar and the detection limits are generally low and comparable for most variables. Hence, there is a very good basis for exchanging data and development of more integrated monitoring activities in main rivers draining to the Barents Sea. Access to existing data from Russian rivers can be a challenge, however, due to restrictions set by different data-owners. An improved access to historical data would be extremely valuable as basis for future monitoring and assessments. Implementation of novel monitoring techniques, including real-time measurements and use of time-integrative passive sampling techniques (cf. pilot studies performed in this project) is highly recommended. The latter can be especially relevant in remote areas, due to relatively low cost and the abilities to detect and quantify heavy metals as well as organic contaminants, which is a major environmental concern in arctic regions.

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Appendix A. Analytical methods

A1 – Methods and equipment applied at NIVA

Variable:	Unit	Name of method	Analytic instrument	Detection limit	Reference
Lead (Pb)	µg/L		Perkin-Elmer Sciex ELAN 6000 ICP-MS, with P-E autosampler AS-90, AS-90b sample board and P-E Rinsing Port Kit.	0.005	NIVA's accredited method E8-3
Cadmium (Cd)	µg/L		Same equipment (ICP-MS)	0.005	NIVA's accredited method E8-3
Copper (Cu)	µg/L		Same equipment (ICP-MS)	0.01	NIVA's accredited method E8-3
Zinc (Zn)	µg/L		Same equipment (ICP-MS)	0.05	NIVA's accredited method E8-3
Arsenic (As)	µg/L		Same equipment (ICP-MS)	0.05	NIVA's accredited method E8-3
Chromium (Cr)	µg/L		Same equipment (ICP-MS)	0.1	NIVA's accredited method E8-3
Nickel (Ni)	µg/L		Same equipment (ICP-MS)	0.05	NIVA's accredited method E8-3
Mercury (Hg)	ng/L		Perkin-Elmer FIMS-400 with P-E AS-90 autosampler and P-E Amalgam System AA Accessory	1	NS-EN 1483 and NIVA's accredited method E4-3
Optional:					
pH			Metrohm titrator (Titrino 799 GPT)	0.01	NS 4720
Conductivity	mS/m		Metrohm Conductivity Meter 712	0.05	NS-ISO 7888
Suspended particulate matter (SPM)	mg/L		Sartorius 4503 Micro with Static Eliminator Bar Pu 210, Item LC 9793	0.1	NS 4733 modified, nuclepore filter with mesh size 0.4 µm and diameter 47 mm.
Total Organic Carbon (TOC)	mg C/L		Phoenix 8000 TOC-TC analysator	0.1	EPA number 415.1 and 9060A STD.
Total phosphorus	µg P/L	Peroxidisulphate oxidation method	Skalar San Plus Autoanalysator	1	NS 4725 –
Orthophosphate (PO4-P)	µg P/L	Automated molybdate method	Skalar San Plus Autoanalysator	1	NS 4724 –
Total nitrogen	µg N/L	Peroxidisulphate oxidation method	Skalar San Plus Autoanalysator	10	NS 4743 –
Nitrate (NO3-N)	µgN/L	Liquid chromatography	Dionex model DX 320	1	NS-EN ISO 10304-1
Ammonium (NH4-N)	µg N/L	Liquid chromatography	Dionex model DX 320	2	NS-EN ISO 14911
Silicate (SiO2)	mg SiO2/L		ICP-AES	0.02	ISO 11885 + NIVA's accredited method E9-5

A2 – Methods and equipment applied at IO-RAS

Parameter	Unit	Name of method	Analytic instrument	Detection limit	Reference
Lead (Pb)	µg/L	Atomic absorption spectrometry (AAS)	Atomic Absorption Spectrometry "Kvant-2A"	2	Accredited method PND F 14.1:2.214-2006
Cadmium (Cd)	µg/L	Atomic absorption spectrometry (AAS)	Atomic Absorption Spectrometry "Kvant-2A"	0.2-0.3	Accredited method PND F 14.1:2.214-2006
Copper (Cu)	µg/L	Atomic absorption spectrometry (AAS)	Atomic Absorption Spectrometry "Kvant-2A"	0.4-0.6	Accredited method PND F 14.1:2.214-2006
Zinc (Zn)	µg/L	Atomic absorption spectrometry (AAS)	Atomic Absorption Spectrometry "Kvant-2A"	0.2-0.3	Accredited method PND F 14.1:2.214-2006
Arsenic (As)	µg/L	Hydride generation technique	Atomic Absorption Spectrometry "Kvant-2A" Generator mercury - hydride "GRG-107"	0.05	Accredited method PND F 14.1:2.49-96
Chromium (Cr)	µg/L	Atomic absorption spectrometry (AAS)	Atomic Absorption Spectrometry "Kvant-2A"	1.5-2	Accredited method PND F 14.1:2.214-2006
Nickel (Ni)	µg/L	Atomic absorption spectrometry (AAS)	Atomic Absorption Spectrometry "Kvant-2A"	3	Accredited method PND F 14.1:2.214-2006
Mercury (Hg)	ng/L	Cold vapor technique	Atomic Absorption Spectrometry "Kvant-2A" Generator mercury - hydride "GRG-107"	6	Accredited method PND F 14.1:2.20-95
Optional					
pH			pH-meter HI 991001 by «HANNA instrument»	0.01	RD 52.10.243-92
Conductivity	mS/cm (mkS/cm)		Cond 197i from WTW (Germany)	0.01	
Eh	mV		ORP HI 988202 by «HANNA instrument»	0.1	RD 52.10.243-92
Suspended particulate matter (SPM)		membrane ultrafiltration method under vacuum through nuclear filters with a diameter of 0.45 mm		3	PND F 14.1:2.110-97
Total Organic Carbon (TOC)					
Total phosphorus	µg/L	Colorimetric method	Single-beam spectrophotometer UNICO (model 1201), the company «United Products & Instruments, Inc», USA	0.01	RD 52.10.243-92
Orthophosphate (PO4-P)	µg/L	Colorimetric method	-//-	0.01	RD 52.10.243-92
Total nitrogen		-	-	-	-
Nitrate (NO3-N)	µg/L	Colorimetric method	-//-	0.01	RD 52.10.243-92
Nitrite (NO2-N)	µg/L	Colorimetric method	-//-	0.01	RD 52.10.243-92
Ammonium (NH4-N)		-	-	-	-
Silicate (SiO2)	µg/L	Colorimetric method	-//-	0.1	RD 52.10.243-92
Oxygen (O2)	µg/L	Winkler method		0.02	RD 52.10.243-92

A3 – Methods and equipment applied at INEP

Parameter	Unit	Name of method	Analytic instrument	Detection limit	Reference
Lead (Pb)	µg/L	AAS-GF	Perkin-Elmer Aanalyst-800, with P-E autosampler AS-800.	0.5	Russia's accredited method
Cadmium (Cd)	µg/L	AAS-GF	Perkin-Elmer Aanalyst-800, with P-E autosampler AS-800.	0.05	Russia's accredited method
Copper (Cu)	µg/L	AAS-GF	Perkin-Elmer -5000, HGA-400	0.2	Russia's accredited method
Zinc (Zn)	µg/L	AAS-GF	Perkin-Elmer -5000, HGA-400	0.1	Russia's accredited method
Cobalt (Co)	µg/L	AAS-GF	Perkin-Elmer Aanalyst-800, with P-E	0.5	Russia's accredited method
Chromium (Cr)	µg/L	AAS-GF	Perkin-Elmer -5000, HGA-400	0.2	Russia's accredited method
Nickel (Ni)	µg/L	AAS-GF	Perkin-Elmer -5000, HGA-400	0.5	Russia's accredited method
Lead (Pb)	µg/L	ICP-EOS	Perkin-Elmer ICP-EOS OPTIMA 2100DV	1	Russia's accredited method
Cadmium (Cd)	µg/L	ICP-EOS	Perkin-Elmer ICP-EOS OPTIMA 2100DV	0.1	Russia's accredited method
Copper (Cu)	µg/L	ICP-EOS	Perkin-Elmer ICP-EOS OPTIMA 2100DV	0.5	Russia's accredited method
Zinc (Zn)	µg/L	ICP-EOS	Perkin-Elmer ICP-EOS OPTIMA 2100DV	0.2	Russia's accredited method
Cobalt (Co)	µg/L	ICP-EOS	Perkin-Elmer ICP-EOS OPTIMA 2100DV	0.3	Russia's accredited method
Chromium (Cr)	µg/L	ICP-EOS	Perkin-Elmer ICP-EOS OPTIMA 2100DV	0.2	Russia's accredited method
Nickel (Ni)	µg/L	ICP-EOS	Perkin-Elmer ICP-EOS OPTIMA 2100DV	0.4	Russia's accredited method
Lead (Pb)	µg/L	ICP-MS	Perkin-Elmer ICP-MS ELAN 9000	0.005	Russia's accredited method
Cadmium (Cd)	µg/L	ICP-MS	Perkin-Elmer ICP-MS ELAN 9000	0.005	Russia's accredited method
Copper (Cu)	µg/L	ICP-MS	Perkin-Elmer ICP-MS ELAN 9000	0.005	Russia's accredited method
Zinc (Zn)	µg/L	ICP-MS	Perkin-Elmer ICP-MS ELAN 9000	0.03	Russia's accredited method
Cobalt (Co)	µg/L	ICP-MS	Perkin-Elmer ICP-MS ELAN 9000	0.01	Russia's accredited method
Chromium (Cr)	µg/L	ICP-MS	Perkin-Elmer ICP-MS ELAN 9000	0.1	Russia's accredited method
Nickel (Ni)	µg/L	ICP-MS	Perkin-Elmer ICP-MS ELAN 9000	0.05	Russia's accredited method
Optional					
pH			Metrohm pHM-82	0.01	Russia's accredited method
Conductivity	mS/m		Metrohm Conductivity Meter 660	0.05	Russia's accredited method
Suspended particulate matter (SPM)	mg/L		Sartorius 2472	0.1	Russia's accredited method
Total Organic Carbon (TOC)					
Total phosphorus	µg P/L	Peroxidisulphate oxidation method	Spectrophotometry	2	Russia's accredited method
Orthophosphate (PO4-P)	µg P/L	Molybdate method	Spectrophotometry	2	Russia's accredited method
Total nitrogen	µg N/L	Peroxidisulphate oxidation method	Spectrophotometry	10	Russia's accredited method
Nitrate (NO3-N)	µgN/L	Cd reduction method	Spectrophotometry	5	Russia's accredited method
Ammonium (NH4-N)	µg N/L	Phenol-hypochlorite method	Spectrophotometry	2	Russia's accredited method
Silicate (SiO2)	mg SiO2/L	Molybdate method	Spectrophotometry	5	Russia's accredited method

Appendix B. River data

B1. Norwegian rivers (sorted from west to east) – catchment characteristics (Skarbøvik et al. 2012)

Name of river	Catchment	Mean flow	Position at outlet	Dominating landuse	Population	Hydrol data	Water quality data (metals)	Water quality data (other parameters)
	km^2	m^3/s	Latitude/longitude					
Barduelva	2906	82.2398	69.04299/18.596474	88% Mountains, 10% forest	5046	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn *	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Målselv	3200	92.9	69.035985/18.667482	84% Mountains, 12% forest	2480	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn*	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Nordkjoselva	191	5.2907	69.217998/19.55799	72% Forest, 15% mountains	1194	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Signaldalselva	473	13.1021	69.265994/19.898977	87% Mountains, 9% forest	3649	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Skibotnelva	770	13.86	69.363996/20.274979	Mountains	583	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Kåfjordelva	358	7.16	69.491993/20.815979	Mountains	1501	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Reisa	2702	43.232	69.764991/21.017979	60% Mountains, 33% forest	1089	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Mattiselva	325	8.6125	69.913991/23.032989	Mountains	336	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Tverrelva	234	3.5334	69.956994/23.412996	Mountains	1325	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Repparfjordvasdraget	1090	27.25	70.443998/24.333	Mountains	381	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Stabburselva	1108	20.2764	70.181993/24.908978	Mountains	331	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Lakselv	1533	24.3747	70.065995/24.930985	Mountains	890	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Børselva	883	26.3134	70.315993/25.568997	Mountains	323	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Mattusjåkka	101	2.3028	70.389991/26.489998	Mountains	71	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Storelva (Stuorrajåkka)	690	15.111	70.313992/26.387991	Mountains	71	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Soussjåkka	92	2.3276	70.343995/26.520978	Mountains	71	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Adamselva	705	14.0295	70.381991/26.633989	Mountains	279	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Tanavassdraget	16389	188.4735	70.229993/28.173988	Mountains	5700	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn*	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Vesterelva	469	16.2274	70.525998/29.997978	Mountains	51	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
V. Jakobselv	627	11.3487	70.112/29.328976	Mountains	785	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Pasvikelva	18404	171.1572	69.500996/30.115996	Mountains	1129	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn*	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Neiden	2960	29.008	69.691992/29.369979	Mountains	390	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***
Grense Jakobselv	234	4.212	69.730995/30.886987	Mountains	266	yes	As, Cd, Cr, Cu, Hg, Ni,Pb, Zn**	pH, Kond, TOC, SPM, Tot-N, NH_4, NO_3, Tot-P, PO_4, SiO_2, PCB, Lindan***

* 0-1 times/yr, 1990-2003, 4 times/yr from 2004

** 0-1 times/yr, 1990-2003

*** frequency as for metals

B2. Norwegian rivers (sorted from west to east) – chemical data (Skarbøvik et al. 2012)

Arithmetic mean 1990-2011

Name of river	TOC	SPM	Cu	Cd	Cr	Ni	Zn	Hg	Pb
	mg C/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Barduelva	1.3	6.68	0.80	0.010	1.5	0.86	2.45	0.001	0.11
Målselv	1.3	6.99	0.75	0.010	1.6	0.94	1.85	0.001	0.11
Nordkjoselva	1.0	1.34	0.60	0.018	0.4	0.32	0.70	0.002	0.11
Signaldalselva	3.7	3.10	0.86	0.018	1.0	0.67	1.38	0.002	0.17
Skibotnelva	1.4	0.81	0.66	0.019	0.4	0.87	0.74	0.002	0.12
Kåfjordelva	0.78	0.79	1.26	0.024	0.4	0.57	0.94	0.001	0.10
Reisa	1.6	1.27	0.87	0.020	0.4	0.47	0.96	0.002	0.13
Mattiselva	2.1	0.61	0.72	0.019	0.5	0.43	1.00	0.002	0.18
Tverrelva	3.6	0.89	0.87	0.018	0.6	0.49	0.98	0.002	0.11
Repparfjordvasdraget	2.8	0.61	1.07	0.017	0.8	0.47	0.64	0.002	0.10
Stabburselva	2.2	0.61	0.72	0.022	0.5	0.34	0.83	0.001	0.34
Lakselv	2.5	4.19	0.82	0.016	0.8	0.64	0.90	0.002	0.18
Børselva	0.90	0.74	0.29	0.017	0.5	0.29	1.42	0.002	0.15
Mattusjåkka	1.2	0.71	0.46	0.028	2.2	0.54	2.02	0.002	0.24
Storelva (Stuorrajåkka)	0.72	0.45	0.33	0.022	1.7	0.71	1.76	0.002	0.15
Soussjåkka	1.1	0.55	0.29	0.019	0.7	0.35	1.22	0.002	0.11
Adamselva	1.7	0.58	0.40	0.021	1.2	0.39	1.46	0.002	0.29
Tanavassdraget	3.1	1.32	0.90	0.019	0.4	0.39	2.57	0.001	0.19
Vesterelva	0.78	0.50	0.26	0.017	0.9	0.28	0.54	0.002	0.11
V. Jakobselv	2.0	0.65	0.38	0.018	0.8	0.40	0.89	0.002	0.11
Pasvikelva	3.3	1.38	3.26	0.021	0.4	6.71	2.08	0.001	0.14
Neiden	3.7	1.59	0.77	0.024	0.5	1.04	3.23	0.002	0.13
Grense Jakobselv	2.5	0.95	2.26	0.024	1.8	7.77	2.04	0.002	0.28

TOC = total organic carbon, SPM=suspended organic matter

B3. Russian rivers (sorted from east to west) – catchment characteristics

References: Brittain et al. 2008, Grigory Khomenko (pers. comm.), Anna Chultsova (pers. comm.), Nikolay Kashulin (pers. comm.)

Main river	Tributary river	Sub-tributary	Catchment km2	Mean flow m3/s	Coordinates Degree N	Degree E	Distance with tidal fluct, km	Landuse	Population in catchment	Pollution sources	Hydrological data available	Data series - metals	Data series - other elements
Pechora			322000	4100	68.3045	54.4167	141	53.1% forest, 42.5% natural grassland	no data	Industry, agriculture, population	yes	Fe, Cu, Al, Cd, Cr, Ni, Zn, Hg, Pb	O2, NH4, NO3, NO2, PO4, totP, Si, BOD5, phenols, formaldehyde, methanol, DDT, DDE, α-HCH, β-HCH
	Usa		93600	1310	65.9668	56.9335		Forest, tundra	"	Oil production			
		Kolva	18100		65.9213	57.3168		"	"	"			
Northern Dvina			357000	3490	64.7000	40.4833	137	90.6% forest, 7.2% arable	"	Industry, agriculture, population	yes		"
	Pinega		42600	430	64.1338	41.9007	no	Forest, bogs, agriculture, lakes	"	Population	yes		"
	Yomtsa		14100	70	63.5385	41.8853	no	"	"	Agriculture, population	yes		"
	Vaga		44800	384	62.8067	42.8700	no	Mainly forest	"	"	yes		"
	Uftyuga		6300	37.5	61.5520	46.2230	no	Forest, bogs, agriculture, lakes	"	"	yes		"
	Vychegda		121000	1160	61.2833	46.6183	no	"	"	Industry, agriculture, population	yes		"
		Vishera	8780						"				
	Yug		35600	292	60.7248	46.3249	no	"	"	"	yes		"
	Sukhona		50300	456	60.7263	46.3235	no	"	"	"	yes		"
		Vologda	3030		59.2850	40.2173	no	"	"	"	yes		"
Northern Dvina estuary (17 sampling points)									"	"	>40 yrs	"	"
Mezen			78000	866	66.1915	43.9712		56.5% forest, 24.8% pasture, 11.9% wetland	"	"	yes		"
Onega			56900	505	63.9343	37.9862	25	51.9%forest, 19.1% arable, 11.3% pasture, 14.7%wetland	"	"	yes		"
Kem			27700	275	64.9532	34.6713	9.8	Bogs, taiga, agriculture, lakes	20000	Agriculture, population	yes		"
Niva			12800	164	67.1541	32.3735	0.5	Forest, bogs, agriculture, lakes	210000	Industry, agriculture, population	yes	yes	
Varzuga			9840	77	66.2581	36.9398	8.3	49.9%forest, 20.2% pasture, 26.2% wetland,	400	Agriculture, population	no		
Ponoy			15500	140	66.9720	41.2882	12.36	Forest, bogs, agriculture, lakes	1000	Population	no		
Iokanga			6020	60	68.0232	39.6237	6.2	"	2200	"	no		
Voronya			9800	110	69.1751	35.7926	10.3	"	3000	Industry, agriculture, population	yes		
Kola			3850	40	68.8834	33.0338	1	"	45000	"	yes	"	Monthly sampling
Tuloma			21500	241	68.8867	33.0085	10.4	"	34700	"	yes	"	
Pechenga			1829	22.5	69.5500	31.2500	5.6	Bogs, taiga, agriculture, lakes	19500	"	yes	"	
Teriberka			2227		69.1681	35.1241	5.2	"	1000	No data	yes	"	
Umba			6250	78.2	66.6566	34.3005	4.3	"	5532	Agriculture, population	yes	"	

B4. Russian rivers (sorted from east to west) – chemical data

Main river	Tributary river	Sub-tributary	Calcium	Colour	Cu	Ni	Zn	Hg	Reference
			mg/L	mg Pt/L	µcg/L	µcg/L	µcg/L	µcg/L	
Pechora			14.5-14.8		0.5-5.2	0-5.2	0.2-14.9		1
	Usa		18.1	31	0.6-2	0.4-4.9	0.4-12.2		1
		Kolva	14.8	147	0.8-12.5	0.7-6.2	1.4-16.9		1
Northern Dvina			13-66					0.005-0.18	2 (Ca), 3 (Hg)
	Pinega								
	Yomtsa								
	Vaga								
	Uftyuga								
	Vychegda		7-53.9						2
		Vishera							
	Yug								
	Sukhona								
		Vologda							
Onega			18.8	160					?
Kem			2.56	42					?

References:

1) Lukin set al. (2000)
2) Kuznetsov et al. (1991).
3) Ovsepyan and Fedorov (2011).

Appendix C. DGT data

Site	Station name	Position		Sample	Start exposure			End exposure			Lab		Cd	Cr	Cu	Ni	Pb	Zn	Co
		Latitude	Longitude		Date	Time	Temp C	Date	Time	Temp C			µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
River Pinega	Main station	64.69694	43.39983	DGT	31/08/2012	10:00	10.6	07/09/2012	09:00	12.1	NIVA		0.013	0.15	0.18	0.21	0.0059	0.67	
River Pinega	Main station	64.69694	43.39983	DGT	07/09/2012	09:00	12.1	14/09/2012	09:30	10.2	NIVA		0.0017	0.15	0.081	0.10	0.0088	0.70	
River Pinega	Main station	64.69694	43.39983	DGT	14/09/2012	09:30	10.2	21/09/2012	09:30	10.2	NIVA		0.0055	0.17	0.26	0.17	0.0230	1.9	
River Pinega	Main station	64.69694	43.39983	DGT	21/09/2012	09:30	10.2	28/09/2012	09:30	10.1	NIVA		0.0025	0.11	0.11	0.071	0.0064	0.37	
River Ashamba	Inflow Black Sea			DGT	24/06/2012	10:00	24.0	29/06/2012	13:00	24.0	NIVA		0.00034	0.008	0.013	0.0088	0.0015	0.056	
River Pinega	Main station	64.69694	43.39983	DGT	31/08/2012	10:00	10.6	07/09/2012	09:00	12.1	IO-RAS		0.381			2.300	5.026	0.244	
River Pinega	Main station	64.69694	43.39983	DGT	07/09/2012	09:00	12.1	14/09/2012	09:30	10.2	IO-RAS		0.077	0.126			1.644	0.085	
River Pinega	Main station	64.69694	43.39983	DGT	14/09/2012	09:30	10.2	21/09/2012	09:30	10.2	IO-RAS		0.345			1.589	6.300	0.830	
River Pinega	Main station	64.69694	43.39983	DGT	21/09/2012	09:30	10.2	28/09/2012	09:30	10.1	IO-RAS		0.172	0.925			1.091	0.032	
River Pinega	Main station	64.69694	43.39983	Water	31/08/2012						IO-RAS		5.84	13.94	< 0,4	< 3	33.95	27.4	
River Pinega	Main station	64.69694	43.39983	Water	31/08/2012						IO-RAS		4.35	26.33	< 0,4	< 3	18.66	11.6	
River Pinega	Main station	64.69694	43.39983	Water	31/08/2012						IO-RAS		6.33	32.2	1.29	< 3	31.03	40.98	
River Pinega	Main station	64.69694	43.39983	Water	31/08/2012						IO-RAS		4.22	12.92	< 0,4	3.92	<2	10.65	
River Ashamba	Inflow Black Sea			Water				28/06/2012			IO-RAS		4.90	18.28	< 0,4	20.94	18.96	21.5	
Karpelva	Karpelva	69.652	30.423	DGT	19/06/2012	12:00	12 (est)	14/09/2012	12:00	12 (est)	NIVA		0.0049	0.01	0.7	4.5	0.001	0.61	
Kolosjoki river	Station 1	From Nikel to Pasvik		DGT	22/08/2012	12:00	12 (est)	25/08/2012	12:00	12 (est)	NIVA		0.35	0.29	2.9	310	0.024	17	
Kolosjoki river	Station 2	"	"	DGT	22/08/2012	12:00	12 (est)	25/08/2012	12:00	12 (est)	NIVA		0.36	0.31	6.2	320	0.045	18	
Kolosjoki river	Station 3	"	"	DGT	22/08/2012	12:00	12 (est)	25/08/2012	12:00	12 (est)	NIVA		0.32	0.28	5.14	286	0.027	16	
Kolosjoki river	Station 4	"	"	DGT	22/08/2012	12:00	12 (est)	25/08/2012	12:00	12 (est)	NIVA		0.33	0.25	4.8	300	0.031	15	
Kolosjoki river	Station 1	"	"	Water	22/08/2012						NIVA		0.407	0.69	11.6	384	1.30	15.2	
Kolosjoki river	Station 2	"	"	Water	22/08/2012						NIVA		0.420	0.77	11.6	394	1.31	15.7	
Kolosjoki river	Station 3	"	"	Water	22/08/2012						NIVA		0.387	0.58	10.7	387	1.06	14.8	
Kolosjoki river	Station 4	"	"	Water	22/08/2012						NIVA		0.418	0.69	11.2	383	1.21	15.4	
Kolosjoki river	Station 1	"	"	Water				25/08/2012			NIVA		0.382	0.96	11.1	388	0.492	14.3	
Kolosjoki river	Station 2	"	"	Water				25/08/2012			NIVA		0.372	0.97	11.0	386	0.521	14.2	
Kolosjoki river	Station 3	"	"	Water				25/08/2012			NIVA		0.356	0.99	11.3	392	0.546	13.9	
Kolosjoki river	Station 4	"	"	Water				25/08/2012			NIVA		0.383	1.1	11.8	392	0.604	14.5	
Kolosjoki river	Station 1	"	"	DGT	22/08/2012	12:00	12 (est)	25/08/2012	12:00	12 (est)	INEP	***Average***	***1.08***	***2.10***	***20.3***	***1115***	***1.08***		***22.7***
Kolosjoki river	Station 1	"	"	DGT	22/08/2012	12:00	12 (est)	25/08/2012	12:00	12 (est)	INEP	*St.dev.*	*0.04*	*0.1*	*0.3*	*36*	*0.02*		*0.5*
Kolosjoki river	Station 2	"	"	DGT	22/08/2012	12:00	12 (est)	25/08/2012	12:00	12 (est)	INEP	***Average***	***1.14***	***1.93***	***19.3***	***1160***	***1.54***		***23.1***
Kolosjoki river	Station 2	"	"	DGT	22/08/2012	12:00	12 (est)	25/08/2012	12:00	12 (est)	INEP	*St.dev.*	*0.01*	*0.1*	*0.5*	*12*	*0.04*		*0.4*
Kolosjoki river	Station 3	"	"	DGT	22/08/2012	12:00	12 (est)	25/08/2012	12:00	12 (est)	INEP	***Average***	***1.08***	***1.68***	***14.0***	***1169***	***0.84***		***23.6***
Kolosjoki river	Station 3	"	"	DGT	22/08/2012	12:00	12 (est)	25/08/2012	12:00	12 (est)	INEP	*St.dev.*	*0.03*	*0.05*	*0.2*	*26*	*0.06*		*0.2*
Kolosjoki river	Station 4	"	"	DGT	22/08/2012	12:00	12 (est)	25/08/2012	12:00	12 (est)	INEP	***Average***	***1.14***	***1.92***	***14.9***	***1214***	***1.08***		***24.7***
Kolosjoki river	Station 4	"	"	DGT	22/08/2012	12:00	12 (est)	25/08/2012	12:00	12 (est)	INEP	*St.dev.*	*0.01*	*0.15*	*0.1*	*73*	*0.06*		*0.1*

Site	Station name	Position		Sample	Start exposure			End exposure			Lab		Cd	Cr	Cu	Ni	Pb	Zn	Co	TAl	TFe	TMn	TSr
		Latitude	Longitude		Date	Time	Temp C	Date	Time	Temp C			µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l				
Kolosjoki river	Station 1	From Nikel to Pasvik		Water	22/08/2012						INEP		0.47	1.4	16	398	1.75	18	7.7	84	380	53	210
Kolosjoki river	Station 2	"	"	Water	22/08/2012						INEP		0.41	1.3	15.5	404	1.71	17	7.9	84	385	54	214
Kolosjoki river	Station 3	"	"	Water	22/08/2012						INEP		0.45	1.4	14.7	424	1.86	17	7.8	91	390	52	215
Kolosjoki river	Station 4	"	"	Water	22/08/2012						INEP		0.53	1.3	14.5	402	1.84	18	7.8	87	360	53	213
											INEP												
Kolosjoki river	Station 1	"	"	Water				25/08/2012			INEP		0.4	1.9	14.5	404	0.74	15	8	86	430	58	228
Kolosjoki river	Station 2	"	"	Water				25/08/2012			INEP		0.39	1.8	14.7	406	0.75	16	8	92	430	58	227
Kolosjoki river	Station 3	"	"	Water				25/08/2012			INEP												
Kolosjoki river	Station 4	"	"	Water				25/08/2012			INEP												
Kolosjoki river	Station 1	"	"	DGT	22/08/2012			25/08/2012			INEP	AAS-GF	1.08	2.1	20.30	1083	1	48	22.7				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	ICP-EOS		2.3	17.9	1120		38	21.0				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	ICP-MS	1.0	1.9	18.4	1051	1	41	18.8				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	***Average***	***1.1***	***2.1***	***18.9***	***1085***	***1***	***39***	***20.8***				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	***St.dev.***	***0.03***	***0.2***	***1.03***	***28***	***0.0***	***4***	***2***				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	***±Sr,%***	***2***	***8***	***5***	***3***	***0***	***11***	***8***				
Kolosjoki river	Station 2	"	"	DGT	22/08/2012			25/08/2012			INEP	AAS-GF	1.1	1.9	19.3	1155	2	41	23.1				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	ICP-EOS		1.8	19.8	1111		39	19.7				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	ICP-MS	1.0	1.9	17.4	1088	1	44	19.6				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	***Average***	***1.3***	***1.9***	***18.8***	***1118***	***1***	***41***	***20.8***				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	***St.dev.***	***0.1***	***0.1***	***1.3***	***34***	***0***	***3***	***2***				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	***±Sr,%***	***7***	***4***	***7***	***3***	***15***	***7***	***10***				
Kolosjoki river	Station 3	"	"	DGT	22/08/2012			25/08/2012			INEP	AAS-GF	1.1	1.7	14.0	1192	1	47	23.6				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	ICP-EOS		2.3	12.0	1177		40	20.8				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	ICP-MS	1.1	1.8	12.7	1109	1	42	20.1				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	***Average***	***1.2***	***1.9***	***12.9***	***1159***	***1***	***41***	***21.5***				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	***St.dev.***	***0.02***	***0.3***	***1.0***	***44***	***0***	***4***	***1.8***				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	***±Sr,%***	***2***	***16***	***8***	***4***	***2***	***9***	***8***				
Kolosjoki river	Station 4	"	"	DGT	22/08/2012			25/08/2012			INEP	AAS-GF	1.1	1.9	14.9	1276	1	36	24.7				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	ICP-EOS		1.1	12.8	1209		45	21.4				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	ICP-MS	1.1	1.6	13.9	1161	1	44	21.2				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	***Average***	***1.1***	***1.5***	***13.8***	***1215***	***1***	***44***	***22.4***				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	***St.dev.***	***0.1***	***0.4***	***1.1***	***58***	***0***	***5***	***2.0***				
Kolosjoki river	"	"	"	DGT	22/08/2012			25/08/2012			INEP	***±Sr,%***	***5***	***28***	***8***	***5***	***7***	***11***	***9***				

Appendix D. Svanvik workshop programme

Venue:
Svanvik conference centre

Date:
18-20 June 2012

Participants:

IO RAS:	Anna Chultsova, Grigory Khomenko
INEP:	Nikolay Kashulin, Tatyana Kashulina
Akvaplan-NIVA	Guttorm Christensen
NIVA:	Øyvind Kaste, Evgeniy Yakushev, Kari Austnes, John Rune Selvik, Tore Høgåsen

Workshop programme:

Monday 18 June:

1230-1330	Lunch
1330-1400	Welcome and short introduction of participants
1400-1530	Presentations (20-30 min) followed by discussion: About the Norwegian-Russian bilateral project on riverine inputs (*Øyvind Kaste*) The Norwegian monitoring programme on Riverine inputs and direct discharges to Norwegian Coastal Waters – RID (*Kari Austnes*)
1530-1600	Coffee break
1600-1800	Presentations (30-40 min) followed by discussion: An overview of INEP's monitoring activities in lakes and rivers draining to the Barents Sea (*Nikolay Kashulin*) An overview of relevant monitoring activities at IO RAS (*Grigory Khomenko/Anna Chultsova*)
1900	Dinner

Tuesday 19 June:

0900-1030	Presentations (20-30 min) followed by discussion: An overview of relevant monitoring activities at Akvaplan-NIVA (*Guttorm Christensen*) The Norwegian Marine Pollution Monitoring programme – some results from the Barents Sea monitoring and modelling in 2009 (*Evgeniy Yakushev*)
1030-1100	Coffee break
1100-1230	Presentations (20-30 min) followed by discussion: Modelling direct discharges and diffuse inputs in river basins – an introduction to the TEOTIL model (*John Rune Selvik*) Methods for calculating riverine export based on measurements and model results – examples from the Norwegian RID programme (*Tore Høgåsen*) Methodological approaches in river monitoring conducted by INEP and IO RAS – manual sampling vs. automatic sampling, passive samplers, sensors, models, etc. (informal discussion with inputs from Grigory Khomenko, Anna Chultsova, Nikolay Kashulin)
1230-1330	Lunch
1330-1430	Preparation for field trip: Potential case study sites for method testing and calculation riverine inputs and direct discharges to the Barents Sea (discussion)

	An introduction to the Pasvik River – a potential case study site on the Norwegian side (*Øyvind Kaste, Kari Austnes, Guttorm Christiansen*)
1500-1800	Field trip to the Pasvik River and other long-term monitoring sites in the Pasvik valley
1900	Dinner

Wednesday 20 June:

0900-1030	Discussion / work session: Use of passive samplers (DGTs) to detect heavy metals and contaminants (*Øyvind Kaste*) Common protocol for case studies/ pilot studies (sampling, analysis, reporting).
1030-1100	Coffee break
1100-1230	Discussion / work session: Workplan and deliverables (notes, reports, etc.), next 12 months Project finance Next meeting, any other business
1230-1330	Lunch
1400-	Workshop ends / departure from Svanvik.

Appendix E. Final meeting, Oslo

Venue:
CIENS, Oslo

Date:
21-22 October 2013

Participants:

IO RAS:	Anna Chultsova, Grigory Khomenko
INEP:	Nikolay Kashulin, Tatyana Kashulina
Akvaplan-NIVA	Guttorm Christensen
NIVA:	Øyvind Kaste, Evgeniy Yakushev, Kari Austnes, Ian Allan

Programme:

Tuesday 22 October:

1030-1100	Welcome and introduction to the meeting *(Øyvind Kaste)*
1130-1200	New developments in the RID monitoring programme (Riverine inputs and direct discharges to Norwegian coastal waters) – continuous monitoring and inclusion of more organic contaminants *(Kari Austnes)*
1200-1230	Passive sampling techniques for organic contaminants: General overview, experiences from the RID programme, and preliminary results from the Pasvik river *(Ian Allan)*
1230-1330	Lunch
1330-1400	Review of the draft project report – current status and supplementary information needs (*Øyvind Kaste*)
1400-1430	On-going research at INEP with relevance to the NordRID project – inputs or comments to the final report (*Nikolay Kashulin*)
1430-1500	Coffee brake
1500-1530	On-going research at IO-RAS with relevance to the NordRID project – inputs or comments to the final report (*Anna Chultsova/Grigory Khomenko*)
1530-1600	The Pasvik project – overview and results so far (*Guttorm Christensen*)
1600-1610	End of first day: Practical information and a brief introduction to tomorrow's programme
1800	Dinner

Wednesday 23 October

0900-0930	Examples from monitoring and modelling activities with relevance to the Barents Sea *(Evgeniy Yakushev)*
0930-1030	Working session on the final report
1030-1100	Coffee brake
1100-1145	Working session on the final report (*cont.*)
1145-1200	Follow-up and conclusions - end of meeting
1145-1200	Lunch

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NIVA
Norwegian Institute for Water Research

Gaustadalléen 21 • NO-0349 Oslo, Norway
Telephone: +47 22 18 51 00 • Fax: 22 18 52 00
www.niva.no • post@niva.no