

ICP Waters Report 110/2012

Proceedings of the 27th meeting of the ICP
Waters Programme Task Force in Sochi, Russia,
October 19 – 21, 2011



Task Force members in Sochi. Photo: NIVA

International Cooperative Programme on Assessment
and Monitoring Effects of Air Pollution on Rivers and Lakes

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Title Proceedings of the 27 th meeting of the ICP Waters Programme Task Force in Sochi, Russia, October 19 – 21, 2011.	Report No.. 6300 - 2012 ICP Waters 110/2012	Date January 2012
	Project No. O 10300	Pages Price 60 Free
Editors Brit Lisa Skjelkvåle (NIVA), Bente M. Wathne (NIVA) and Tatyana Moiseenko (V.I.Vernadsky Institute of Geochemistry and Analytical Chemistry, Russia) (editors)	Topic group Air pollution	Distribution
	Geographical area Europe and North America	Printed NIVA

Client(s) The Norwegian Climate and Pollution Agency (Klif) United Nations Economic Commission for Europe (UNECE)	Client ref.
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Abstract Proceedings of presentations of national activities to the 27 th meeting of the ICP Waters Programme Task Force in Sochi, Russia, October 19 – 21, 2011.

4 keywords, Norwegian 1. Overvåking 2. Ferskvann 3. Luftforurensning 4. Internasjonalt samarbeid	4 keywords, English 1. Monitoring 2. Surface Waters 3. Air Pollution 4. International Cooperation
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CONVENTION ON LONG-RANGE
TRANSBOUNDARY AIR POLLUTION

INTERNATIONAL COOPERATIVE PROGRAMME ON
ASSESSMENT AND MONITORING EFFECTS OF AIR
POLLUTION ON RIVERS AND LAKES

Proceedings of the 27th meeting of the ICP Waters
Programme Task Force in Sochi, Russia,
October 19 – 21, 2011

Prepared at the ICP Waters Programme Centre
Norwegian Institute for Water Research
Oslo, January 2012

Preface

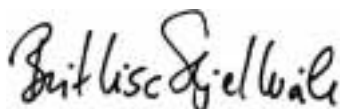
The International Cooperative Programme on Assessment and Monitoring of Air Pollution on Rivers and Lakes (ICP Waters) was established under the Executive Body of the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP) in July 1985. Since then ICP Waters has been an important contributor to document the effects of the implementation of the Protocols under the Convention. Numerous assessments, workshops, reports and publications covering the effects of long-range transported air pollution has been published over the years.

The ICP Waters Programme Centre is hosted by the Norwegian Institute for Water Research (NIVA), while the Norwegian Climate and Pollution Agency (Klif) leads the programme. The Programme Centre's work is supported financially by Klif. Also UNECE contributes to the financing of the activities by the Programme Centre.

The main aim of the ICP Waters Programme is to assess, on a regional basis, the degree and geographical extent of the impact of atmospheric pollution, in particular acidification, on surface waters. More than 20 countries in Europe and North America participate in the programme on a regular basis.

ICP Waters is based on existing surface water monitoring programmes in the participating countries, implemented by voluntary contributions. The ICP site network is geographically extensive and includes long-term data series (more than 20 years) for many sites. The programme yearly conducts chemical and biological intercalibrations.

At the annual Programme Task Force, national ongoing activities in many countries are presented. This report presents national contributions from the 27th Task Force meeting of the ICP Waters programme, held in Sochi, Russia, October 19 - 21, 2011.



Brit Lisa Skjelkvåle
ICP Waters Programme Centre

Oslo, January 2012

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1. Introduction

The International Cooperative Programme on Assessment and Monitoring of Rivers and Lakes (ICP Waters) is a programme under the Working Group on Effects (WGE) under the Executive Body (EB) of the UNECE Convention on Long-Range Transboundary Air Pollution (LRTAP). The main aims of the programme are:

Aims:

- Assess the degree and geographic extent of the impact of atmospheric pollution, in particular acidification, on surface waters;
- Collect information to evaluate dose/response relationships;
- Describe and evaluate long-term trends and variation in aquatic chemistry and biota attributable to atmospheric pollution.

Objectives:

- Maintain and develop an international network of surface water monitoring sites;
- Promote international harmonisation of monitoring practices by:
 - maintaining and updating a manual for methods and operation;
 - conducting interlaboratory quality assurance tests;
 - Compiling a centralised database with data quality control and assessment capabilities.
- Develop and/or recommend chemical and biological methods for monitoring purposes;
- Report on progress according to programme aims and short term objectives as defined in the annual work programme;
- Conduct workshops on topics of central interest to the Programme Task Force and the aquatic effects research community;
- Address water related questions in cooperation with other ICP's

The national contributions on ongoing activities that were presented during the ICP Waters Task Force meeting in Sochi, Russland in October 2011 are grouped thematically;

- **Aquatic biota**
 - Change of biodiversity of subarctic freshwater ecosystems in Russia. *Tatiana Moiseenko, et al. Russia*
 - Natural recovery of the benthic invertebrate fauna in the river Vikedalselva from 1987 to 2008. *Godtfred A. Halvorsen and Arne Fjellheim, Norway*
 - ICP Waters biological trend assessment report in Latvia, *Natalja Grudule, Marina Frolova and Iveta Indriksone, Latvia*
- **Surface water chemistry**
 - Swedish lakes - trends in water chemistry and acidification status. *Jens Følster, Sweden.*
- **Heavy metals and POPs**
 - Effects of air pollution on water chemistry of River Hrazdan, Armenia, *Marine Nalbandyan, Armenia*
 - Polychlorinated biphenyls (PCBs) in Rybinsk Reservoir, Russia. *Chuiiko Grigory, Institute for Biology of Inland Waters RAS*

2. Change of biodiversity of subarctic freshwater ecosystems in Russia

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Abstract

The problem of biodiversity conservation has become one of the leading ecological problems with social attention. Changes in environmental conditions on the Earth as a result of global and local anthropogenic impacts, unreasoned operation of biological resources result in violation of ecosystems balance formed for centuries. The Arctic and Subarctic regions are the least studied ones with respect to the modern state of flora and fauna. At the same time the anthropogenic load on natural catchments during the last years is realized in growing scales because of the exploration and processing of mineral resources in all northern countries. The vulnerability of the Northern nature to any kinds of impact is broadly well known. On the basis of generalisation of extensive materials on surface waters flora and fauna condition in the Kola North (Russia) there is formed the conception of contemporary tendencies in changes of biodiversity under impact of water pollution by heavy metals, eutrophication, acidification and discharge of warm water by nuclear power station (NPS). There are marked both general “threats to communities” reorganisation and specific response to the given kinds of impact. There are suggested the indices for monitoring of biodiversity of subarctic freshwater ecosystems.

Keywords: subarctic, aquatic ecosystem, toxic impacts, modification, reference condition, degradation

Introduction

The European North - Kola region of Russia are the unique model for studying the regularities in biodiversity changes under anthropogenic impacts. There is represented the large number of negative factors (metallurgical, mining, chemical production complexes, nuclear energetics, growing cities and settlements) polluting the water reservoirs by the run off water for a long time. The situation is aggravated by the airborne acid and metals deposition to the catchments from the “Severonickel” and “Pechenganickel” smelters.

The objective of the work in question was to form the conception of contemporary tendencies in changes of biodiversity of the Arctic aquatic ecosystems depending on the type of anthropogenic impact and its gradient (levels of waters pollution by heavy metals, eutrophication, acidification and thermal impact).

Objects and methods

The work is based on generalization of materials on long-term investigations of the authors at the water areas of the Fennoscandia North which results are given in a number of publications (Yakovlev, 1998; Vandysch, 1996; Moiseenko et al., 2002; 2003; 2009). There were investigated more than 200 water objects, among them there were picked out water areas and sites where under the impact of anthropogenic load became visible the negative ecological processes for Northern regions: acidification, eutrophication, toxic pollution by heavy metals and thermal impact of NPS. The analysis of biodiversity changes was carried out in close relation to hydrochemical indices. The toxic impact on phyto-, zooplankton, zoobenthos and fish was studied on the example of the lakes Imandra and Kuetsyarvi (receivers of the run off water from the copper-nickel smelters “Severonickel” and “Pechenganickel”) and also small

tundra and forest-tundra lakes located in the 30-km zone being under the impact of air emissions from the smelters. As a criterion of toxic pollution by heavy metals there was used the nickel concentration (gradients: <10 , $10-20$, $>20 \mu\text{g l}^{-1}$) as the priority toxicant for the North Fennoscandia waters. For Subarctic flora and fauna the consequences of waters concentration with nutrient and organic matters coming in with sewage were studied on the example of the river Pasvik bays. The waters eutrophication was estimated according to the criteria complex, as the gradient there was considered the phosphorus content <10 , $10-20$, $>20 \mu\text{g l}^{-1}$. The thermal impact was studied on the example of the Imandra lake in the Kola NPP warm waters area. The impact of industrial acidification - on the example of the small mountain and tundra lakes on the northern territories of Kola peninsula, Finland and Norway where there took place the reduction of waters acid-neutralizing capacity and pH as a result of natural sensitivity of the water catchment area and long-term load of acid-forming matters. In the water reservoirs of the same type being under acidification on the whole territory studied there was analysed the communities state depending on pH index: >6.5 ; $6.5-5$; <5 . The naturally acidified humificated lakes with high water colour were not considered.

Under all kinds of impacts as the indices of changes there were used the species composition of the leading complexes and ecological species valency; general species quantity and Shannon diversity index on quantity ($H \text{ bit ind.}^{-1}$); number of structure-forming species was picked out on the basis of rank distribution function $-r(i)$ where to the natural i numbers correspond the relative species quantities $n_i N^{-1}$ in a series being in a size order of quantity going down (Fyodorov et al., 1977).

The sampling and processing have corresponded to the methods generally accepted in hydrobiology and hydrochemistry. The results of taxonomy and physical-chemical analyses were checked up by a number of international intercalibrations (Intercalibration..., 2009).

The brief characteristic of natural structure of flora and fauna

A basis for revealing the changes in communities of water ecosystems is the knowledge of species and natural features under conditions of non-violated ecosystems. The investigation of freshwater phytoplankton of various types in the North Fennoscandia lakes has revealed about 400 species and subspecies of them: *Cyanophyta* - 7%, *Euglenophyta* - 0,5%, *Dinophyta* - 2%, *Cryptophyta* - 1,5%, *Chrysophyta* - 6%, *Bacillariophyta* - 60%, *Chlorophyta* - 23%. In the majority of reservoirs there dominate the algae of genera *Aulacoseira*, *Asterionella*, *Tabellaria*, *Ceratoneis*.

In zooplankton community there are determined more than 120 species: usual for North-West of the European part of Russia rotifers (50% of species structure), cladocerans (40%) and copepods (10%). Species structure and quantitative ratio of systematic and ecological groups of phyto- and zooplankton in the reservoirs of the Kola North are basically determined by the landscape-geographical situation, reservoirs' sizes and their cathments, running water and intensity of nutrient elements entry into the reservoirs (Letanskaya, 1974; Flora..., 1978; Drabkova, Sorokin, 1979; Yakovlev, 1991).

In zoobenthos of lakes and streams there are revealed about 300 species. The greatest taxonomic diversity falls into the group of Chironomidae (more than 120) represented mainly by Orthoclaadiinae, Tanypodinae, Trichoptera (about 50), bugs (about 50), Ephemeroptera and stoneflies (more than 60) and other taxa. The most diversified benthic fauna is in the coastal zone of large flowing lakes as well as in the rivers and wide streams with stony ground and rich moss undergrowth. In benthic fauna there are two relict species: mysis *Mysis relicta* and beach flea *Pontoporeia (Monoporeia) affinis* (Yakovlev, 1991).

Table 1. The dominating communities' species in natural waters of the Fennoscandia North (Moiseenko et al., 2002).

Phytoplankton	Zooplankton	Zoobenthos	Fish
<i>Aulacoseira distans</i> , <i>A. italica</i> , <i>A. islandica</i> , <i>Asterionella formosa</i> , <i>Cyclotella comta</i> , <i>Tabellaria fenestrata</i> , <i>Dinobryon divergens</i> , <i>Anabaena</i>	<i>Kellicottia logispina</i> , <i>Conochilus unicornis</i> , <i>C. hippocerpis</i> , <i>Bosmina obtusirostris</i> , <i>Daphnia longispina v.</i> <i>hyalina</i> , <i>Cyclops scutifer</i> , <i>Eudiaptomus gracilis</i>	<i>Chironomus f. l.</i> <i>bathophilus</i> , <i>Ch. f. l. salinarius</i> , <i>Ch. f. l. plumosus</i> , <i>Procladius</i> , <i>Tanytarsus</i>	<i>Salmo trutta</i> , <i>Coregonus lavaretus</i> , <i>C. albula</i> , <i>Salvelinus alpinus</i> , <i>Thymilus thymallus</i>

In ichthyofauna structure of the Kola North domestic water reservoirs there are 23 species which belong to 11 families. The representatives of species *Salmo* (atlantic salmon *Salmo salar*, brown trout *Salmo trutta*), arctic char *Salvelinus alpinus*, whitefish *Coregonus lavaretus* and *Coregonus albula*- up to 90 % on ichthyomass are dominate. From tundra to taiga zone the faunal core varies from brown trout-arctic char to perch and perch-pike.

The list of dominating species for the Fennoscandia North shows table 1. As a whole, in the structure of flora and fauna of the Kola peninsula and north-east Fennoscandia the arctic species are represented poorly, there prevail the boreal species many of them are the immigrants from north-east and north-west of Europe (Biological efficiency..., 1975; Flora...1978; Illies, 1978, Noest et al., 1986; Lillehammer, 1988; Moiseenko, Yakovlev, 1990; Yakovlev, 1991; Lukin, Kashulin, 1992).

TOXIC IMPACT

The toxic pollution of surface waters of the Kola North and neighbouring countries is connected first of all with the activity of metallurgical companies "Pechenganickel" and "Severonickel". Heavy metals (among which Ni is a priority) coming in directly with the run off water and by aerotechnogenic way pollute their catchments. The pollution areas of waters ($Ni > 10$, $Cu > 5 \mu g l^{-1}$) are limited by the 30 km zone at the expense of air emissions from the smelter; being in the structure of waste water, heavy metals migrate in water systems on distances up to 200 km in the direction of flow distribution (Moiseenko et al., 1999).

By toxic pollution of waters (for example, with concentration of Ni 20-100, Cu 10-50 $\mu g l^{-1}$) there takes place the formation of pure communities from eurybionthic species widely represented in Palearctic and cosmopolites as well. The reorganization of structure of phytoplankton communities occurs in the direction of mass development of green algae of genus *Scenedesmus*, *Pandorina* and a number of diatoms. The reduction of phytoplankton species' diversity by increasing of nickel pollution is shown on table 2.

In zooplankton there prevail rotifers - organisms with low individual mass, typical pollution indicators by domination of *Asplanchna priodonta*, *Keratella ñochlearis*, *Keratella quadrata*, *Kellicottia longispina*. The role of large cladocerans (*Leptodora kindtii*, *Daphnia cristata*) and copepods (*Eudiaptomus graciloides*, *Heterocope appendiculata*) is insignificant..

Fauna of macrozoobenthos is represented extremely by larvae of *Chironomus*, *Procladius* (*Holotanypus*) steady against pollution by heavy metals. On the significant water area, where there are distributed waste waters of the metallurgical companies, the species diversity is reduced at the expense of disappearance of relict crustaceans, Ephemeroptera, leeches, Bivalvia and other typical inhabitants of the regional lakes.

The fish population under the given pollution can be represented by 1-3 species. Among the northern species in the pollution zones is typical whitefish *Coregonus lavaretus*, which earlier

was considered as a oligotobiotic species by the classification of Lesnikov (1979). The predatory fishes of the freshwater-arctic complex - brown trout *Salmo trutta* and arctic char *Salvelinus alpinus* disappear from the faunal complex, at the coastal sites are met perch *Perca fluviatilis* and pike *Esox lucius*, in profundal - burbot *Lota lota* (Moiseenko et al., 2002). In table 2 there is given the summary species' characteristic of dominating complexes of water communities under conditions of water reservoirs' toxic pollution; along with the tendency to the reduction of biodiversity indices there is shown their variability under various impact gradients.

Communities of the water reservoirs the most polluted by heavy metals are characterized the low species' diversity by the minimum quantity and biomass as well. It should be noted that the natural conditions of water and impact factors under that the toxic impact dose is formed can have the determinative meaning for the north waters, what explains the exceeding amplitude of biodiversity indices variation under different concentrations of pollutants. For example, in the large lakes (Imandra, Kuetsyarvi) where the waters have high mineralization and contents of nutrient elements (at the level of a mesotrophic reservoir), concentration of Ni 5 - 10 $\mu\text{g l}^{-1}$ has not a significant negative impact on water organisms, as in the fine mountain lakes, where the mineral structure of waters is comparable with atmospheric precipitation - degradation of communities here becomes apparent already under concentrations of Ni 5 $\mu\text{g l}^{-1}$.

Table 2. Biodiversity indices (N - species' quantity, H_N - Shannon index) and dominating species in communities of aquatic ecosystems of the Kola North under conditions of toxic pollution (Moiseenko et al., 1999)

	Pollution marker Ni, $\mu\text{g l}^{-1}$			Dominating species under the high pollution gradient
	< 10	10-20	20-100	
Phytoplankton N H_N	15 - 40 > 2.5	10- 30 1.5 - 3.5	10 - 30 1.0 - 3.0	<i>Aulacoseira islandica</i> , <i>Rhizosolenia</i> , <i>Eudorina</i> , <i>Pandorina</i>
Zooplankton N H_N	10 - 25 > 2.5	10 - 20 1.0 - 2.5	10 - 15 0.5 - 2.5	<i>Keratella cochlearis</i> , <i>Asplanchna priodonta</i> , <i>Kellicottia longispina</i> , <i>Polyarthra sp.</i>
Zoobenthos N H_N	> 60 > 2.5	5 - 60 1.0 - 2.5	< 5 0 - 2.0	<i>Chironomus</i> , <i>Procladius</i> , Dytiscidae, Nematoda
Fish N	5 - 10	2 - 6	1 - 3	<i>Esox lucius</i> , <i>Perca fluviatilis</i> , <i>Lota lota</i> , <i>Coregonus lavaretus</i>

EUTROPHICATION

Eutrophication of waters in the north Fennoscandia has more local distribution at the places of their pollution by waste waters and agricultural drains. The Subarctic waters are oligotrophic by their natural characteristics; the contents of phosphorus rarely exceeds 6 $\mu\text{g l}^{-1}$. At the water objects of urbanized areas the contemporary contents of phosphorus has increased up to 12 - 24 $\mu\text{g l}^{-1}$.

In the small thoroughly warmed bays and lakes by their pollution by municipal sewage there take place the forming of phytoecosis non-typical for Subarctic, with limited abundance of arctic and north-alpine species. In the phytoplankton structure increases the role of diatomic *Asterionella formosa*, *Cyclotella*, *Stephanodiscus*. In contrast to the toxic pollution, along with the reduction of biodiversity increases the total biomass of algae - at the latter half of summer and early autumn it can reach 17 g m^{-3} (Moiseenko et al., 2002). To compare - in the similar lakes of the Kola North it does not exceed 3.0 g m^{-3} (Letanskaya, 1974).

Zooplankton under conditions of eutrophication is represented by species of Rotatoria - *Kellicottia longispina*, *Keratella cochlearis*, *Asplanchna priodonta*, *Notholca caudata*,

Cladocera - - *Bosmina longirostris*, *Daphnia cristata* and Copepoda - *Eudiaptomus gracilis*. On the whole, in the fauna of crustaceans increases the role of small forms - “fine” filtrates by the disappearance of large Cladocera and Calanoida - “rough” filtrates at the same time what leads to the reduction of activity of zooplankton in the water reservoirs’ self-cleaning processes. The typical representatives of the northern oligotrophic lakes *Leptodora kindtii*, *Bythotrephes sp.*, *Holopedium gibberum* and others are found out only in reservoirs with concentration $P_{tot} < 10 \mu\text{g l}^{-1}$.

In the zoobenthos structure dominate some oligochaete species of Tubificidae and larvae of *Chironomus*, *Procladius*. A diversity of the typical profundal representatives of the northern oligotrophic lakes - Orthocladiinae, Diamesinae and Tanytarsini is sharply reduced.

The reorganization of fish part of communities under conditions of eutrophication by reservation of a leading position of whitefish goes in the direction of replacement of predatory species (*Salvelinus alpinus*, *Osmerus eperlanus*, *Lota lota*) requiring oxygen with perch and pike ones.

The dominating forms and variability of biodiversity indices in water communities under various gradients of phosphorus concentrations in water shows table 3. It should be noticed that the eutrophication consequences for the Subarctic waters are mainly determined by the oxygen regime and water circulation. By water concentration with phosphorus up to 10-20 $\mu\text{g l}^{-1}$ and high saturation with dissolved oxygen (70-90%) in the structure of faunal core there may keep safe the aboriginal northern species. As an example there could serve the relic beach flea *P. affinis*, which accumulates in significant quantities at some sites of the Imandra Lake where its part may amount to 96% of the zoobenthos biomass (Yakovlev, 1998).

Table 3. Biodiversity indices (N - species’ quantity, H_N -Shannon index) and dominating species in communities of the water ecosystems of the Kola North under eutrophication conditions

	Pollution marker P, $\mu\text{g l}^{-1}$			Dominating species by P >20
	< 10	10 - 20	> 20	
Phytoplankton				
N	25 - 40	20 - 35	10 - 30	<i>Microcystis aeruginosa</i> , <i>Stephanodiscus</i> , <i>Asterionella</i> , <i>Aulacoseira islandica</i> , <i>Synedra</i> , <i>Sphaerocystis</i>
H_N	> 3.5	2.0 - 4.0	1.0 - 3.5	
Zooplankton				
N	10 - 25	10 - 20	10 - 15	<i>Keratella cochlearis</i> , <i>Asplanchna priodonta</i> , <i>Kellicottia longispina</i> , <i>Bosmina obtusirostris</i>
H_N	> 2.0	1.2 - 2.7	0.5 - 2.5	
Zoobenthos				
N	> 50	5 - 50	< 5	<i>Chironomus</i> , <i>Tubifex tubifex</i> , <i>Limnodrilus</i> <i>hoffmeisteri</i> , <i>Procladius</i>
H_N	> 2.5	1.0 - 2.5	0.5 - 1.0	
Fish				
N	> 6	2 - 6	1 - 2	<i>C. lavaretus</i> , <i>E. lucius</i> , <i>P. fluviatilis</i>

THERMAL POLLUTION

The thermal influence of the spent waters of power stations leads in Subarctic water reservoirs to the communities’ changes similar in certain limits to the eutrophication influence. As a result of the Kola NPP functioning warm waters (10 - 12⁰C) in the volume of 40 - 60 m³ sec⁻¹ have been dumped in the Imandra Lake since 1974. The maximum warming up of the water surface layer achieves in a summer period up to 24⁰C, during the larger part of the year it does not exceed 8 - 18⁰C In the distribution zone of warm waters of the power station ($\Delta T = 3-8^{\circ}\text{C}$) on the area about 5 km² there were formed specific biocoenosis. In the coastal zone there is fixed the powerful growth of peryphyton. The abundance of phytoplankton and its special diversity is 2 - 3 times higher at the expense of the development of diatoms - *Diatoma elongatum*, *D. vulgare*, *Fragilaria crotonensis*, *Stephanodiscus astreae* and other groups of algae.

In the zooplankton there dominate the species of rotifers - *Asplanchna priodonta*, *Kellicottia longispina*, *Keratella cochlearis*, *Synchaeta sp.* and cladocerans - *Bosmina obtusirostris*. As the activity of power stations with the straight-flow cooling system is connected with pumping of large water volumes, there takes place the natural quantitative rarity of zooplankton community as a result of destruction of the most rotifers (being the dominating group) and large crustacea in cooling system of the power station. The number of structure-forming species in the discharge canal has reduced two times (from 8 to 4) as regards to the intake area. There was fixed the presence of traumatized individuals (many of them had the detected integument, no extremities and outgrowths what is the evidence of the lack of their vital capacity. Mainly there are destroyed the bodies of large non- testa organisms.

In zoobenthos along with the widely distributed palearctic species there are met typical stenothermic organisms excepting relict crustaceans, the top temperature limit for which in deep-water lakes of the region does not exceed 10-14 °C. Relict *Mysis relicata* is not met in the warm zone. *P. affinis* actively migrating into the water layers, probably avoids the top warmer layers of water and is found only some hundred meters far from the canal mouth at a depth of more than 8-10 m, where the thermal conditions are kept close to the natural ones. The benthos species' structure keeps mainly the features of natural communities, that is connected with the impact of compensatory, colder currents at the bottom (Moiseenko, Yakovlev, 1990).

The fish population at a mouth site of the canal for the whole year is represented only by 2 - 3 local species steadiest to the high temperature and more heat-loving species-introducents (carp *Cuprinus carpio* and iridescent trout) (Moiseenko, Yakovlev, Lukin, 1988). The cold-loving species such as arctic char *Salvelinus alpinus*, burbot *Lota lota* and grayling *Thumallus thumallus* avoid the warm zone. Brown trout *Salmo trutta*, easily enduring the temperature increase up to 16-17 °C, uses this area for fattening practically for the whole year. Whitefish (*Coregonus albula* and *Coregonus lavaretus*) can make fodder daily and seasonal migrations choosing an optimum temperature mode in the warmed zone. Changes of the biodiversity indices depending on the gradient of the temperature increase shows table 4.

Table 4. Biodiversity indices (N - species' quantity, H_N Shannon index) and dominating species in the communities of water ecosystems of the Kola North under conditions of thermal impact

	Pollution marker Temperature ΔT °C			Dominating species by the maximum ΔT
	< 3.0°	3.0 - 8.0°	> 8.0°	
Phytoplankton				<i>Rhizosolenia</i> , <i>Diatoma</i> , <i>Fragilaria</i>
N	25 - 40	20 - 35	10 - 30	<i>crotonensis</i> , <i>Cyclotella</i> , <i>Tabellaria</i>
H_N	> 3.5	2.0 - 4.0	1.0 - 3.5	<i>Stephanodiscus astreae</i>
Zooplankton				<i>Asplanchna priodonta</i> , <i>Synchaeta sp.</i> ,
N	10 - 20	10 - 15	10 - 15	<i>Kellicottia longispina</i> , <i>Bipalpus hudsoni</i> ,
H_N	> 2.5	1.0 - 2.5	0.5 - 2.5	<i>Bosmina obtusirostris</i>
Zoobenthos				Tubificidae, <i>Procladius</i> , <i>Monodiamesa</i>
N	> 90	10 - 90	< 15	<i>bathyphila</i> , <i>Polypedilum</i>
H_N	> 3.0	1.0 - 3.5	0.5 - 2.0	
Fish				<i>Phoxinus phoxinus</i> , <i>Salmo trutta</i> , <i>P</i>
N	15	14	4	<i>fluviatilis</i> , <i>Cyprinus carpio</i>

It should be noted that in the impact zones of the NPP discharge waters the significant influence on communities along with the temperature factor belongs to the hydrodynamic conditions making both by pumping over of large water volumes and compensatory currents.

ACIDIFICATION

Acidification of waters in the Fennoscandia North becomes apparent at pH decrease of small lakes water, pH-shock at the streams during the high water period and decreasing of buffer capacity of the large water catchment areas. In the Kola North more than 10% of small lakes (from 500 explored ones) are acidified, more than 30% are in the critical state, when the acid-neutralizing waters capability is less than $50 \mu\text{eq l}^{-1}$. There are found the heavily acidified lakes with pH 4.2- 4.5 (Moiseenko, 2003).

Table 5. Biodiversity indices (N -species quantity, H_N -Shannon index) and dominating species in the communities of freshwater ecosystems of the Kola North under conditions of acidification

	Pollution marker pH			Dominating species by pH < 5
	> 6.5	5.0 - 6.5	4 - 5	
Phytoplankton N H_N	> 25 > 3.5	15 -20 1.5 - 2.5	< 15 1.0 - 2.0	<i>Aphanothece clathrata</i> , <i>Gloecarsa</i> , <i>Mycrocystis</i> , <i>A. distans</i> , <i>Tabellaria</i> <i>quadrisepitata</i>
Zooplankton N H_N	> 30 > 3.5	10 -25 1.0 - 3.0	< 10 < 2.0	<i>Holopedium gibberum</i> , <i>Bosmina</i> <i>obtusirostris</i> , <i>Eudiaptomus</i> <i>gracilis</i>
Zoobenthos N H_N	>100 > 3.0	20 - 100 1.5 - 3.5	< 20 0.5 -2.0	Chironomidae, <i>Asellus aquaticus</i> , Leptophlebiidae, <i>Nemoura</i> , Polycentropodidae, Dytiscidae
Fish N	> 6	1 - 2	0 - 1	<i>P. fluviatilis</i>

The water acidification leads to the biodiversity decreasing at the expense of reduction of the species sensitive to the pH decrease: in the flora of diatoms at the general background of the biodiversity decreasing there increase the part of acidobionthic and acidophylic species: *Aulacoseira distans*, *Cyclotella antiqua*, *C. kuetzingiana* v. *planetophora*, *Tabellaria fenestrata*, *T. flocculosa*, *T. quadrisepitata*. In the zooplankton of the lakes with low pH there dominate (in the number) the acidification steady species: *Holopedium gibberum*, *Bosmina obtusirostris*, *Eudiaptomus gracilis*. From the bottom organisms of lotic and lentic systems the most sensitive to the water pH lowering are beach fleas, snails *Lymnaea*, Valvatidae, mayflies (excluding Leptophlebiidae, *Heptagenia fuscogrisea*, *Caenis horaria*) stoneflies (excluding *Nemoura* spp.). Beach flea *Gammarus lacustris* is not found in water with pH < 6.5. From snails only *Gyraulus albus* is found by pH < 6.0. On the contrary, oligochaetes, crustaceans *Asellus aquaticus*, mussels *Pisidium* spp., water-mites, beetles Dytiscidae, bugs Corixidae, larvae of non-biting midges, dragonflies, alder flies (*Sialis* spp.), mayflies Leptophlebiidae, stoneflies *Nemoura* spp., caddis flies (Phryganeidae, Limnephilidae, *Cyrnus flavidus*, *Polycentropus flavomaculatus*, *Neureclepsis bimaculata*, *Plectrocnemia conspersa*) are the common inhabitants of the acidified lakes and streams (Yakovlev, 1997; Vandish).

Changes in the ichthyofauna of the acidified water reservoirs of the Kola North take place in accordance with the known scheme of replacement of salmon and whitefish with perch and pike. In water with pH less than 5.0 only perch is typical. The dominating species and variability of biodiversity by pH lowering shows table 5.

CONCLUSIONS

Changes in biodiversity of the arctic basin waters occurs under the impact of both local impact of various anthropogenic factors and global changes of the northern hemisphere environment. Under conditions of the industrially developed Subarctic regions there actively run the forming processes of new biological complexes which specific is determined by the kind of

anthropogenic load and natural conditions of the water reservoir and level of the water pollution as well.

The general tendencies in forming the contemporary biodiversity of the regional ecosystems under impact of various kinds of anthropogenic loads are the following:

- Decreasing of the species' diversity under any kind of waters pollution because of the disappearance of species typical for the northern water reservoirs - relict crustaceans (*M. relictus*, *P. affinis*), and also leeches, mayflies (excepting Leptophlebiidae), stoneflies (excepting *Nemoura*), chironomids (Tanytarsini, Diamesinae, Orthoclaudiinae), diatoms, large cladocerans (*L. kindtii*, *B. longimanus*) and calanoida (*E. gracilis*, *E. graciloides*).
- Dominating of the eurybionts' forms many of which have extensive natural habitats or are cosmopolites (*K. cochlearis*, *K. longispina*, *A. priodonta*, *B. obtusirostris*, Cyclopoida, Chironomini, Tanyptodinae, Polycentropodidae, *Sialis*, Hydracarina and Tubificidae). In such communities usually more than 75% of the total number and biomass fall on 3-6 species.

As a result, by the disappearance of a number of species there takes place the simplification of the communities' structure, what leads to simplification of trophic connections: in zoobenthos there takes place the replacement of filters-collectors, scrapers with collectors-detritophages, pulverizers, pelophages and predators, the zooplankton structure - replacement of large Cladocera and Calanoida with small "fine" filtrates (Bosmines) being unable to filter large food elements under conditions of the heightened water turbidity; there reduces the role of predatory pelagic salmon fish (brown trout *Salmo trutta*, arctic char *Salvelinus alpinus*) in the trophic structure of the ecosystems.

Along with general ecological regularities in changes of waters biodiversity under all kinds of pollution there could be emphasised a number of specific communities' responses to the various kinds of anthropogenic loads. Under acidification in diatom flora there prevail acidiphilous and acidophile species (*Aulakoseira distans*, *Tabellaria quadriseptata*, *T. flocculosa*), in zoobenthos the most steady are mayflies *E. aurivilli*, caddis flies Polycentropodidae, stoneflies Nemouridae. Under toxic pollution in plankton there dominate: diatom *Aulakoseira islandica*, green algae *Eudorina*, *Pandorina* and rotifers *Asplanchna priodonta*, *Keratella cochlearis*, *Kellicottia longispina* steady to the pollution. By eutrophication there increases the diatoms' quantity: *Stephanodiscus*, *Asterionella*, *Aulakoseira islandica*, *Synedra*; and eurybionte zooplankton species: *Keratella quadrata*, *Keratella cochlearis*, *Notholca caudata*, *Bosmina longirostris*, *Daphnia cristata*. Under thermal impact there increases the species' diversity of diatom algae.

The main directions determined by us in forming the species' structure of communities under the impact of various anthropogenic loads can become the basis for organization of the biodiversity control in the Subarctic freshwater ecosystems.

It is possible to use the following indices: general number of species and class species' distribution; structure of the dominating forms group; diversity of relict forms, including their quantity and biomass, and also systematic groups typical for the region: mayflies, stoneflies, chironomids Diamesinae, Orthoclaudiinae, Tanytarsini, large cladocerans and copepods, diatom algae, salmon fish.

ACKNOWLEDGMENTS

The work was supported by grants from the Russian Fund for Fundamental Investigation (Grant 10-05-00302).

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3. Natural recovery of the benthic invertebrate fauna in the river Vikedalselva in Norway from 1987 to 2008

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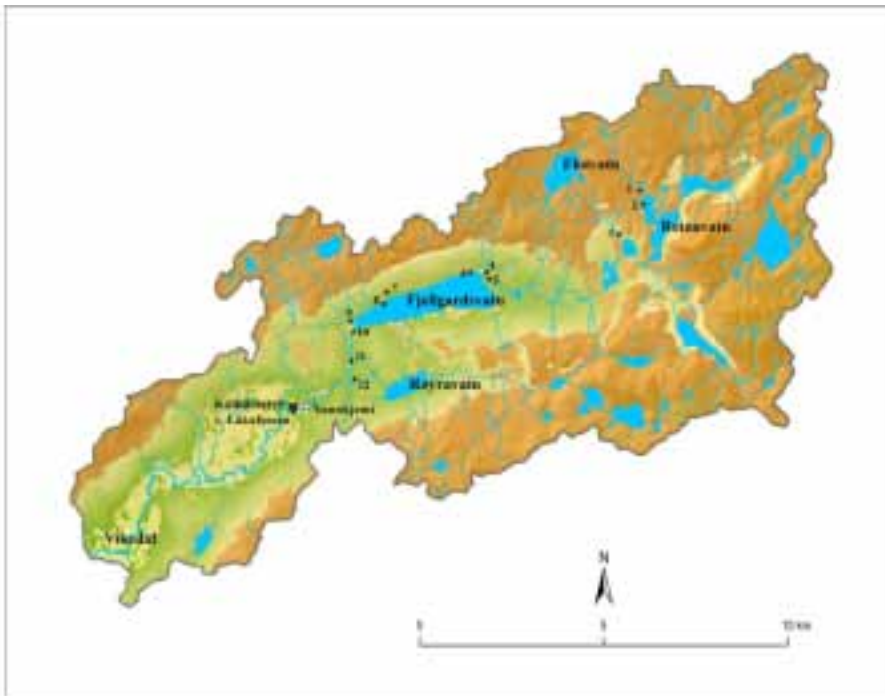
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Introduction

Reduced emissions of sulphur have been followed by a chemical recovery in lakes and rivers in Europe the last decades (Stoddard et al., 1999). This is also evident in the river Vikedalselva in the south-west of Norway (Skanche & Hindar in Sandlund et al., 2010). The aim of this report is to examine whether we can find the any recovery in the benthic invertebrates following the chemical recovery. This report builds on results reported in Sandlund et al., (2010).

Material and methods

The invertebrates have been collected by kick-sampling in the spring and autumn (Frost et. al., 1971) at 12 localities in the unlimed part of the Vikedal watershed (Figure 1). Three of the localities are in the littoral zone of lakes (St. 2 in the lake Botnavatn, St. 6 and 8 in the lake Fjellgardsvatn), while the remaining localities are in running water.



1. The Vikedal watershed with the benthic localities shown as circles. The star denotes the sampling station for water chemistry, and the triangle shows the location of the lime dozer.

The acidification indexes used are described in Fjellheim & Raddum (1990) and Raddum (1999). The multivariate analyses are described in Skjelkvåle et al. (2000) and Halvorsen et al. (2003). The relative abundance data (in percent) were $\ln(x+1)$ transformed in the

Redundancy analyses (RDA), downweighting were not used, the samples were centered and standardised and the total abundance variation was set to one.

The water chemistry data have been provided by NIVA (Norwegian Institute for Water Research). The following variables have been used in the RDA: pH, Ca (mg/l), TOC (mg/l), SO₄ (mg/l), labile aluminum (LAl) (µg/l), and ANC (µekv/l). The values for the spring samples used in the multivariate analyses were the average of the measurements in March, April and May. The values for the autumn samples were the averages from September, October and November. All water chemistry variables except pH were ln(x+1) transformed. In addition to the water chemistry variables, a 'dummy' variable called Time was used in the analyses. This was a linear variable coded as 0 to 43 for each successive sampling from spring in 1987 to autumn in 2008.

Results and discussion

Figure 2 shows the development of the pH on various sampling stations in Vikedalselva as an example of the recovering water chemistry. The filled yellow triangles represent the station with the water chemistry data used in this report.

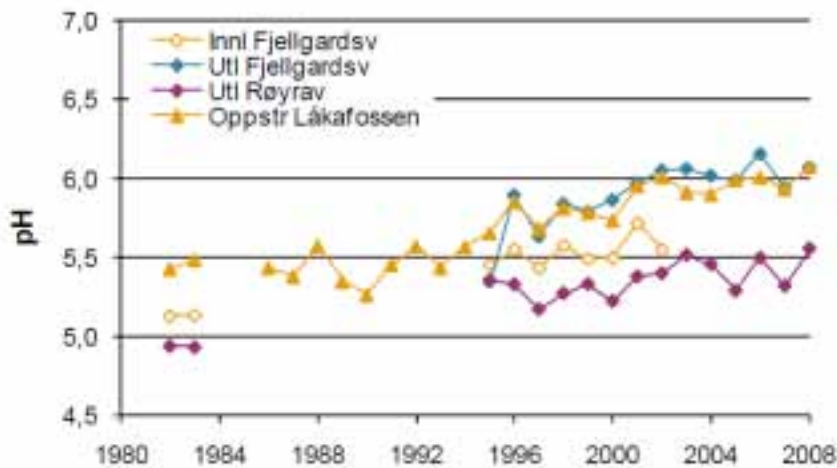


Figure 2. Annual mean pH on various stations in Vikedalselva. (Figure from Skancke & Hindar in Sandlund et al., 2010). Filled yellow triangles shows the measurements from the locality upstream the lime dozer.

The recovery in water chemistry has been followed by an increase in the number of specimens of acid sensitive species in most of the unlimed localities, as exemplified by the mayfly *Baetis rhodani* (Pictet) (Figure 3) at St. 11.

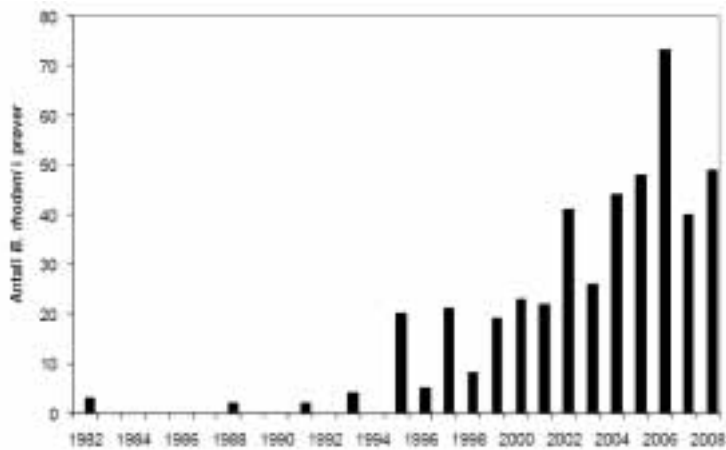


Figure 3. Number of specimens of *Baetis rhodani* per kick-sample at St. 11 in Vikedalselva.

This increase of acid-sensitive species is also mirrored in the development of the acidification indexes (Figure 4), which shows a significant increase in the unlimed localities.

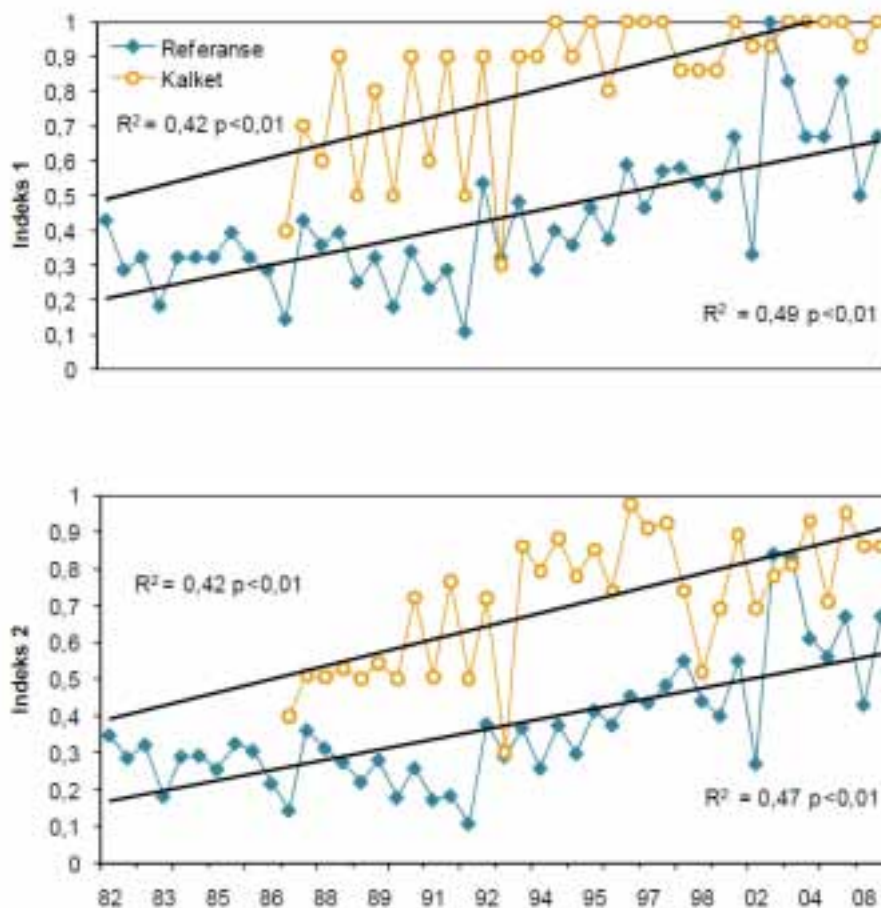


Figure 4. The development in the acidification indexes in Vikedalselva from 1982 to 2008. Upper panel shows Index 1 (Fjellheim & Raddum 1990), lower panel shows Index 2 or the adjusted acidification index (Raddum 1999). Filled blue squares show the unlimed localities, open yellow circles show the localities in the limed part of the river.

Multivariate analyses (RDA's) have been done on the benthic invertebrates in Vikedalselva before (Halvorsen et al., 2002). These analyses covered the ten-year period from 1989 through 1998. Only two localities showed significant changes in abundance variation with chemistry and time, that is, showed a significant sign of recovery. We redid these analyses with the years 1987 and 1988 added, and the result was the same. This is shown in Figure 5.

When the analyses were run with data from 1997 through 2008, all localities showed significant signs of recovery (Figure 5). Also the amount of variation explained by linear changes in water chemistry increased in the two localities where recovery was indicated in the first period. A Spearman rank correlation showed that pH and ANC increased significantly with linear time, while the concentrations of SO₄ and LAI decreased significantly. That is, a natural recovery in water chemistry is responsible for significant changes in the benthic community.

To examine these changes closer, we analysed the species response on each locality with only the linear variable 'Time' included as environmental variable. This gives us the species that increases or decreases with time, and the amount of weight each species gives to the RDA. We did only look for species with increasing abundance and a species score of 0.5 or above. The response was weighted up against previous knowledge about the acid sensitivity for the different species or taxa. The results for the running water localities are shown in Table 1. Seven of the stream localities showed changes in the benthic communities that were consistent with recovery from acidification, and a recovery was regarded as proven. For Station 4 the changes were regarded as uncertain. This is a small stream in a farmed field. *B. rhodani* increased in this locality, but the species score was only 0.3078. The taxon giving greatest weight in the RDA was a decrease of unidentified Diptera, which is hardly indicative of anything. The other stream locality we regarded as uncertain was Station 7. This is a small groundwater stream that has never acidified very much, and has held a viable population of *B. rhodani* for the whole period we have monitored this river. The caddisfly *Sericostoma personatum* did increase through the period, with a species score above 0.5.

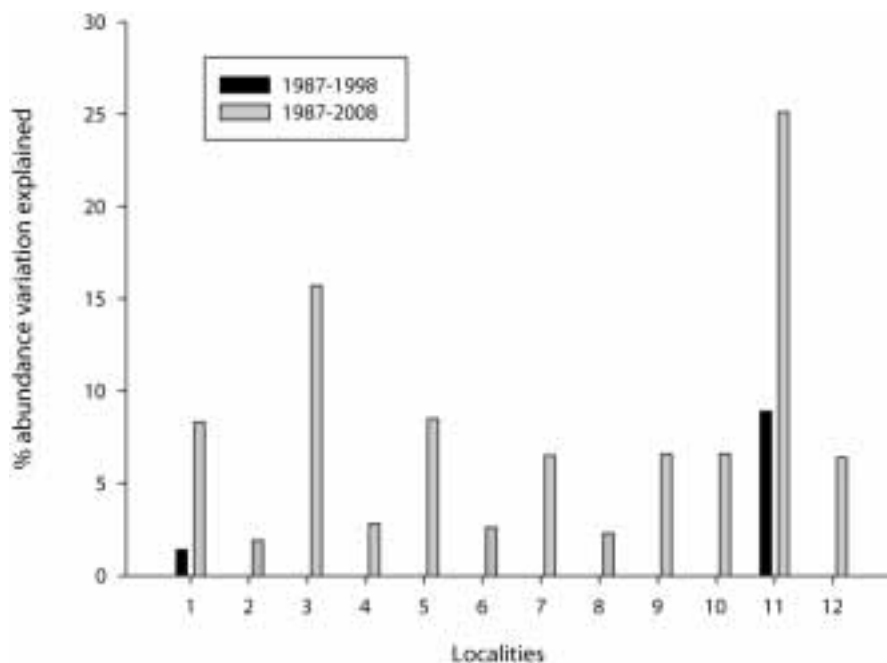


Figure 5. Localities where RDA's show significant signs of recovery with water chemistry and time in Vikedalselva. Black bars shows the results from the period 1987 through 1998, grey bars shows the result from the period 1987 through 2008.

This species is regarded as moderate sensitive. However, other variables may be responsible for this species increase since, as mentioned, the stream has never really acidified.

Of the three localities in the lakes, only the one in Botnavatnet (St. 2) showed some proof of recovery (Table 1). The other two localities in Fjellgardsvatnet were regarded as uncertain with respect to showing natural recovery, although the ordination analyses gave significant results.

The ordination analyses indicate significant changes in the benthic communities following natural recovery in the water chemistry in the Vikedal watershed during the period from 1987 to 2008. The results also indicates that the recovery have been strongest after 1998. The amount of abundance variation in the benthic community also increases on the two localities which showed significant results in the period from 1987 to 1998. However, the abundance data are not equally unambiguous on all of the localities. One explanation may be that the water chemistry data we have used are from one locality only, and that none of the examined localities have experienced this particular water chemistry. Accordingly, the changes in the water chemistry must thus be looked upon as a model for the changes in the watershed, with the uncertainties this will create for the explanation of the changes at the different localities.

Table 1. Species scores (in parantheses) from the RDA's with linear time as the single environmental variable. '(S)' behind a species indicates sensitivity to acid water.

Locality	Abundance variation explained %	Species scores > 0.5 (increase in abundance)	Natural recovery
<i>Stream localities:</i>			
Locality 1	8.3	<i>Baetis rhodani</i> (0.7293) (S) <i>Amphinemura borealis</i> (0.6924) <i>Isoperla</i> sp. (0.6215) (S)	Yes
Locality 3	15.7	<i>A. borealis</i> (0.7967)	Yes
Locality 4	2.8	-	Uncertain
Locality 5	8.5	<i>Lepidostoma hirtum</i> (0.6457) (S) <i>A. borealis</i> (0.6358) (S) Tipuloidea indet. (0.5413)	Yes
Locality 7	6.5	<i>Sericostoma personatum</i> (0.6696) (S)	Uncertain
Locality 9	6.6	<i>B. rhodani</i> (0.5686) (S) Tipuloidea indet. (0.5348)	Yes
Locality 10	6.6	<i>Hydropsyche</i> spp. (0.6557) (S)	Yes
Locality 11	25.1	<i>B. rhodani</i> (0.8728) (S) <i>Hydropsyche</i> spp. (0.7905) (S) Coleoptera indet. (0.7038) <i>A. borealis</i> (0.6517) <i>L. hirtum</i> (0.6203) (S)	Yes
Locality 12	6.4	<i>A. borealis</i> (0.6937)	Yes
<i>Lake localities:</i>			
Locality 2	1.9	Siphoneuridae indet. (0.5319) (S)	Yes
Locality 6	2.6	-	Uncertain
Locality 8	2.3	<i>Mystacides</i> sp. (0.5349)	Uncertain

Station 11 is the locality which have a water chemistry closest to the one measured. A tributary is entering the main river below the locality with a more acid water quality, so the water chemistry measured are worse than the one experienced by the animals at St. 11. However, the main river is dominating the waterflow at the point where measurements were made. This locality (St. 11) was one of the two localities first showing signs of recovery, and

this locality is the one in which linear changes in water chemistry explain the largest part of the abundance variation in the benthic community.

The three localities in the lakes also show signs of a natural recovery. The ordination analyses give significant results, but the amount of variation explained are low at all sites. With the exception of St. 2, no acid sensitive species have large influence on the ordinations. Longer distance to refuge populations may be an explanation for the weaker response in the littoral zone of the lakes. However, another explanation may be that the fauna normally examined in the monitoring (i.e. specimens of Mayflies, Stoneflies and Caddisflies or EPT taxa) have too low diversity and abundance to give a good signal of recovery in oligotrophic lakes. Analyses of the dominant taxon in the lakes, both in diversity and abundance (that is non-biting midges or chironomids), may be necessary to spot changes due to a recovering water chemistry.

Conclusions

- Analyses in the unlimed parts of the Vikedal watershed show that the benthic community in most of the running water localities respond to a recovering water chemistry, and that a natural recovery is occurring
- The analyses show that most of this recovery has happened after 1998
- There are indications that the recovery proceeds faster in running water than in the littoral of lakes in this watershed
- However, this difference may be an effect of the taxonomic groups analysed. Other groups than the EPT taxa (i.e. chironomids) must be analysed in order to settle this difference

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4. Trends in aquatic biology for ICP Waters sites in Latvia

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There are included 5 ICP Waters sites: Amula-estuary, Tervete-Tervete, Liela Jugla-Zaki, Tulija-Zoseni and Zvirbuli stream in the trend assessment analyses and the biological data time series ranged from 1999 through 2010. ICP Waters sites are situated in each of the 4 Latvian River Basin District (Figure 1).

Biological samples were collected by the standardized kick-sampling technique and using a handnet with a mesh size of 0,5 mm. Macroinvertebrate communities of the sites were sampled during late spring and autumn. Invertebrates were determined to the lowest practical taxonomic level, mainly species or genus for *Trichoptera*, *Ephemeroptera*, *Plecoptera*, *Crustaceans*, *Coleoptera* and *Molluscs*; to genus or family for *Diptera*.

Percentage ratio of main groups of macroinvertebrate communities - *Ephemeroptera*, *Plecoptera*, *Trichoptera*- in samples and Shanona-Winnera index (SW index) have been calculated for trend analysis separately for spring and autumn periods. Biological time series data has been compared with the trends of the hydrochemical parameters.

In general, the rivers in Latvia are rather stable aquatic ecosystems, and the main changes in river biota are caused by changed of river hydrology and aquatic chemistry.

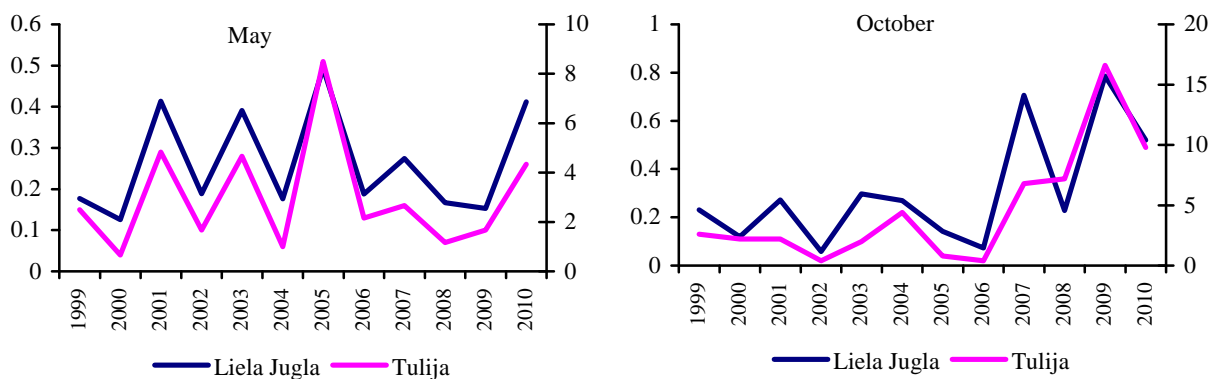


Figure 2. The monthly average water discharge, m³/sec.

Trend analysis of monthly water discharge and water temperature during the biological samples collection in May and October (Figure 2 and 3) has identified the positive slope of the trends for both hydrological parameters in the 1999-2010, though it was not statistically confirmed. It should be noted clearly expressed decreasing water discharge and increasing water temperature in May since 2005 and opposite tendencies of parameters in October.

In general, the river waters bodies of ICP waters sites are currently assessed as having high good or good ecological status, and therefore meeting the requirements of the Water Frame Directive (Table 1). Only, Tervete-Tervete, which is situated in Nitrate Vulnerable Zone with most intensive agriculture, has bad chemical status for the N_{tot} concentrations.

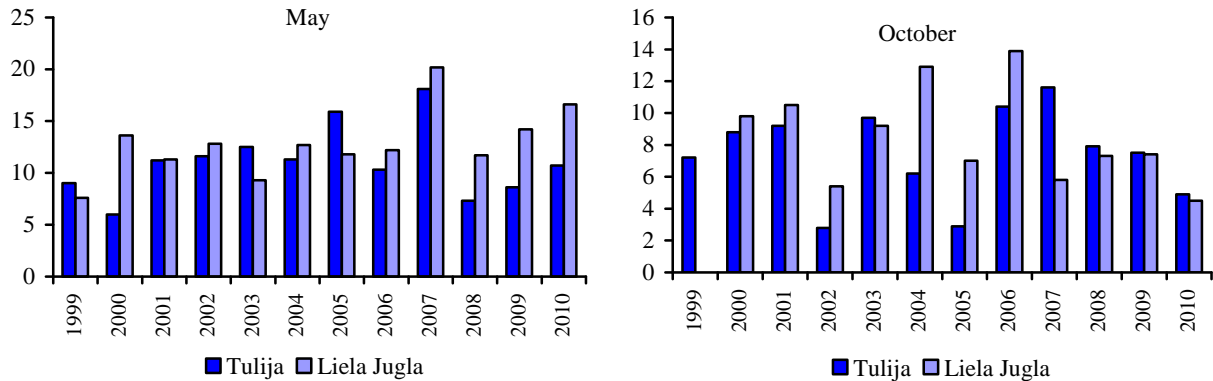


Figure 3. Water temperature during the samples collection in May and October, °C

Table 2. Ecological quality status of surface water bodies, 2010

Sites	O ₂	BOD ₅	N/NH ₄	N _{tot.}	P _{tot.}	Sapr. index.
Tulija-Zoseni	high quality	good quality	high quality	high quality	high quality	high quality
Amula estuary	high quality	good quality	high quality	high quality	high quality	high quality
Tervete-Tervete	high quality	good quality	high quality	bad quality	high quality	high quality
Liela Jugla-Zaki	high quality	good quality	high quality	high quality	high quality	high quality
Zvirbuli stream	high quality	good quality	high quality	high quality	high quality	high quality

high quality good quality bad quality

The trend analyses were made for hydrochemical compounds which have influence to the *Macroinvertebrate communities*. Trends results shown decreasing tendency for BOD₅ (biological oxygen demand) in the all monitored sites, at significance level in Tulija-Zoseni, Liela Jugla-Zaki and Zvirbuli stream. The tendencies of the O₂, pH, NO₃, N_{tot} and P_{tot} concentrations are different at different ICP Waters sites. Statistically confirmed increasing of O₂ and decreasing of N_{tot} concentrations have been found in Zvirbuli stream, increasing of NO₃, N_{tot} and P_{tot} - in Amula estuary and P_{tot} - in Tulija-Zoseni (Table 3).

Table 3. Results of Mann-Kendall hydrochemical parameters trend and Sen's slope estimate

Site	Period		pH		O ₂		BOD ₅		NO ₃ /N		N _{tot}		P _{tot}	
			Sign.	Slope	Sign.	Slope	Sign.	Slope	Sign.	Slope	Sign.	Slope	Sign.	Slope
Tulija	1999	2010		-0.01	+	0.11	*	-0.06		-0.01		-0.04	**	0.0040
L.Jugla	1999	2010		0.01	+	-0.09	*	-0.07		-0.01	+	-0.04		-0.0003
Amula	2002	2010	*	-0.03		-0.16		-0.09	*	0.07	+	0.08	*	0.0021
Tervete	2005	2010		0.03		-0.02		-0.02		-0.04		0.39		-0.0002
Zvirbuli	2002	2010		-0.11	*	0.37	*	-0.28		0.00	*	-0.06		-0.0021

Note: + - if there is a trend at the $\alpha = 0.1$ level, * - $\alpha = 0.05$ level, ** - $\alpha = 0.01$ level

During the period from 1999 to 2010 only in the Tulija-Zoseni have been detected positive trends at significance level for all main biological groups as well as for SW index. Different tendencies of changes can be seen for the sites Amula estuary, Tervete-Tervete, Liela Jugla-Zaki and Zvirbuli stream, trends no statistically significant (Table 4, Figure 5).

In 2005-2010 the biological observations in sites Liela Jugla-Zaki and Tulija-Zoseni indicate increasing numbers of *Ephemeroptera* and *Trichoptera* compare with 1999-2004 years. During the 2005-2010 average taxon richness in rivers Liela Jugla and Tulija increased until 31 and 12 number respectively versus 12 and 5 number in 1999-2004. Average taxon richness in Amula estuary, Tervete-Tervete and Zvirbuli stream were relatively stable during the 2002-2005 – respectively 32, 34 and 6 taxons.

Table 4. Results of Mann-Kendall hydrobiological parameters trend and Sen's slope estimate

Site	First year	Last Year	Ephemeroptera		Plecoptera		Trichoptera		SW index	
			Signific.	Q	Signific.	Q	Signific.	Q	Signific.	Q
Tulija	1999 V	2010 V	*	2.96	+	0.05	*	1.69	*	0.11
	1999 X	2010 X		0.53	**	0.19	+	0.82	**	0.19
Liela Jugla	1999 V	2010 V		4.04		0.00		-0.17	+	0.10
	1999 X	2010 X		0.32		-0.25		0.89		-0.01
Amula	2002 V	2010 V		1.51		-0.21		-0.90		0.02
	2002 X	2010 X		-0.69		0.47		1.48		0.03
Tervete	2005 V	2010 V		-3.15		-0.34		0.77		0.01
	2005 X	2010 X		1.23		0.26		4.03		-0.11
Zvirbuli	2002 V	2010 V		0.00		5.89		0.00		0.08
	2002 X	2010 X		0.00		0.00		0.00		0.19

In October 2005 in the site Tulija-Zoseni was found 25 stonefly of *Capnopsis schilleri* (Figure 5). This is a first record of this species in Latvia as well. This stonefly is a widely distributed in Norway, Sweden, Finland and Russian Karelija and considered extremely rare and endangered in Central Europe. *Capnopsis schilleri*, *Nemurella pictetii*, *Nemoura avicularis* and *Isoptera difformis* were recorded for the first time in the Tulija river.



Figure 4 The stonefly *Capnopsis schilleri* (left) and size in 1 cm scale (right) in Latvian water (Photo of Natalja Grudule)

Acidification indices from 2005 for both seasons (spring and autumn) in the ICP Waters sites are 1, this indicates stable water quality with no harmful effect on sensitive species. The macroinvertebrate communities is very low in Zvirbuli stream, that feeds with acid and weakly acid reaction water of Kemeru bog, presented generally by *Plecoptera*, and acidification indices is 0 or not possible calculated.

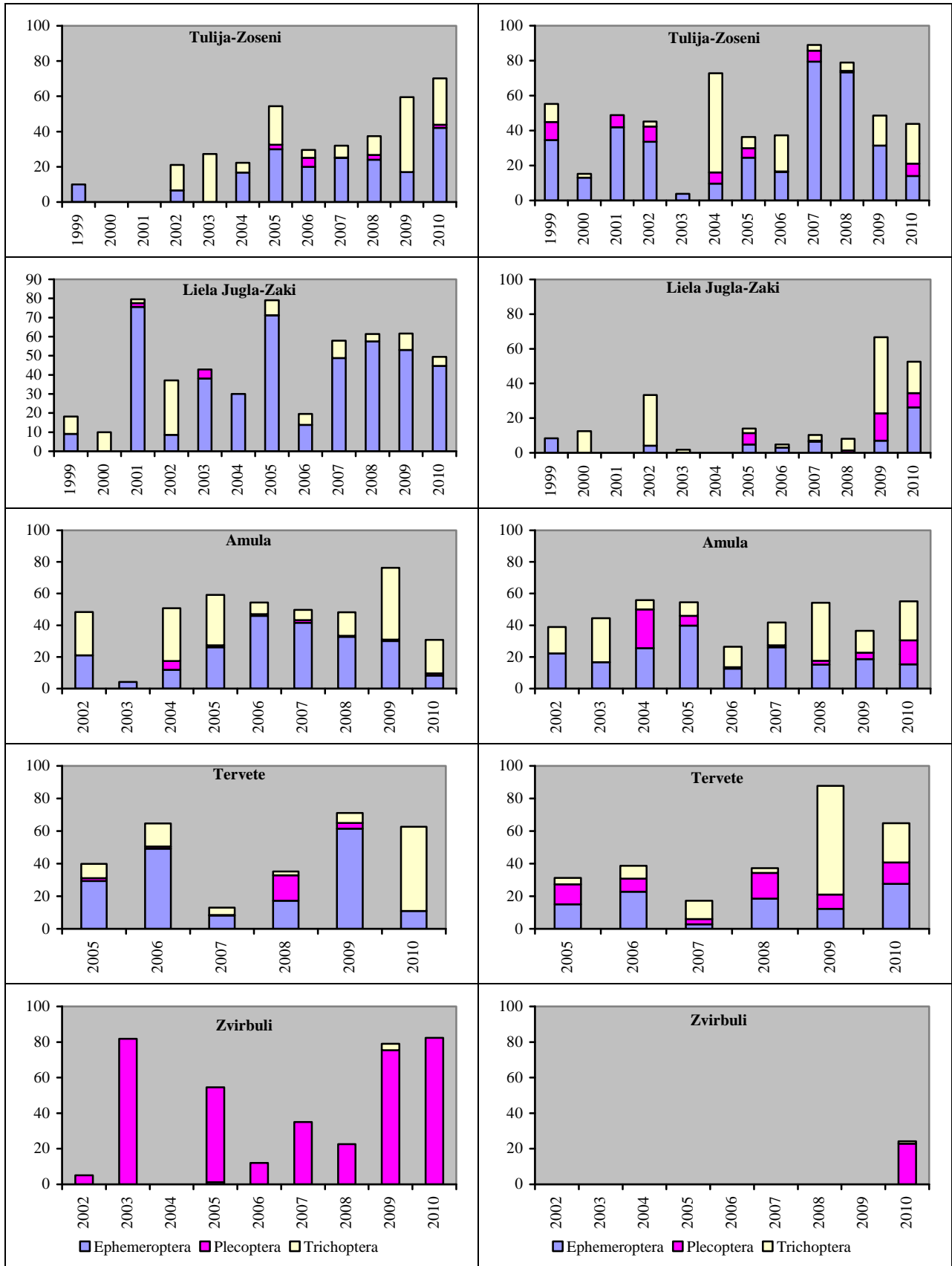


Figure 5 Percentage ratio of main groups of macroinvertebrate communities in samples (left – in May and right – in October)

Conclusions

- ☞ Positive trends at significance level for all biological groups as well SW index have been detected only in site Tulija-Zoseni during the period 1999-2010.
- ☞ Trends results shown decreasing tendency for BOD₅ (biological oxygen demand) in the all monitored sites, at significance level in Tulija-Zoseni, Liela Jugla-Zaki and Zvirbuli stream. The tendencies of the O₂, pH, NO₃, N_{tot} and P_{tot} concentrations are different at different ICP Waters sites.
- ☞ 2005-2010 period shown the increasing taxon richness of *Ephemeroptera* and *Trichoptera* in warm period at all ICP Waters sites that might be associated with the tendency of increasing water temperature and decreasing water discharge this years.
- ☞ In October 2005 in the site Tulija-Zoseni was dated first record of the *Capnopsis schilleri*, totally were founded 25 stoneflies. This stonefly is a widely distributed in Norway, Sweden, Finland and Russian Karelija and considered extremely rare and endangered in Central Europe.
- ☞ Since 2005 acidification indices in spring and autumn at the sites Liela Jugla-Zaki, Tulija-Zoseni, Amula estuary and Tervete-Tervete are 1 and indicate stable water quality with no harmful effect on sensitive species.

5. Trends in Swedish lakes and its implication on the definition of reference states for acidity

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Introduction

The dramatic decline in sulphur deposition during the 1990s was followed by a chemical recovery in surface water in northern Europe and North America (Stoddard et al, 1999) that has stabilized during the most recent decade. The lag time in response of water chemistry to the changes in sulphur depends on a number of factors including hydrological, abiotic and biotic retention of sulphur in the catchment (Kirchner et al, 2000, Mörth et al, 1999). Recently an increase in the content of natural organic matter has been detected in most regions in northern Europe and North America which has been correlated to both declining sulphur deposition and runoff (Monteith et al, 2007, Erlandsson et al, 2008)

In this study we follow the response between lake water chemistry and the most recent 20-year change in sulphur deposition in Sweden. Time series are divided into two parts in order to contrast the differences in slopes and magnitudes of sulphur deposition during the last two decades. The 68 lakes included in the study cover a large gradient of sulphur deposition making it possible to study the dependence of lake water chemistry on sulphur deposition (figure 1). The results are then interpreted to make predictions for further recovery and to further refine the definition of reference state.

The lake data set

The Swedish national monitoring program for time series of water chemistry in lakes started in 1983. Selection criteria limited monitored lakes to non-limed, acid-sensitive systems and the overall aim was to develop a set of reference lakes to be included in the extensive program of liming against acidification. The lakes cover the whole country, with a bias to regions with high sulphur deposition and regions sensitive to acidification (figure 2). Lake size ranges between 0,4 and 370 km², however most lakes are between 1 and 20 km². Lake catchments consist mostly of forest and mire areas. There are no point sources in the catchments and there is no other environmental impact other than deposition of airborne pollutants and extensive forestry. Ten of the lakes are reported to ICP-waters. The sites were divided into two regions based on climate and deposition level.

Surface water samples were taken in the middle of each lake four times a year, representing spring and autumn mixing and winter and summer stagnation periods. Water chemistry was analysed with standard methods by the ISO-accredited laboratory at the Swedish University of Agricultural Sciences using standard international and Swedish analytical methods. The laboratory regularly takes part in the ICP-Waters intercalibration activities.

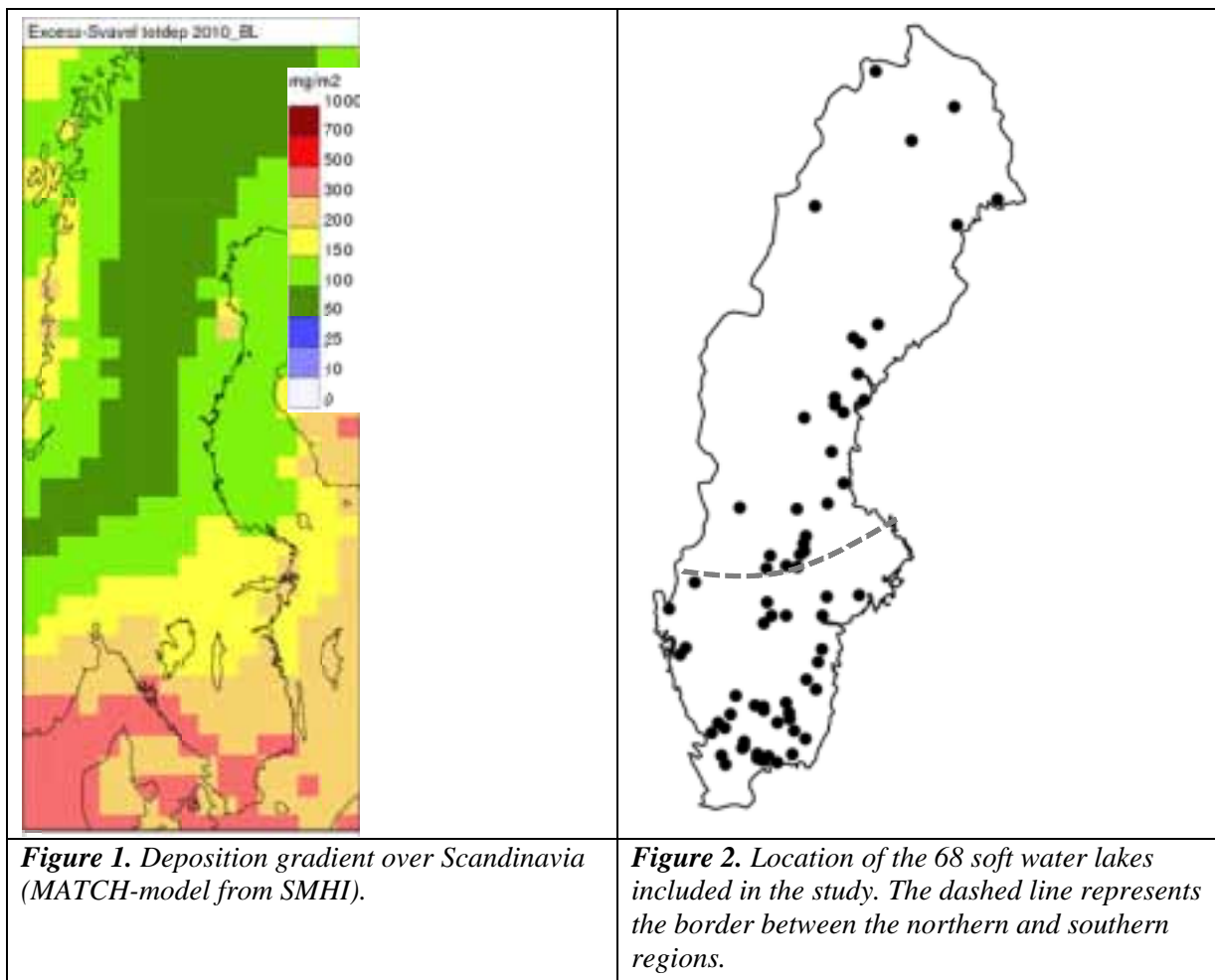
In this study we restricted the analysis to data for SO₄, base cations (BC = Ca + Mg + Na + K), acid neutralizing capacity (ANC = BC – SO₄ – Cl – NO₃) and total organic carbon for the two time periods 1991-2000 and 2001-2010.

Methods

Trends were estimated as Theils slope on a seasonal basis and statistical significance by Seasonal-Kendall (Hirsch and Schlack, 1984).

Results and discussion

The SO_4 -concentration decreased significantly in all lakes with two exceptions 1991-2000 (table 1 and figure 3a). The decrease continued through the most recent decade with a few exceptions, but with somewhat weaker trends and fewer significant trends. The difference in magnitude of trend, however, was not as large as expected from the decline in deposition (data from EMEP), indicating substantial retention of sulphur within the catchment. A pronounced regional pattern was detected with declining trend magnitudes from south to north, following the sulphur deposition gradient (figure 1).



In the southern region, the BC-concentration followed the SO_4 -concentration during the earlier period, with significant declining trends in all lakes but two. This follows what is expected during declining deposition according to general soil chemistry with a decrease in ion exchange (Reuss and Johnson, 1984). In the northern region there was a contrasting tendency towards increasing trends, especially in the northernmost lakes (figure 3b). Water chemistry in this low deposition region is more controlled by natural climate variation than deposition. During the most recent decade this regional pattern continued, but with fewer significant changes in the southern region. The variability in magnitude was greater during this period with both stronger and weaker trends compared to the previous decade.

During the 1991-2000 periode the SO_4 -decline was only partly counteracted by the BC-decline resulting in statistical significant increases in a net increase ANC during this period in most lakes. In the northernmost region this was probably due to the natural variation mentioned above. Chemical

recovery from acidification levelled out during the most recent decade with only a few significant changes detected but the overall increasing trend prevailed.

TOC-concentrations increased throughout the country between 1991 and 2000, with stronger and more significant trends in the southern region. This follows the hypothesis that the increase in organic matter is a response to the decline in sulphur deposition (Monteith et al, 2007). During the most recent decade, however, trends increased in strength but fewer were significant and a less pronounced regional pattern was detected, indicating the complex controls on organic matter.

The strong decline in SO₄ throughout the last two decades, and only a minor levelling out of this trend, indicates that the recovery process is on going. The poor trends in ANC from the most recent decade, however, indicate further improvement in acid status of these lakes is less likely. Further monitoring will reveal to what extent the dynamics in ANC during the last 20 years depend on natural variability and if further recovery from acidification will occur.

Sulfat		Decreasing trend		Increasing trend	
		Sign.	Non-Sign.	Non-Sign.	Sign.
1990-1999	North	25	1	0	1
	South	41	0	0	0
2000-2010	North	19	5	2	1
	South	33	5	2	1

BC		Decreasing trend		Increasing trend	
		Sign.	Non-Sign.	Non-Sign.	Sign.
1990-1999	North	6	4	13	4
	South	39	1	1	0
2000-2010	North	2	10	14	1
	South	22	17	2	0

ANC		Decreasing trend		Increasing trend	
		Sign.	Non-Sign.	Non-Sign.	Sign.
1990-1999	North	0	0	0	27
	South	0	2	4	35
2000-2010	North	0	6	17	4
	South	2	16	23	0

TOC		Decreasing trend		Increasing trend	
		Sign.	Non-Sign.	Non-Sign.	Sign.
1990-1999	North	0	1	12	14
	South	0	1	6	34
2000-2010	North	0	0	24	3
	South	0	2	17	22

Table 1. Lake chemistry trends in Swedish soft water lakes. Blue denotes trends towards a less acid state and red denotes trends toward a more acid state. Pale colours denote non-significant trends (Non.Sign.) and darker shade colours denote significant trends ($p < 0.05$, Seasonal-Kendall)

The increase in TOC has been given attention as a confining factor for recovery from acidification. Because natural organic matter is acidic, it depresses the pH which is the acidity parameter most correlated to biological species composition (Holmgren and Buffam, 2005, Johnson et al, 2007). From a long-term perspective, TOC dynamics are much more important than just dampening the recovery. If the hypothesis that TOC increases as a consequence of the declining acid deposition is correct, then TOC should have decreased during the beginning of the acidification period, partly dampening acidification effects in lakes. In the Swedish Quality Criteria, acidification is defined as a change in pH compared to 1860 according to the MAGIC-model (Fölster et al, 2007, Moldan et al, 2004). The TOC level is assumed as a constant because knowledge of the long-term change in TOC is unknown. Changes in TOC, however, have a substantial impact on the reference condition for pH.

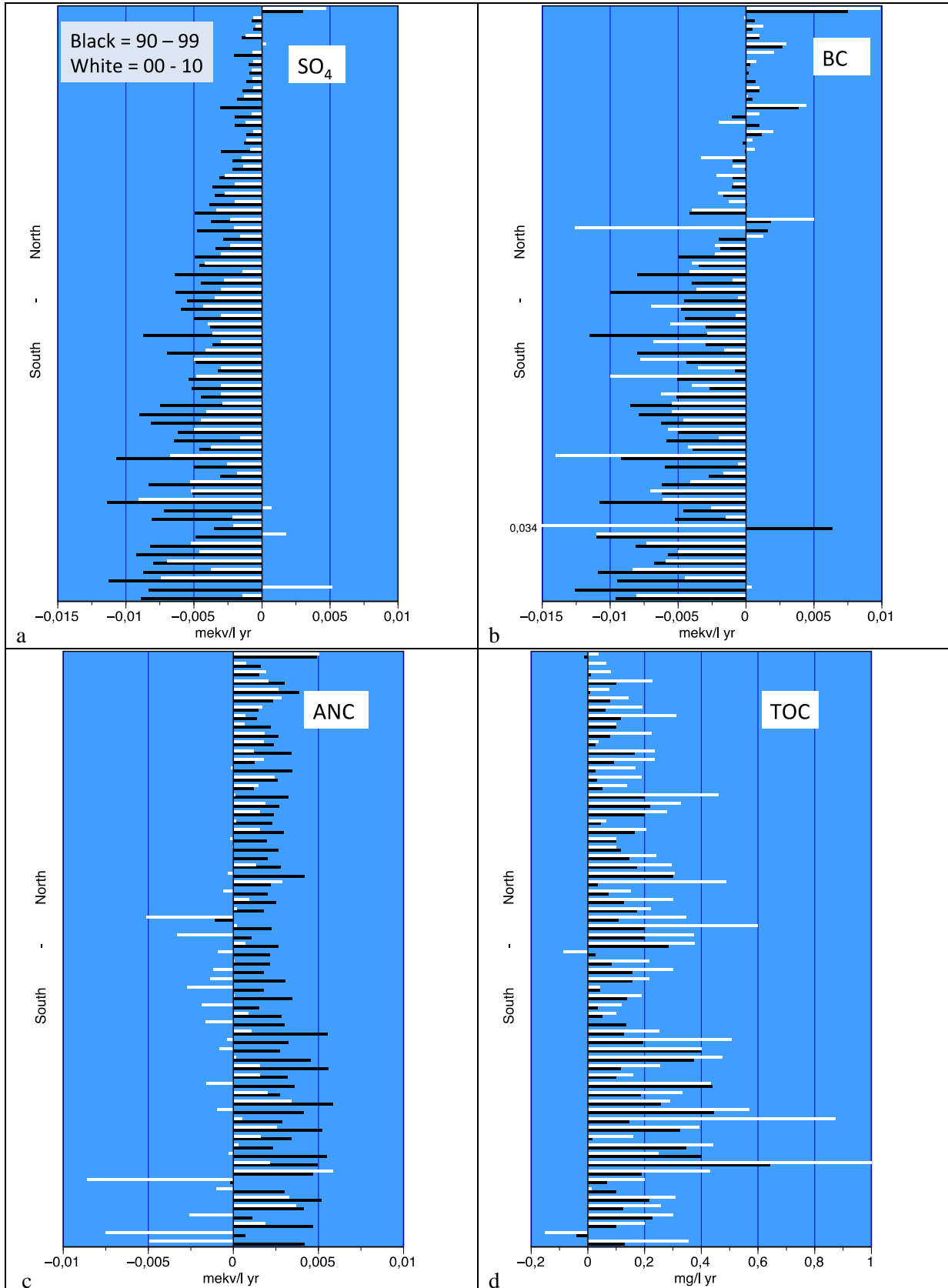
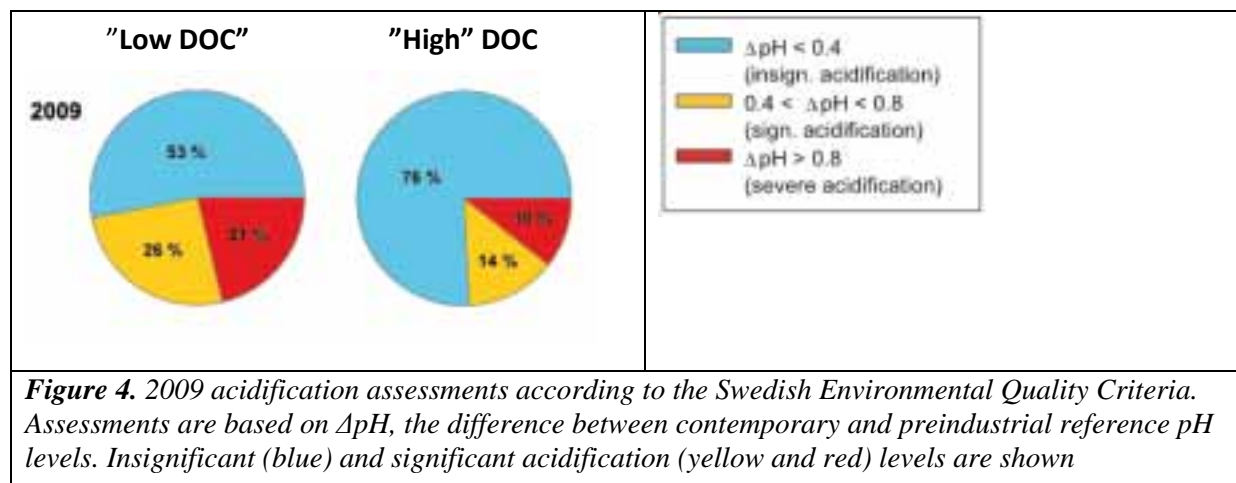


Figure 3. Trends in lake water chemistry for the two periods 1991 – 2000 and 2001 -2010 in 68 Swedish soft water lakes.

In a recent publication we showed that consideration of DOC (the dissolved fraction of TOC, which is similar to TOC in the study lakes) is crucial for the assessment of acidification (Erlandsson et al, 2011). If the present high concentrations of DOC were used for the calculation of the reference pH, the pH value was lower than if the 1990 low levels of DOC were used. Because acidification is defined as a difference in pH from a reference condition, the choice of DOC-level is crucial for the quantification of acidification. Using the low DOC-level for the calculation of the reference pH results in twice as many acidified lakes than if higher reference value of DOC is used (figure 4). This example shows on the importance of understanding the long term DOC-dynamics when assessing the environmental impacts from the acid rain.



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6. Effects of air pollution on water chemistry of River Hrazdan, Armenia

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Introduction

The watershed of the river Hrazdan is a complex ecosystem, which is under significant load of different anthropogenic factors. They include sources of industrial and agricultural pollution, as well as domestic drains. The river is a strategic water artery of the Republic, which requires serious control of the quality and management of the established ecosystem. In this paper we have focused on greatly urbanized part of the watershed, which is under significant pressure of pollution from transportation, industrial discharges and municipal wastewater. It is an area of the capital agglomeration.

General Characterization of the River Hrazdan Water Basin in Limits of Yerevan

River Hrazdan is the longest tributary of River Araks in the territory of Armenia. The Hrazdan river originates from Lake Sevan and flows into River Araks. The length of river Hrazdan is 146 km and its watershed area is 2560 km² (excluding Lake Sevan basin). The mean long-term water discharge is 7.57 m³/sec. The total drop of the river is 1090 m and the mean annual runoff is 0.71 km³.

In the studied area, surface and groundwater source sites are mainly the western slopes of the Geghama Range. They display a unique development of the hydrographic network. In groundwater formation and distribution within the boundaries of the city of Yerevan, a notable role is played by rock composition in that region.

A considerable part of western slopes display fractured Quaternary lavas – andesites and andesite-basalts. In those rocks alteration of several layers is observed, which are separated by slag formations. In most cases such layers are water resistant. The lava rock thickness varies between 700 and 800m (*Shaginyan, 2005*). In the whole, rocks are water pervious and water bearing. Sedimentary formations show a limited distribution and are represented there by clay and argillaceous slates and sandstone (*Avetissyan et al., 1974*).

In this area 55% of river water is fed from rainfalls and melted snow and 45% from groundwater. The city's territory is home to a number of industrial enterprises including “Molybdenum Production”, “Chistoe zhelezo” plants, “Nairit” (producing artificial resins) and “Polyplast”, a thermal energy generation plant.

Results and discussion

The ecological monitoring of the river Hrazdan ecosystem has been conducted from 2001 to 2008 for 28 parameters including main ions, general indicators, heavy metals and several organic pollutants. Due to long-term monitoring studies, the levels of main ions and heavy metals in the water, sediments and coastal vegetation are revealed, as well as tendencies of their change.

Figure 1 presents the dynamics of contents of nitrites, nitrates, sulfates and ammonium nitrogen in waters of River Hrazdan within the Yerevan City. The contents of nitrates and nitrites are in the limits of the Maximum Permissible Concentrations (MPC) values, while the concentrations of sulfates and ammonium nitrogen exceed the MPC by their toxicological indices (*Saghatlyan and Nalbandyan 2002*)

The water from this section of River Hrazdan is characterized as *hydrocarbonate – sulfate with relatively high mineralization*. pH varies between 6,6 and 7,8. Mean annual mineralization makes 556,1 mg/L. Carbonate hardness is equal to 3,2 mg-eqv/L and according to classification of natural waters is characterized *as soft*.

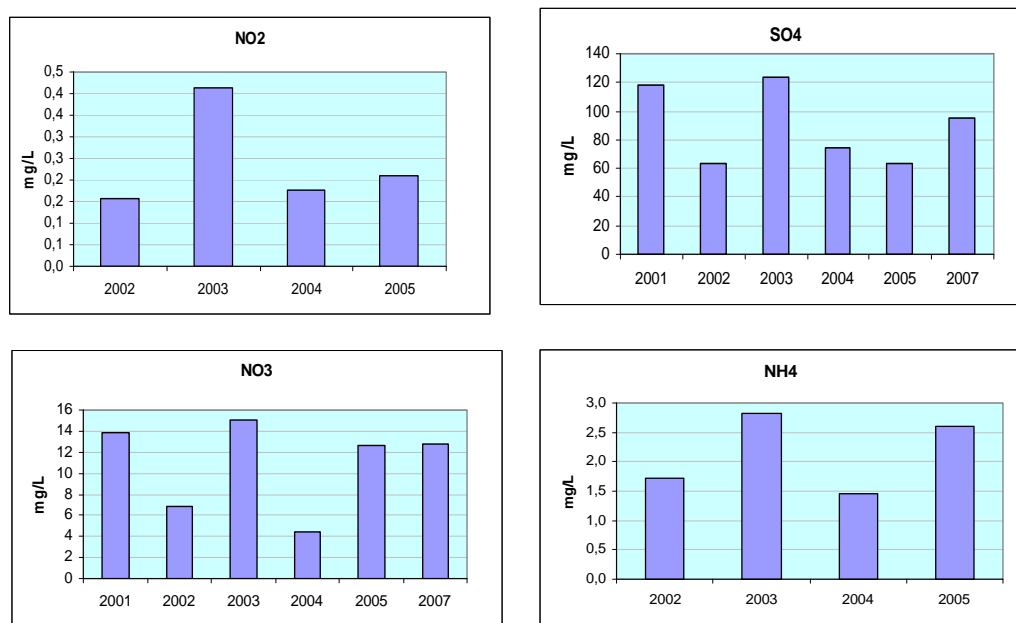


Figure 1. Main ions contents in the river Hrazdan waters, mg/ l.

We carried out also determination of HMs in water and sediments. The results of investigations revealed that concentrations of Cu, Ag, Cr, Ni, Cd, Pb, As, Mn, Zn in the river water exceeded the background values multiple times. It was revealed that Cu, Pb and Zn were accumulated mostly in bottom sediments, the processes transformations and HM substitutions in the aquatic environment were studied as well. Correlations among studied HM were revealed (Nalbandyan, 2008).

A balance mathematical model was elaborated to describe dynamics of primary pollutants in heavy metals man-made associations (Zn, Cu, Pb) in the system “soil-surface waters-ground waters” for the basin of the river Hrazdan in limits of Yerevan (Nalbandyan and Ajabyan, 2010). Local subsystems were analyzed for the techno-ecosystem in mentioned part of the river water aimed at for verification of model. Components of the latter present the atmosphere, river water, soil, bottom sediments and ground waters. Heavy metals studied on the base of method corresponding to that proposed by Venetsianov for conservative pollutants (Venetsianov, 2009).

We also studied the HMs accumulation processes in plant, particularly in Bur reed. The detailed investigation shows that Bur reed actively accumulates the basic set of elements-pollutants (Zn, Ag, Cd, etc.) from water and adequately reflects qualitative pollution of river waters (Saghatelyan, Arevshatyan and Nalbandyan, 2004).

Within the city region, air quality monitoring has been conducted continuously since 1998 by the Environmental Impacts Monitoring Center. Observations have been conducted at 4 automated stations, 5 stationary, not-automated stations and at 43 passive sampling sites. According the investigations, high levels in limits or exceeding MPC have been registered for sulfur dioxide, nitrogen dioxide and nitrogen oxide contents over recent 10 years (Annual Reports, Environmental Impacts Monitoring Center) (Figure2).

The results from these investigations show that the ecosystem of the river Hrazdan is under substantial anthropogenic pressure, including the part from the air basin. The long-term monitoring can serve as a scientific base under various loads accounting.

Further research can include “volumes of discharges and runoffs – processes in waters-loads”. The method of integral indicators of the water quality and critical loads estimation can be calculated and used for definition the level of load (Moiseenko, 2001).

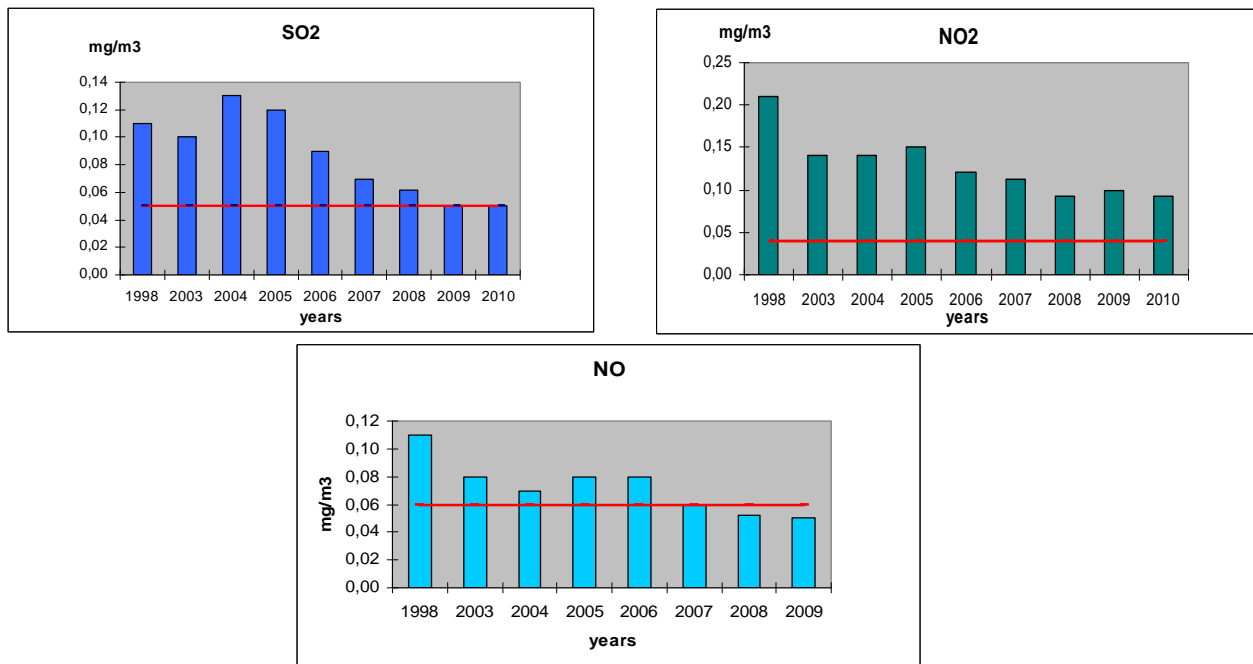


Figure 2. The levels of sulfur dioxide, nitrogen dioxide and nitrogen oxide in the air in limits of Yerevan (the river Hrazdan bassin).

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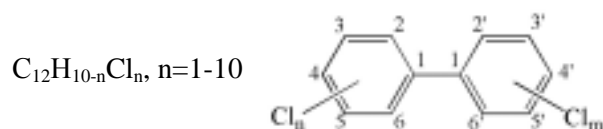
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7. Polychlorinated biphenyls (PCBs) in Rybinsk Reservoir, Russia

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Polychlorinated biphenyls (PCBs) are one of the abundant groups of environmental contaminants. They belong to the class of organochlorine compounds and are referred among the persistent organic pollutants (POPs). PCBs are bicyclic compounds consisting of two benzene rings and substituted with one to ten chlorines. Owing to this structure there are 209 individual PCB congeners differing with number and position of chlorine.



PCBs were manufactured and used in the industry in large scales since 1929. Near 2 million tonnes of PCBs were produced in whole world and entered to environment until cessation of their production in 1986. In former USSR and then in Russia 0.18 millions tonnes of PCBs were produced from 1939 till 1995. Main usage of PCBs is following: electrical fluids in transformers and capacitors (major use), flame retardants, lubricating and hydraulic oils, carbonless paper, additives to paints and plastics etc. Most of the use was in the northern hemisphere of the Earth (**Figure 1**).

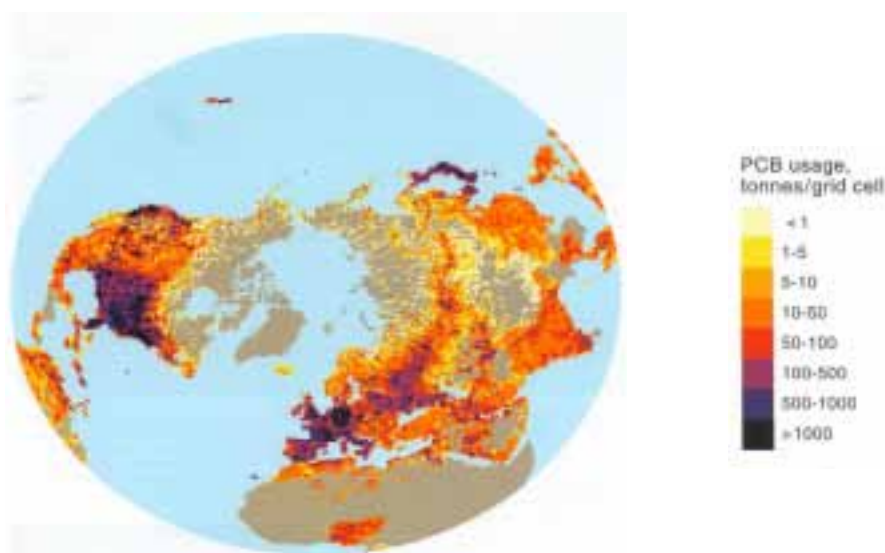


Figure 1. Global PCB usage, tonnes/grid cell [1]

Commercial PCB products are mixture of congeners produced under the different trademarks: Aroclor (USA and U.K.), Phenoclor and Pyralene (France), Fenclor (Italy), Kanechlor and Santotherm (Japan),

Clophen (Germany), Delor (former Czechoslovakia) and Sovol and Sovtol (former USSR and Russia). Composition and proportion of congeners for each trademark are unique and stable that makes possible their identification.

Wide use of PCBs containing products leads to their emission to environment. Contribution of different countries and regions to the total PCB emission is shown on **Figure 2**.

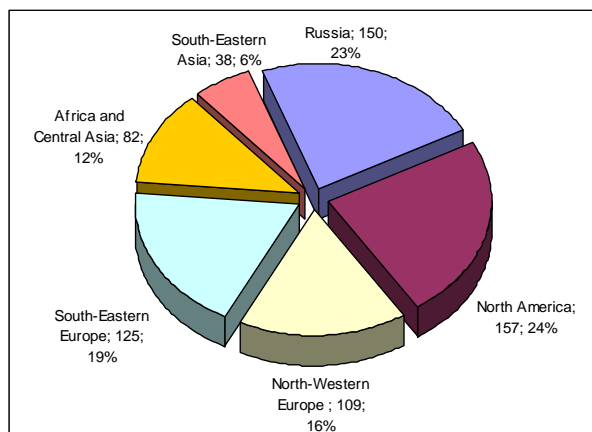


Figure 2. Contribution of different regions of northwestern hemisphere of Earth to world emission of PCBs, tonnes/year [2].

Most world PCB emission falls to the share of North America and Russia, while less part is related to South-Eastern Asia. South-Eastern and North-Western Europe hold an intermediate position. In the aquatic ecosystems PCBs enter through transboundary atmospheric transfer and from the local sources. They possess such specific properties as very low hydrophilicity (pg/L), bioaccumulation and transduction through food web due to high lipophilicity, high resistance to physical, chemical and biological factors ($t_{1/2}$ =years), long-term circulation in environment (tens of years), global occurrence in the environment, and toxicity at extremely low doses ($\mu\text{g}/\text{kg}$ weight). Owing to mentioned above properties PCBs remain in aquatic ecosystems for a long time. In inland freshwater bodies they initially are accumulated in the bottom sediments and then transferred along the food web to the higher trophic levels causing adverse effects in aquatic organisms, fish eating birds and animals, and human. The toxic effects of PCBs include: reproductive impairment, endocrine disruption, immunotoxicity, carcinogenicity, hepatotoxicity, neurotoxicity, lethality.

In 2001 the Stockholm Global International Convention on the ban of production and use of POPs including PCBs was signed and Russia joined this convention in 2002. The use and production of PCBs in the countries signed the convention is now prohibited. However, due to high environmental persistence PCBs still occur in the aquatic ecosystems.

During last 30 years PCBs are in a focus of many ecotoxicological researches. However the environmental monitoring of PCBs in Russia is limited due to deficit of laboratories with appropriate analytical equipment and specialists. By this reason there are a few data concerning different aspects of PCB contamination of freshwater bodies in Russia content in freshwater bodies of Russia. However several regions are studied more than remaining part of Russia. These regions are following: arctic territory, Baikal Lake and central European part. Since bottom sediments are primary link and more conservative element in freshwater ecosystems they reflect most properly ways of entry and spatial distribution of PCBs. The PCB content in bottom sediments of inland waters in Russia and arctic area of other countries are presented on **Figure 3**. These data show that freshwater bottom sediments in Central European part of Russia are more polluted with PCBs. Their contents reach more than 1000 ng/g dry weight there.

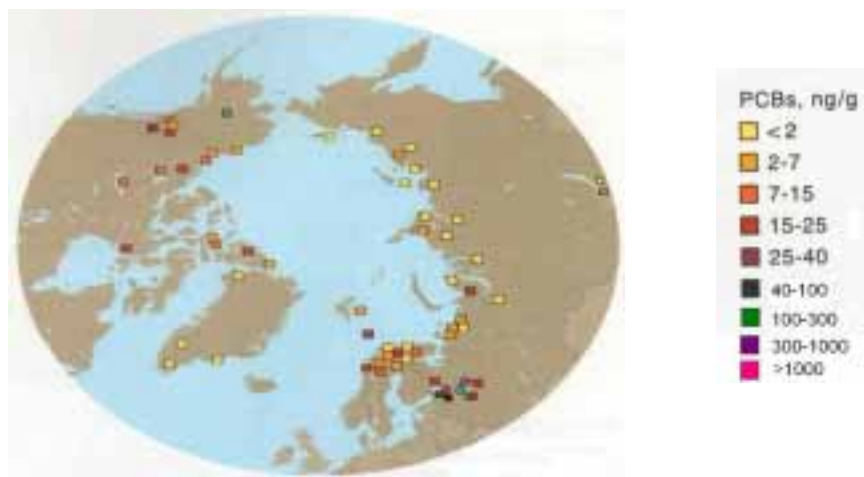


Figure 3. PCBs in lake and river sediments(modified from [3])

In more details PCBs are studied in ecosystem of the Rybinsk Reservoir (58°30' N; 38°20' E), which is one of the largest in the Europe man-made water body (**Figure 4**). The Rybinsk Reservoir was impounded after erection of the dams on the rivers Sheksna and Volga upstream of Rybinsk City.



Figure 4. Location of the Rybinsk Reservoir

It was filled up since 1941 till 1947. Its basic hydromorphometric parameters are following: maximal volume of 25.5 km³, surface square of 4550 km², shallow area of 2553 km², total length of 250 km, length of lake part of 180 km, maximal width of 56 km, maximal depth of 30 m, average depth of 5.6 m, and full water cycle period 1.9 year⁻¹.

Locations of sampling sites and spatial distribution of different types of bottom grounds in the Rybinsk reservoir are presented on **Figure 5**.

The spatial distribution of PCBs in the reservoir is nonuniform. Their highest levels are found in the Sheksna reach at the locations closest to the source of contamination in Cherepovets City while other reaches are only slightly contaminated with PCBs. The PCBs are found in all main compartments of

ecosystem (bottom sediments, benthic invertebrates, fish) of the Rybinsk reservoir except water where they are revealed only occasionally at the most polluted area in Cherepovets City. Due to low hydrophilicity PCBs coming into water are adsorbed on suspended organic and mineral particles, transported along the former river bed at a long distance and settle with them to the bottom accumulating in the bottom sediments (**Figure 5**). Along with increasing the distance downstream from the source of the local contamination the level of PCBs gradually decreases and after 52 km it drop down to the values observed in the remaining parts of the reservoir.

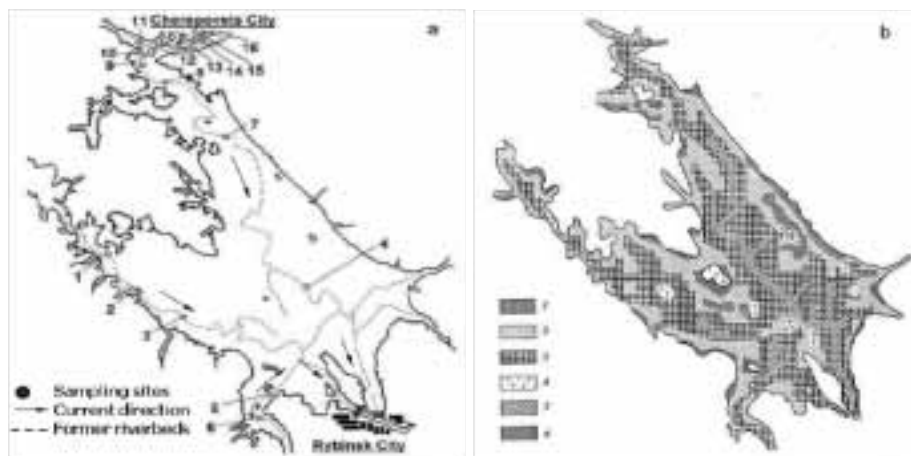


Figure 5. Charts of the Rybinsk Reservoir with localization of sampling stations (a) and spatial distribution of different types of bottom grounds in 1992 (b).

Legends: (a) empty circle and number from 1 to 16 is location and mark of sampling stations, —> current direction, - - - the former riverbed; (b) 1 – transformed basic grounds, 2 – sand, silty sand, 3 – sandy grey silt and clayey dark silt, 4 – peat, 5 – transitional silt, 6 – peaty silt [11].

In the Rybinsk Reservoir the type of a ground, its granulometric content and concentration of total organic material (TOM) plays the most important role in the BSs accumulation capacity for PCBs [3, 8, 12]. At the equal distance from the local source of PCB income into the reservoir, the highest levels of these compounds are found in the various types of clayey grounds with mean diameter of particles < 0.11 mm and TOM content > 7 % confined to sunken river channels and situated at depths > 8 m (**Figure 6**).



Figure 6. Locations of Sheksna reach transections for sampling the bottom sediments.

Strong correlation of PCB content with mean diameter of particles ($r = -0.93$) and TOM content ($r = 0.88$) is observed (**Table 1**).

The patterns of PCB distribution (**Figure 7**) and homolog composition (**Figure 8**) evidences at least two different sources of these compounds are in the Rybinsk reservoir. In the more polluted area of the reservoir (Sheksna reach) sources of PCB is local industrialization in Cherepovets. The most probable source of PCBs in the other part of the reservoir (Mologa, Volga and Main reaches) is global transboundary transfer that may be contributed by the emissions from the Cherepovets industrialization.

Composition of PCBs accumulated in elements of ecosystem of Sheksna reach mainly consists of tetra-, penta- and hexachlorine substituted homologs (TeCB, PeCB, HxCB) and more fits with Aroclor 1254 or Sovol. In remaining parts of the reservoir PCB profile more corresponds to Aroclor 1248.

In the ecosystem of the reservoir PCB content is increased along food web as follows: water > bottom sediments > benthic invertebrates > benthivorous fish (**Figure 7**). PCB content in benthic invertebrates with short life cycle (chironomids) is lower than in organisms with long life cycle (oligochaets, mollusks). The accumulation of PCBs in the fish liver is markedly higher than in the muscles.

Table 1. Relation of PCB accumulation with ground type

Type of ground	Mean diameter of particles, mm	Total organic material, %	PCB content, $\mu\text{g}/\text{kg}$ dry weight
Sand	0.26	0.6	70
Sand	0.21	3.6	90
Silty sand	0.12	3.5	210
Sandy silt	0.11	7.1	330
Clayey silt	0.06	22.4	510
Clayey silt	0.03	25.6	580
Peaty silt	0.07	42.4	550
Coeff. Corr., $r, P < 0.01$	-0.93	0.88	-

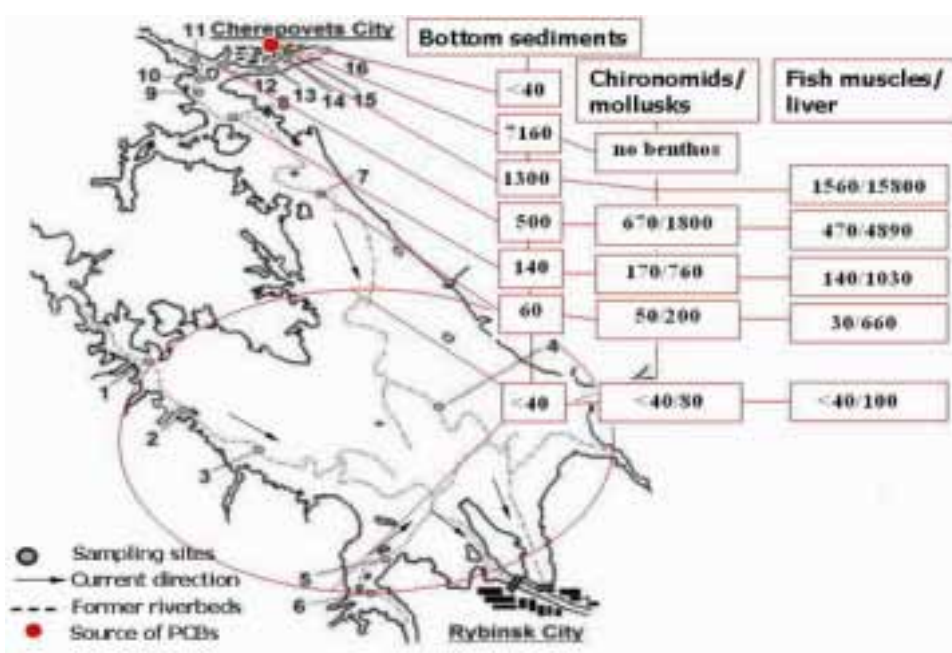


Figure 7. PCB content in sediments ($\mu\text{g}/\text{kg}$ dry weight), benthos and benthivorous fish ($\mu\text{g}/\text{kg}$ wet weight) in different sites of the Rybinsk reservoir

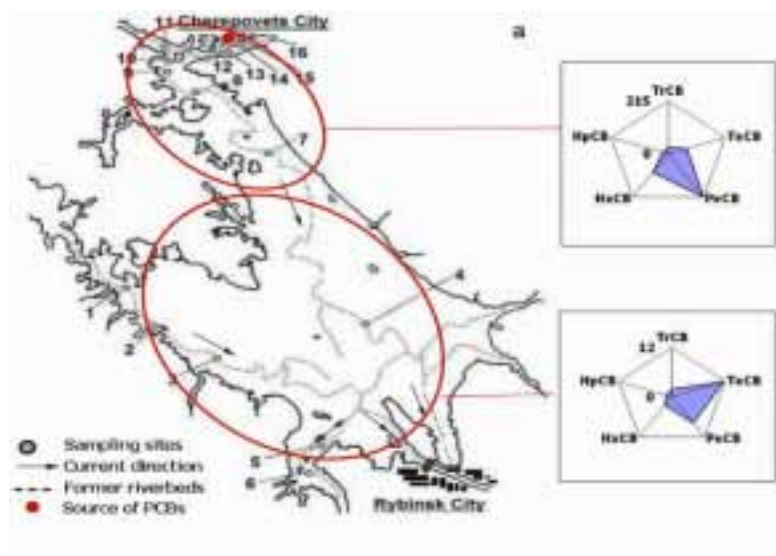


Figure 8. Patterns of PCB homologues in bottom sediments of the Rybinsk reservoir.

In the muscles of benthivorous fish, bream (*Abramis brama* L), from the Rybinsk Reservoir five most toxic PCB congeners (105, 118, 156, 157, and 167) with established toxic equivalence factors (WHO-TEFs) were found. In the Sheksna reach, more polluted area of the reservoir, the sum dioxin toxic equivalent (TEQ) values in the bream muscles based upon the contents of these congeners reach 1.42 ng TEQ/kg w.w. when total PCB content is minimal (50 µg/kg w.w). This value is approximately 2 times higher than the safety level for consumers. It is necessary to note that value are determined without most toxic PCB congeners (126, 169), which caused more than half of sum TEQ values. The Canadian guidelines for the residual levels of PCBs harmful for the consumers calculated with respect to WHO-TEFs of individual congeners are 0.79 ng TEQ /kg w.w. [13].

The work was supported by RFBR grant # 08-05-00805 and partly by Government of Russian Federation grant #11.G34.31.0036.

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Appendix I: Minutes from the 27th ICP Waters Task Force meeting

CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION

Working Group on Effects

International Cooperative Programme on Assessment and Monitoring of the Effects of Air Pollution on Rivers and Lakes

MINUTES

of the twenty-seventh meeting of the Programme Task Force held in Sochi, Russia, October 19-21, 2011

1. The meeting of the International Cooperative Programme on Assessment and Monitoring of the Effects of Air Pollution on Rivers and Lakes (ICP Waters) was attended by 22 experts from the following Parties to the Convention on Long-range Transboundary Air Pollution (CLRTAP): Armenia, Croatia, the Czech Republic, Estonia, Finland, Germany, Latvia, Norway, Poland, Russian Federation, Spain, Sweden, Switzerland, and the United Kingdom. In addition representatives for ICP Integrated Monitoring participated. From outside the Convention representatives from the EU projects WISER and BIOFRESH and from the Tyumen State University and V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry (RAS) Geokhi Ran participated. The list of participants is attached as **Annex II**.

Introductions

2. Ms. TI Moiseenko, Professor, V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry of RAS, Russia warmly welcomed all participants to the ICP Waters meeting in Sochi. Ms N. Gegechkorishe (Russia) also gave general information about the meeting and excursion.
3. Ms. B. Kvaeven (Norway), Chair of the Programme Task Force, thanked Ms. Moiseenko for the opening speech and the warm welcoming words, and for inviting us. Then she welcomed all participants to the 27th Task Force Meeting of ICP Waters in Sochi. New representatives from Germany and Poland were introduced, together with a representative from Armenia and a representative from the EU projects WISER and BIOFRESH. Participants from Tyumen State University and V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry (RAS) were also introduced to the group.
4. The Task Force adopted the agenda of the meeting (**Annex III**).
5. Ms. B. Kvaeven (Norway) reported from the Working Group on Effects (WGE). An overview was given of the organization and all activities under WGE.

Reports from the ICP Waters Programme activities 2009/2010

6. Ms. BL Skjelkvåle (Norway) reported on recent achievements from the ICP Waters activities in 2010/2011. She gave a résumé of the main results from the last TF meeting, showed the aims of the Programme and described its main activities. The

status of participation and data collection as of October 2011 is shown **Annex IV**. The participation in the Task Force meeting is declining slightly, but the number of sites for which data are delivered is stable or slightly increasing. New data for sites both in Austria and Ireland will be included this year. Participation in the chemical intercomparison and biological intercalibration is stable.

7. Ms. BL Skjelkvåle (Norway) provided information on the most important 2010 and 2011 publications presenting the results of ICP Waters. The following documents were mentioned:
 - **ICPW 101/2010**. Nutrient enrichment effects of atmospheric N deposition on biology in oligotrophic surface waters – a review.
 - **ICPW 103/2010**. Biological intercalibration: Invertebrates 1410.
 - **ICPW 104/2010**. Proceedings of the 26th meeting of the ICP Waters Programme Task Force in Helsinki, Finland, October 4 – 6, 2010.
 - **ICPW 105/2011**. ICP Waters Programme Manual
 - **ICPW106/2011**. Trends in precipitation chemistry, surface water chemistry and aquatic biota in acidified areas in Europe and North America from 1990 to 2008.
 - **ICPW 107/2011**. Intercomparison 1125: pH, Cond, HCO₃, NO₃-N, Cl, SO₄, Ca, Mg, Na, K, TOC, Al, Fe, Mn, Cd, Pb, Cu, Ni, and Zn.
8. Ms. BL Skjelkvåle (Norway) reported on representation of ICP Waters in other bodies/meetings under the Convention:
 - Joint expert group on dynamic modelling, Sitges, Spain, October 2011
 - Working group on Effects, Extended bureau, Geneva, February 2011
 - Workshop Coordination Centre for Effects, Bilthoven, April 2011
 - Nitrogen & Global Change 2011, Edinburg April 11-15, April
 - Task Force meeting of ICP IM, Roma, Italy, May 2011
 - Acid Rain conference, Beijing, June 2010
 - Joint EMEP/ Working group on Effects Workshop Geneva September 2011
 - Working group on Effects, Extended bureau meeting, Geneva, September 2011.

The 2011 trend report

9. Ms. BL Skjelkvåle (Norway) gave an introduction to the 2011 trend report, linking this report to the six earlier 3 year reports prepared every third year since 1991, describing the changes in acid sensitive aquatic ecosystems in Europe and North America due to emission reductions.
10. Mr. Ø Garmo (Norway) presented the trend report on surface water chemistry. Data from almost 200 acid-sensitive sites in North America and Europe were presented, many of them with records of over 20 years. Variables considered were: SO₄, NO₃, base cations, ANC (acid neutralizing capacity), alkalinity, pH and DOC (dissolved organic carbon). Trends were calculated for two time spans, 1990-1999 and 1999-2008. For 1999-2008, negative trends for SO₄ dominate but they tend to be less negative than before. Declines in SO₄ in precipitation are generally similar to surface waters. For NO₃, most sites do not have a trend. If there are trends, they are smaller than for SO₄ and can be both positive and negative. For base cations, about half of the sites do not have a trend. Where there are trends, they are usually negative. There is a tendency towards smaller negative trends in 1999-2008. For alkalinity, the majority of sites do not show any trends in 1999-2008. There is a tendency towards smaller positive trends in 1999-2008. For ANC, most sites show positive trends but less so in 1999-2008. For H⁺, most sites show no trend. On a regional basis, negative trends dominate. The trends are not as strong in 1999-2008. For DOC, positive trends dominate by region. Summarizing, in Europe water chemistry trends indicate recovery from acidification but slower than during the

1990s. About 70% of nearly 200 sites show significant declines in non-marine sulphate between 1990-1999 and 1999-2008. Base cations decline almost everywhere, but at a slower rate than before in several regions. About 20% of sites and all regions except 3 show increasing alkalinity and/or ANC in one or both periods. pH is increasing in most regions and more so in Europe than in North America. Most regions and about 15% of sites show increasing levels of organic carbon.

11. Mr. A Fjellheim (Norway) gave a presentation on trends in biological recovery of acidified waters in Europe. The report was prepared on the basis of data from 6 different European countries; The Czech republic (data on zooplankton benthic animals and macrophytes), Finland (data on perch and roach), Germany (data on Number of species, Acid Class, Acidity Index), Norway (data on benthic invertebrates and acidification scores in 5 different regions), Sweden (data from 4 acidified sites and 4 reference sites on littoral invertebrates and phytoplankton together with water chemistry), Switzerland (data on lakes and rivers in canton Ticino). As overall conclusions from the investigations in all six countries it is stated that the national contributions differed considerably in time span of records, targeted groups of biota, and type of variable considered. But some general patterns emerge. Almost all contributions report evidence of recovery for fish, zoobenthos and other biota (algae and water plants) which is attributed to improved water quality. Additionally, other factors like climate might also contribute to explaining temporal variations. Increasing organic acidity related to higher DOC in surface waters could slow down biological recovery. Almost all contributions underline that the present situation is not the endpoint and that more biological recovery can be expected. Recovery from acidification is unlikely to result in the pre-acidification biological community. Comparison with 'reference sites' suggests that species diversity in fully restored aquatic ecosystems could be much higher than is presently observed in aquatic systems that are under recovery from acidification.
12. Ms. BL Skjelkvåle (Norway) presented the main overall conclusions from the trend report. Improvements in acidification of surface waters are related to lower acid deposition, but the reductions of acidifying components in precipitation are larger and quicker than the observed improvements in water chemistry. Increase in pH, alkalinity and ANC indicate that biological recovery can be expected, and biological recovery is documented in many regions in Europe. Full recovery is not documented anywhere. A return to pre-industrial biodiversity is unlikely, and several areas in Europe will never achieve good (non-acidified) water quality with current legislation of emissions of acidifying components. Future reductions of both S and N deposition would be necessary to achieve biological recovery.

The 2012 ICP Waters report: Biodiversity - effects of air pollution and climate change

13. Mr. G Velle (Norway) presented freshwater biodiversity in a changing environment. This will be the main topic of the ICP Waters reporting for 2012. The presentation gave an overview on how to define biodiversity and do biological monitoring in rivers and lakes, evaluate the influencing factors, tipping points, and extinction rate. Last part of the presentation was dedicated to the important question: Can we stop the loss in biodiversity?
14. Mr. M Kernan (UK) introduced the BIOFRESH project (Biodiversity of Freshwater Ecosystems: Status, Trends, Pressures, and Conservation Priorities - <http://www.freshwaterbiodiversity.eu/>). This is an EU funded FP7 project which aims to build a global information platform for scientists and ecosystem managers with access to all available databases describing the distribution, status and trends of global freshwater biodiversity. Additionally the project seeks to predict the responses of freshwater biodiversity and its services to multiple stressors at global, European and local scale. Within the Project Mr. Kernan is looking at freshwater biodiversity patterns in lakes and the drivers of change

which impact on these. He invited all national data holders to contact him if they are interested in becoming involved in collaborative efforts ahead of the next ICP report which will focus on the effects of air pollution and climate change on aquatic biodiversity.

15. Mr.GA. Halvorsen (Norway) presented natural recovery of the benthic invertebrate fauna in river Vikedalselva from 1987 to 2008. Vikedalselva is one of the Norwegian rivers monitored most intensely through the years. The pH (annual mean) and the number of Mayflies have increased in the period from 1987 to 2008. The acidification indexes, the acid sensitive species and the EPT diversity also show a positive development. Water chemistry variables measured are pH, Ca, TOC, SO₄, LAl, ANC. Natural recovery is registered at seven sites while two show uncertain results. The investigation concluded that there has been a natural recovery of the benthic community in most of the stream localities in Vikedal. Most of the recovery has happened after 1998. It is indicated that recovery proceeds faster in running water than in lakes. This may be an effect of the taxonomic groups that are analysed.

Water chemistry

16. Mr. J Fölster (Sweden) gave a presentation on “Swedish lakes - Impact of TOC trends when assessing the acidification status”, looking into trends in water chemistry during declining acid deposition combined with the impact of reference levels for DOC when assessing anthropogenic acidification. 68 soft water lakes with no impact of point sources or intensive land use, were included in the study. The lakes were sampled 4 times per year and trend analyses performed for 1990-1999 and 2000-2010. In conclusions from the study it is noted that chemical recovery from acidification is still proceeding. The choice of pre-industrial reference for DOC is crucial when determining the pre-industrial pH, and because of increasing evidence that human activities do affect DOC concentrations, there is a need to establish reference levels for DOC. The change in DOC over time effects the endpoint of recover, and not only for the purpose of acidification assessment, since DOC is influencing almost every aspect of freshwater quality.
17. Mr. M Kernan (UK) reported that in 2010 a team from UCL with colleagues from other institutes in the UK undertook an analysis of 20 years of monitoring data from the UK Acid Water Monitoring Network (<http://awmn.defra.gov.uk/resources/interpreports/index.php>). This followed up a 15 year report which became an epical issue in Environmental Pollution in 2005. With 20 years of data it was possible to apply new approaches to looking at trends in the data, in particular, non-linear assessments of chemical and biological changes. The report showed that aquatic plant and animal communities are now recovering, as shown by changes in diatom populations, the re-appearance of plant species at many sites, an increase in the abundance of some insect species and the re-appearance of snail populations. Native brown trout, a prominent casualty of acidification, have returned to a few of the most acidified sites and have increased in abundance at some others. Despite the improvement, however, it is clear that biological recovery is still limited and there is a concern that it might not be sustained, falling short of the targets set by the main legislative programmes. There are a number of reasons for this:
 - (i) nitrogen deposition has not declined as dramatically as sulphur deposition;
 - (ii) the soils in the catchments of the lakes and streams have not yet recovered their capacity to neutralise acidity;
 - (iii) many catchment soils are still contaminated by sulphur and nitrogen compounds that continue to be released into surface waters; and
 - (iv) upland waters face new threats, from climate change, changes in land management and in nutrient loading that may confound the recovery or create new problems.

The report was presented in draft form by Mr C. Curtis at the ICP meeting in 2009. Since then UCL has been working on turning the report into a series of papers for a special issue in Ecological Indicators. Further work has also been undertaken on the data with the aim to

- i) relate the biological response explicitly to a series of chemical and climate drivers,
- ii) assess whether different biological groups are responding in the same way to chemical recovery and
- iii) assess whether streams and lakes are exhibiting similar recovery patterns.

This work is mainly being done under the auspices of the EU FP7 project WISER (<http://www.wiser.eu/>). The purpose of WISER is to develop tools for integrated status assessment with a focus on lakes, coastal and transitional waters. The results from the project give some idea about what may be driving the biological change at each site. This is generally combinations of environmental variables and key determinands such as DOC, pH, temperature and precipitation. The preliminary results show that clear patterns change are common to the invertebrates and diatom - the concordance of the responses to the environment in the two biological groups is high given the vast amount of noise in the data sets. Within WISER there is scope for collaboration with national data holders but the Project ends in February so if anyone is interested in using these approaches they should contact Mr. Kernan as soon as possible.

Heavy metals and POPs

18. Mr. C Grigory (Russia) presented “The role of transboundary transport in formation of background content levels of some persistent organic pollutants (POPs) in inland water bodies of Russia”. He gave an introduction to the problems with POPs and then concentrated on PCBs. The goal of the study was to investigate the role of atmospheric transport of PCBs in contamination of the ecosystem of one of the largest European and Russian man-made water bodies, the Rybinsk Reservoir. The reservoir was built in 1941 and filled between 1941 and 1947. The reservoir consists of four reaches impacted by different main rivers supplying it with water; Mologa River, Volga River, Sheksna River and Main reach. The spatial distribution of PCBs in the reservoir is non-uniform. Their highest levels are found in the Sheksna reach at the locations closest to the source of contamination while other reaches are only slightly contaminated with PCBs. There was found two different PCB congeners in elements of the reservoir ecosystem. However both fit with commercial mixture Aroclor 1254 or Sovol. The investigation concluded that PCBs presented in the Rybinsk Reservoir are originated at least from two sources. One of them is local waste waters of Tcherepovets industrial area. Another source more likely is global transboundary atmospheric transport that may be contributed by the local air emissions from the Tcherepovets industrial area.
19. Ms. M Nalbandyan, (Armenia) presented “Air pollution impacts on waters of River Hrazdan”. The watershed of the river Hrazdan is a complex ecosystem, with a significant anthropogenic pollution load, including industrial and agricultural pollution sources, as well as domestic drains. The river is a strategic water artery of the Republic, which requires serious control of the quality and management of the established ecosystem. The river Hrazdan originates from Lake Sevan and flows into the river Araks. Water quality was investigated for major parameters including common ions, heavy metals in very changing concentrations due to industrial and domestic wastewater impacts. Heavy metals were analysed in water, sediments with seasonal sampling through spring, summer and fall and in bur reed for long-term monitoring. The investigation concluded that the waterplant Bur reed actively accumulates the basic set of elements Zn, Ag and Cd from water and reflects qualitative pollution of river waters. The results are based on data from national budget projects, international project NATO/OSCE project N977991 “South Caucasus River Monitoring”, 2002-2008 and different articles. Results from monitoring air quality in the city of Jerevan were also presented with

SO₂, NO_y, NO and dust from 1998 – 2010, based on data of Environmental Impacts Monitoring Centre. Short information about water and air pollution monitoring results from the transboundary River Debed north in Armenia was also presented together with environmental risk, specified by mining and processing activities in the river watershed. Armenia is involved in EMEP air quality monitoring. In the framework of EMEP an automated station was installed in the Amberd area to determine (nature) background contents of air quality parameters.

Dynamic modelling / Critical Loads

20. Ms. BL Skjelkvåle (Programme Center) reported from the ongoing work on Ex post analysis (New name: Impacts report). The WGE task in the revision of the Gothenburg protocol is to use the WGE indicators to illustrate effects of different possible new emission scenarios. Sites from Norway, Czech Republic, Italy, Poland and UK are included in the scenario analysis. The five scenarios for deposition are very similar to one another, and the modelled future ANC levels are very similar among the various scenarios. All represent substantial decreases in deposition for the year 2020 relative to the new base year 2000. At all sites the modelled results indicate that chemical recovery will continue into the future. At all but the most acid sensitive sites acid neutralising capacity (ANC) will increase to levels above the critical level for biological damage. The greatest reductions in deposition are given by the maximum feasible reduction scenario (MFR2020). This is still substantially above the natural background levels of deposition. Additional improvements in water quality can be obtained in the future with emission reductions beyond those envisioned under MFR2020.

ICP Waters and EU Directives

21. Ms. TI Moiseenko (Russia) presented a new project “Water quality formation and ecosystem in Western Siberia under anthropogenic loads and climatic changes”. The aim of the project is to investigate changes in water quality and ecosystem in the Western Siberia under the condition of anthropogenic loads at local and global scale, as well as climate change. The investigation includes analysis of water chemistry and biology, lake sediments, birds, and communities of small mammals. This extensive project started in November 2010 and will run for two years.

Common work for all effect-oriented programmes under the Working Group on Effects (WGE)

22. Ms. BL Skjelkvåle (Norway) reported from the common work for the WGE.
- Impacts analysis; ICP Waters has participated in the ongoing WGE-assessment on the Impacts Assessment (previous name: Ex-post analysis). Data from six countries has been used in the scenario analysis.
 - Outreach to ECCCA-countries; In 2011 ICP Waters has started a cooperation with Armenia.
 - Reporting on trends and indicators; The trend report ICP Waters report 106/2010.
- For a) and c) there have been separate presentations during the meeting.

Intercalibration/intercomparison

23. Ms. BM Wathne (Norway) gave a presentation on the chemical intercomparison 1125. 57 laboratories from 25 countries participated. All usual variables were included, and also

aluminium and TOC. In total 83% of all results were acceptable. The total results this year were the best registered since the intercomparison started, and may be noted as “all time high”. Lead and TOC had the lowest scores. Sodium cadmium, calcium and iron showed the best results. The Task Force agreed to include the same variables in next years chemical intercomparison.

24. Mr J Fölster (Sweden) proposed to use a legend to show when different methods were used to measure the same variable. He also asked if it was possible to mark labs that not usually analysed as low concentrations that are normal in the ICP Waters intercomparison.
25. Mr. A Fjellheim (Norway) gave a presentation of the biological intercalibration. Four laboratories participated in the biological intercalibration 2011. The laboratories identified a high portion of the individuals in the test samples, usually > 95% of the total number of species. The quality of the identification of the different groups was above the level of acceptance for all laboratories. The taxonomic quality was sufficient for stating the acidity index. The average Quality assurance index ranged between 88 and 98, well above the value 80 - indicating good taxonomic work.

Workplan

26. Ms. BL Skjelkvåle (Norway) presented the 2012 Workplan for ICP Waters (**Appendix V**).
27. It was suggested that the Programme Centre look into the possibilities for making available all the water chemistry data through the home page of ICP Waters.

Other Business

28. Ms. BL Skjelkvåle (Norway) announced on behalf of Italy that the Task Force meeting in 2012 would be held in Pallanza, Italy in October 2012.

Adoption of the minutes

29. Ms.B Kvaeven (Norway) thanked the organizing committee, especially Ms. TI Moisenko and Ms. N Gashinka (Russia) for a splendid organization of the Task Force meeting, including the excursion. All participants were thanked for attending the meeting and for contributing to the discussions. The Programme Centre was thanked for the preparation of the scientific programme for the meeting.
30. The Task Force expressed its appreciation to the Programme Centre for its scientific and coordinating work and acknowledged its important contribution to the programme's successful implementation. It again stressed the importance of the continuing contributions of the National Focal Centres and cooperating institutes and the essential role in ensuring the high quality of the overall programme results.

Appendix II: Participants at the ICP Waters 27th Task Force meeting

Armenia

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Appendix III: Agenda for the 27th Task Force meeting of ICP Waters, October 19-21, 2011

1. Introductions

- Meeting welcome;
- *Alexandre D. Shalabodov, Vice-rector for research and innovation, Professor, Doctor of Biology, Tyumen State University, Russia,*
- *Tatyana I. Moiseenko, Professor, V.I.Vernadsky Institute of Geochemistry and Analytical Chemistry of RAS, Russia*
- Adoption of the agenda, *Berit Kvaeven, ICP Waters Chairperson*
- General information about the meeting and excursion, *Tatyana Moiseenko*
- Reports from the Executive Body, Working Group on Effects and work undertaken by the Bureau of Working Group on Effects, *NN*
- Reports from other ICPs

2. Reports from the ICP Waters Programme activities 2009/2010

- Status of the ICP Waters programme, *Brit Lisa Skjelkvåle, Programme centre*

3. The 2011 trend report

- Introductions - *Brit Lisa Skjelkvåle, Programme Centre*
- Trends in water chemistry – *Øyvind Garmo, Programme Centre*
- Biological recovery – *Arne Fjellheim, Programme Subcentre*
- Main overall conclusions from the report – *Brit Lisa Skjelkvåle, Programme Centre*

4. The 2012 ICP Waters report: Biodiversity - effects of air pollution and climate change

- Freshwater biodiversity in a changing environment, *Gaute Velle, Programme subcentre*
- Natural recovery of the benthic invertebrate fauna in the river Vikedalselva from 1987 to 2008. *Godtfred A. Halvorsen and Arne Fjellheim, Programme subcentre*

5. Water chemistry

- Swedish lakes - trends in water chemistry and acidification status. *Jens Følster et al, Sweden*

6. Heavy metals and POPs

- The role of transboundary transport in formation of background content levels of some persistent organic pollutants (POPs) in inland water bodies of Russia. *Chuiko Grigory. Institute for Biology of Inland Waters RAS*
- The mercury bioaccumulation in muscles of a perch from small lakes of the European part of Russia and bioindication of airborne pollution. *Viktor Komov. Institute for Biology of Inland Waters RAS*
- Air pollution impacts on waters of River Hrazdan, *Marine Nalbandyan, Armenia*

7. Dynamic modelling / Critical Loads

- Ex post analysis – report from the ongoing work, *Brit Lisa Skjelkvåle, Programme centre*

8. ICP Waters and EU Directives

- Water quality formation and ecosystem in Western Siberia under anthropogenic loads and climatic changes - Presentation of new project *Tatiana Moiseenko*

9. Common work for all effect-oriented programmes under the Working Group on Effects

- *Report by Brit Lisa Skjelkvåle, Programme centre*

10. Intercalibration/intercomparison

- *Chemical intercomparison, Bente Wathne, Programme centre*
- *Biological intercalibration, Arne Fjellheim, Programme subcentre*

11. Workplan

- *Draft 2012 Workplan, Programme centre*

12. Other Business

- **TF meeting 2012**

13. Adoption of the minutes

Appendix IV: Status of participation in the ICP Waters programme as of October 2011

	Chemical data	Biological data	Participating in chemical intercomparison	Participating in biological intercalibration	Participation in TF meeting 2009-2011
Austria	2010		•		
Armenia					•
Belarus	2010				
Belgium			•		
Canada	2009		•		•
Croatia				•	•
Czech Rep.	2010	•	•	•	•
Estonia	2010		•	•	•
Finland	2010	•	•	•	•
France			•		•
Germany	2010	•	•	•	•
Hungary	2007				
Ireland	2010		•		
Italy	2010		•		•
Latvia	2010	•	•	•	•
Lithuania			•		
Netherlands					•
Norway	2010	•	•	•	•
Poland	2010	•	•		•
Portugal			•		
Romania			•		
Russia			•		•
Slovenia			•		
Spain	2010		•		•
Sweden	2010	•	•	•	•
Switzerland	2010	•	•	•	•
UK	2010	•	•	•	•
USA	2009		•		•
Total	15	9	23	10	19

Appendix V: ICP Water: Workplan for 2011–2012

2012

- Finalize the report on: Biodiversity changes – effects of air pollution and climate change
 - Send out invitation to all TF members about possible contribution to the report – before **1. December 2011**
 - Draft report finish by **1. July 2012**
 - Comments back from Task Force members by **15. August 2012**
 - Finalize the report for the 28th Task Force meeting
- Make a draft report on Ecosystem services of acid sensitive surface waters in Europe and North America
 - Present outline and concept at next Task Force meeting
- Finalize the ICP Waters “Ex-post” analysis of sites from six countries and prepare a report of the work
 - **March 2012**
- Prepare proceedings from the 27th Task Force meeting
 - abstracts (2-6 pages) by **1. December 2012**
- Arrange and report chemical intercomparison 1226
 - in collaboration with all ICPs. **Send out invitations 1 May 2012.**
- Arrange and report biological intercalibration 1612
 - in collaboration with all ICPs. **Send out invitations 1 May 2012.**
- Arrange twenty-eight meeting of the Programme Task Force, tentatively scheduled to be held in autumn 2012, and its reports
- Run the Programme Centre in Oslo and the Subcentre in Bergen, including:
 - maintenance of web-pages
 - maintenance of database
- All Focal centres should submit data to the Programme Centre by **June 15th 2012.**
 - participating in meetings of relevance for the programme and reporting to WGE
- Contribute to the Common Workplan items of the Working Group on Effects
 - Finalize the WGE “Ex-post” analysis (Impacts report) by **February 2012**
 - Other possible items to be announced
- Cooperation with other bodies within and outside the Convention
- Cooperation with ECCCA countries (East Central Caucasus and Central Asian countries)

2013

- Finalize the Ecosystem Service report
- Start a new trend assessment

Appendix VI: Reports and publications from the ICP-Water's Programme

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- Wright, R.F., Helliwell, R., Hruska, J., Larssen, T., Rogora, M., Rzychoń, D., Skjelkvåle, B.L. and Worsztynowicz, A. 2011. Impacts of Air Pollution on Freshwater Acidification under Future Emission Reduction Scenarios; ICP Waters contribution to WGE report. NIVA-report SNO 6243-2011. **ICP Waters report 108/2011.**
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- Hovind, H. 2010. Intercomparison 1024: pH, Cond, HCO₃, NO₃-N, Cl, SO₄, Ca, Mg, Na, K, TOC, Al, Fe, Mn, Cd, Pb, Cu, Ni, and Zn. NIVA-report SNO 6029-2010. **ICP Waters report 102/2010.**
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- Skjelkvåle, B.L., Jenssen, M. T. S. and De Wit, H (eds.) 2009. Proceedings of the 24th meeting of the ICP Waters Programme Task Force in Budapest, Hungary, October 6 – 8, 2008. NIVA-report SNO 5770-2009. **ICP Waters report 96/2008.**
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- Skjelkvåle, B.L., and De Wit, H. (eds.) 2008. ICP Waters 20 year with monitoring effects of long-range transboundary air pollution on surface waters in Europe and North-America. NIVA-report SNO 5684-2008. **ICP Waters report 94/2008.**
- Hovind, H. 2008. Intercomparison 0822: pH, Cond, HCO₃, NO₃-N, Cl, SO₄, Ca, Mg, Na, K, Fe, Mn, Cd, Pb, Cu, Ni, and Zn. NIVA-report SNO 5660-2008. **ICP Waters report 93/2008.**
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Reports before year 2000 can be listed on request.

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