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JOINT CROSS-BORDER ENVIRONMENTAL MONITORING SYSTEM – LESSONS LEARNT AND DEVELOPMENT PLAN OF ECO-BRIDGE PROJECT

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FINAL REPORT

Partners:

ANO Energy Efficiency Centre
Karelian Center for Hydrometeorology and Environmental Monitoring (KarCHEM)
Finnish Environment Institute (SYKE)
Finnish Meteorological Institute
Arbonaut Ltd

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INTRODUCTION

The main idea of ECO-bridge project is related to the accuracy, accessibility and promptness of environmental monitoring data. Another issue is the lack of compatibility of the data obtained by Finnish and Russian researchers, which makes comparison quite difficult.

Another significant problem we are striving to solve within the project is the lack of automated data collection at existing surface water quality observation points that leads to the following consequences:

1. Impossibility of providing the necessary up-to-date information (data) for controlling organisations, federal and regional authorities, other stakeholders and population.
2. Due to the lack of automated equipment for permanent pollution control, the frequency of obtaining data is only once a quarter. Thus, such the frequency of data receipt may cause emergency situations;
3. The population of Karelia, in general, is not sufficiently informed about the water and the air quality. The population does not have the opportunity to receive relevant information quickly and on permanent basis, for example, from Internet resources.

The following partners worked on building a kind of «bridge» between the monitoring systems in Karelia and Finland in the framework of ECO-bridge project:

1. 1. Autonomous non-profit organization Energy Efficiency Centre (ANO EEC), one of the most active non-governmental organizations with experience of working as a coordinator and/or partner in several international projects in the field of energy-efficiency, housing, nature protection, ecology and communal services development.

2. Karelian Centre for Hydrometeorology and Environmental Monitoring (Karelian CHEM), the organisation responsible for the state environmental monitoring system in Karelia. This organization is a part of the All-Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet). The Karelian Centre for Hydrometeorology and Environmental Monitoring has its own state network of monitoring stations

for water objects and the atmosphere in Karelia and the Laboratory for Environmental Monitoring. It provides observations of the state and pollution of the atmosphere, surface water and radioactivity. For today the monitoring network of Roshydromet comprise 28 water objects (21 rivers, 5 lakes and 2 water reservoirs).

SYKE

3. Finnish Environment Institute (SYKE) is a multidisciplinary research and expert institute working under the Ministry of the Environment and Ministry of Agriculture and Forestry in Finland. SYKE's Freshwater Centre is responsible for the monitoring and assessment of the quantitative and qualitative variations of water resources, the status of surface and ground water bodies and various biological variables. The Laboratory Centre fulfils SYKE's function as the national reference laboratory in the environmental field under the Environmental Protection Act. Its duties include providing external quality assessments (proficiency testing), standardization of methods, as well as training and expert support for the authorities and other parties within the environmental field.

FINNISH METEOROLOGICAL INSTITUTE

4. The Finnish Meteorological Institute (FMI) is the official expert authority on air quality in Finland. The FMI is a weather service and research institute working under the Ministry of Transport and Communication of Finland. The FMI operates meteorological, air quality, radioactivity and space weather observation networks, delivers meteorological service to the society and conducts research in these fields of science.

arbonaut

5. Arbonaut Ltd., an IT company that together with SYKE has developed an open source web GIS platform, named Vesinetti, which provides an information infrastructure for operational and interactive use and exchange of data and models, including estimation of nutrient loading as well as its ecological impacts and cost-efficiency of management measures.

1 ACHIEVEMENTS OF THE ECO-BRIDGE PROJECT IN WATER AND AIR QUALITY MONITORING

1.1 COMPARISON OF MEASUREMENT METHODS AND TOOLS

1.1.1 Joint intercalibration in the Tohmajoki river on the Russian side

Sampling and methods of analysis

Interlaboratory comparative tests (intercalibrations) were carried out during 24.01-28.02.2019. Participants were analytical laboratories of Savo-Karjala Environment laboratory in Kuopio (Finland) and in Joensuu (Finland), and KarCHEM laboratory of environmental pollution (the Republic of Karelia, Russia). In sampling Finnish participants were from Finnish Environment Institute (SYKE).

Primary objective was to compare the analytical methods used by the participating laboratories and how comparable are results of water quality variables. Samples were taken together with same method. Besides, synthetic control samples prepared by both partners were analyzed without knowing the original concentration.

The grab sampling took place in Russia at a cross-border watercourse Tohmajoki river by representatives of KarCHEM and SYKE on 23.01.2019. Joint water sampling of natural river water was performed according to the Russian guideline 52.24.309-2016 «Arrangement and holding of routine observations of the state and pollution of land surface waters».

The river was opened with an ice-drill and the hole was cleaned from the ice with an enamel strainer. The sample was taken with a five-liter, enameled bucket and carried to a car (at a distance of about 50 meters) where the sample was divided into sample bottles.

The following variables were measured from the split water sample:

Nutrients

- NH4-N (ammonium nitrogen)
- PO4-P (phosphate phosphorus)
- NO2-N+NO3-N (nitrate nitrogen and nitrate nitrogen as sum or separately)
- Total P (total phosphorus)
- Total N (total nitrogen)

Metals

- Total Fe (total iron)
- Total Mn (total manganese)

Suspended solids

- Mass concentration of solids in a liquid, normally determined by filtration or centrifuging and then drying all under specified conditions.

Participants used same standard methods that they are using in daily operations (Table 6). KarCHEM used test methods that they have certificate for (Accreditation certificate RA.RU.511024 of 12.08.2015). Savo-Karjala Environment laboratory is accredited (SFS-EN ISO/IEC 17025:2005) and uses SFS-ISO standard methods.

Preparation and exchange of control samples with fixed concentrations of ingredients and schemes for analyses:

- Control samples of KarCHEM were made from the standard (state-approved) samples corresponding the measured ingredients.
- The lists of control samples with labels

(number of sample) and assigned levels of ingredients are presented in tables 2 and 3.

- The participants of intercalibration exchanged control at a work meeting in Sortavala on 23.01.2019.
- The results of qualitative chemical analyses performed by both laboratories participating in intercalibration are presented in tables 4 and 5.

Results and conclusions

The full procedure for intercalibration of the analysis of all control samples was performed by laboratories of KarCHEM and SAVO-Karjala Environmental Research laboratory in Kuopio.

Separate analyses for NH4-N and NO2-N+NO3-N was performed in SAVO-Karjala Environmental Research laboratories in Kuopio and Joensuu. KarCHEM analysed NH4-N and NO3-N separately.

Unsatisfactory comparability of measurement was revealed for several ingredients (Table 1).

Significant discrepancies in measurement of the content of manganese, suspended solids, ammonium nitrogen and phosphorus were revealed.

The differences in results are partly linked to the differences of sample preparation and analysis methods. For instance, suspended solids were filtered from water using different types of filters: in KarCHEM 0.45 µm pore size filter and in Savo-Karjala glass fiber filter was used. The latter allows small particles, with size greater than 0.45 µm, wash away from analysis.

A result of manganese analyzes depends essentially of how much Mn degrades from particles in natural water. There is no difference between results of control samples (Table 5) but results of Mn concentration in river water differ remarkably (Table 1).

Control samples

Control samples prepared by KarCHEM for Savo-Karjala were provided with enclosed instructions for preparation of control samples from basic solutions. Nevertheless, this proposed procedure was not implemented by laboratories Kuopio and Joensuu that analyzed basic solutions.

The results of the analysis of the control samples can be considered satisfactory for most parameters taking into account the confidence intervals of margins of error set for the analysis methods used.

Due to the fact, that the laboratory of Kuopio did not dilute the control samples with distilled water according the instructions of KarCHEM, all the other parameters (except PO4-P) were on the same level than the non-diluted Russian control samples. Result of PO4-P was clearly higher than the assigned concentration in the non-diluted sample (Table 4).

Analytical results of synthetic samples prepared by Savo-Karjala are in Table 5. Total P result of KarCHEM is clearly higher than the original concentration. Total Fe result of KarCHEM is lower than the original result.

Recommendations

It is recommended that KarCHEM would take apart to Proftest organized by SYKE laboratory. All Finnish laboratories take part to these tests and sometime also laboratories in other countries. Annual schemes of proficiency tests and intercomparison tests are published on SYKE website

Differences in sample preparation and analytical methods of natural water in Finnish laboratories and KarCHEM should be studied in more detail.

KarCHEM does not yet have an analytical methodfor total nitrogen. It is a basic water quality variable and important indicator for nutrient status of natural waters and thus it is very recommended that KarCHEM would have it.

Fig. 1 Sampling at Tohmajoki River.

Table 1. Results of analysis of a split sample of surface water of Tohmajoki river

Variable	Kuopio		Joensuu		KarCHEM		
	Result µg/l	Margin of error %	Result µg/l	Margin of error %	Result µg/l	Margin of error %	Confidence interval of the result µg/l
NH4-N	41.7	13	43.4	12	24± 10	41	14 - 34
PO4-P	9.3	12	-	-	13 ± 3	23	10 - 16
NO2-N+NO3-N	210	8	213	15	242 ± 64	26	178 - 306
Total P	22.6	15	-	-	34 ± 6	17	28 - 40
Total N	688	15	-	-	-	-	-
Total Fe	1130	10	-	-	1420 ± 150	10	1270 - 1570
Total Mn	27.6	10	-	-	99 ± 13	13	86 - 112
Suspended solids*)	1080	8	-	-	6950 ± 400	57	2950 - 10950

** Suspended solids: Savo-Karjala used glass fiber filter. It is not possible to give the exact pore size of that filter type. Karelia CHEM used filter with pore size 0.45 µm.*

Table 2. Control (synthetic samples) prepared by KarCHEM

Elements	Used state standard reference sample (SSRS) or reagent	Range for diluted sample µg/l	Bottle number	Assigned concentration in the non-diluted sample µg/l
NH4-N	SSRS 7747-99	10 - 20	1	9940
PO4-P	SSRS 7748-99	3 - 10	2	7990
NO2-N	SSRS 7753-2000	180 - 230	4	-
NO3-N	SSRS 820-2000	180 - 230	5	10050
Total P	SSRS 7241-96	10 - 20	3	9800
Total Fe	SSRS 7835-2000	1300 - 1500	6	50000

Table 3. Control (synthetic) samples prepared by SAVO-Karjala Environmental Research

Elements	Range µg/l	Assigned concentration µg/l
NH4-N	10 - 20	18
PO4-P	3 - 10	9
NO2-N+NO3-N	180 - 230	200
Total P	10 - 20	15
Total N	550 - 650	600
Total Fe	1300 - 1500	1400
Total Mn	100 - 150	130

Table 4. Results of analysis of a control (synthetic sample) prepared by KarCHEM

Elements	Assigned concentration in the non-diluted sample µg/l	Kuopio		Joensuu		Assigned concentration in the diluted control sample, µg/l	KarCHEM*	
		Result µg/l	Margin of error %	Result µg/l	Margin of error %		Resultµg/l	Margin of error µg/l
NH4-N	9940	9400	12	9710	10	20	23	±10
PO4-P	7990	9490	10	Not analyzed	-	10	10	±4
NO2-N+NO3-N	10050	11300	8	11000	15	200	180	±50
Total P	9800	9770	12	Not analyzed	-	14.7	13.4	-
Total N	No control sample	Not analyzed		Not analyzed	-	-	-	-
Total Fe	50000	50700	10	Not analyzed	-	1500	1590	±160
Total Mn	10000	10000	10	Not analyzed	-	150	130	±17

** Control samples prepared by KarCHEM for SYKE were provided with enclosed instructions for preparation of control samples from basic solutions. This proposed procedure of diluting the samples was not implemented by laboratories Kuopio and Joensuu that analyzed basic solutions. KarCHEM followed the instructions when analyzing the samples.*

Table 5. Results of analysis of a control (synthetic sample) prepared by SAVO-Karjala Environmental Research

Elements	Assigned concentrations µg/l	Kuopio		Joensuu		KarCHEM		
		Result µg/l	Margin of error %	Result µg/l	Margin of error %	Result in µg/l	Margin of error %	Confidence interval of the result µg/l
NH4-N	18	16.8	13	19.1	26	22	45	12 - 32
PO4-P	9	7.9	13	Not analyzed	-	10	…	6 - 14
NO2-N+NO3-N	200	205	8	202	15	223	26	164 - 282
Total P	15	15.8	15	Not analyzed	-	25	24	19 - 31
Total N	600	625	10	Not analyzed	-	Not analyzed	-	-
Total Fe	1400	1390	10	Not analyzed	-	1260	11	1120 - 1400
Total Mn	130	136	8	Not analyzed	-	127	13	111 - 143

Table 6. List of water quality variables and their analytical methods used by laboratories participated in intercalibration

Indicated elements	Laboratory	Methods	Method range/ detection limit 1)	Sampling, preservation and storage of samples			
				Sample bottle	Preservation and storage	Analysis done in	Analysis done within
Ammonium nitrogen (NH4)+	KarCHEM	РД 52.24.383-2005	0.02-1.0 mg/dm3	Polymeric material or glass	1. No preservation 2. Preserving at pH<2 3. Freezing down to -20 – -40°C	Labora-tory	1. 6 h 2. 3-4 days 3. Conti-nuous
	Savo-Karjala	In-house method, fluorometric, CFA analyser (based on Skalar analytical method no. A157/158)	5 µg/l	Polymeric material	No preservation	Labora-tory	24 h
Phosphate phosphorus (PO43-)	KarCHEM	РД 52.24.382-2006, paragraph 11	0.010-0.2 mg/dm3	1.-2. Glass 3. Polymeric material	1. No preservation 2. Storage at 3-6° C with addition of chloroform 3. Freezing down to -20 – -40°C	Labora-tory	1. 4 h 2. 3 days 3. Conti-nuous
	Savo-Karjala	In-house method, colorimetric, FIA analyser (based on SFS-EN ISO 15681-1:2005, Part 1.)	2 µg/l	Polymeric material	No preservation		24 h
Nitrite nitrogen (NO2)	KarCHEM	РД 52.24.381-2006	0.01-0.25 mg/dm3	Polymeric material or glass	1. No preservation 2. Storage at 3-6° C 3. Freezing down to -20 – -40°C	Labora-tory	1. 2 h 2. 24 h 3. Conti-nuous
	Savo-Karjala	SFS-EN ISO 13395:1997	2 µg/l	Polymeric material	No preservation	Labora-tory	24 h

Indicated elements	Laboratory	Methods	Method range/ detection limit 1)	Sampling, preservation and storage of samples			
				Sample bottle	Preservation and storage	Analysis done in	Analysis done within
Nitrate nitrogen (NO3)	Kar CHEM	M-02-1805	0.080-4.0 mg/dm3	Polymeric material or glass	No preservation	Labora-tory	8 h
	Savo-Karjala	SFS-EN ISO 13395:1997	2 µg/l	Polymeric material	No preservation	Labora-tory	24 h
Total phosphorus (mineral and organic)	KarCHEM	РД 52.24.387-2006	0.02-0.4 mg/dm3	1.-2. Glass 3. Polymeric material	1. No preservation 2. Freezing down to -20 – -40°C 3. Freezing down to -20 – -40°C	Labora-tory	1. 4 h 2. 3 days 3. Conti-nuous
	Savo-Karjala	SFS-EN ISO 15681-2:2003	5 µg/l	Polymeric material	1. No preservation 2. Preserva-tion with H2SO4	Labora-tory	1. 24 h 2. 7 days
Total nitrogen	Savo-Karjala	SFS-EN ISO 11905-1:1998	50 µg/l	Polymeric material or glass	1. No preservation 2. Freezing down to -20 – -40°C	Labora-tory	1. 24 h 2. 1 month
Total Fe	KarCHEM	M-02-1109	0,0020-1,0 mg/dm3	Polymeric material	Preservation with HNO3 at pH< 2	Labora-tory	1 month
	Savo-Karjala	SFS-EN ISO 17294-1 (2006) and 17294-2 (2016) ICP-MS (low concentrations) 2)	1 µg/l	Полимерный материал	Preservation with H2SO4	Labora-tory	6 months

Indicated elements	Laboratory	Methods	Method range/ detection limit 1)	Sampling, preservation and storage of samples			
				Sample bottle	Preservation and storage	Analysis done in	Analysis done within
Total Mn	KarCHEM	M-02-1109	0,0050-50 mg/ dm3	Polymeric material	Preservation with HNO3 at pH< 2	Labora-tory	1 month
	Savo-Karjala	SFS-EN ISO 17294-1 (2006) and 17294-2 (2016) ICP-MS (low concentrations)2)	0.5 µg/l	Polymeric material	Preservation with H2SO4	Labora-tory	6 months
Suspended solids	KarCHEM	РД 52.24.468-2005. paragraph 10.1, filter size 0.45 µm	5.0-100 mg/dm3	Polymeric material or glass	Cool down to 3-6°C	Labora-tory, right after samp-ling	7 days
	Savo-Karjala	SFS-EN 872:2005, glass fibre filter was used.	1 mg/l	Polymeric material	Cool down to 2-8°C	Labora-tory	2 days

1) Accredited method range in KarCHEM lab, the limit of determination in Savo-Karjala lab

2) SFS-EN ISO 11885 (2009) ICP-OES for high concentrations

Guidelines in Russia: International standard GOST-31861-2012, P 52.24.353-2012

Guidelines in Finland: Reports of the Finnish Environment Institute 22/2016. Quality recommendations for data entered into the environmental administration's water quality registers: Quantification limits, measurement uncertainties, storage times and methods associated with analytes determined from waters. TeemuNäykki and TeroVäisänen (eds.).

In Finland: transportation cool down to 2-8°C, storage in laboratory -1 - 5ºC [SFS-EN ISO 5667-3]

1.1.2 One-line water quality measurements on the Russian side

The basis of the organizational structure of the environmental pollution monitoring system is formed by the observation points on rivers, lakes and reservoirs. They perform the monitoring of pollution of water bodies in a discrete mode, with a frequency set in accordance with the category of an observation point.

On the territory of the Republic of Karelia, there are 28 hydrochemical monitoring points, including 26 observation points of the 4-th category, where sampling is performed 4 times a year in the main hydrological seasons and 2 observation points of the 3rd category with monthly sampling. A map of the location of the observation points and more detailed information about each of the observation points is provided below:

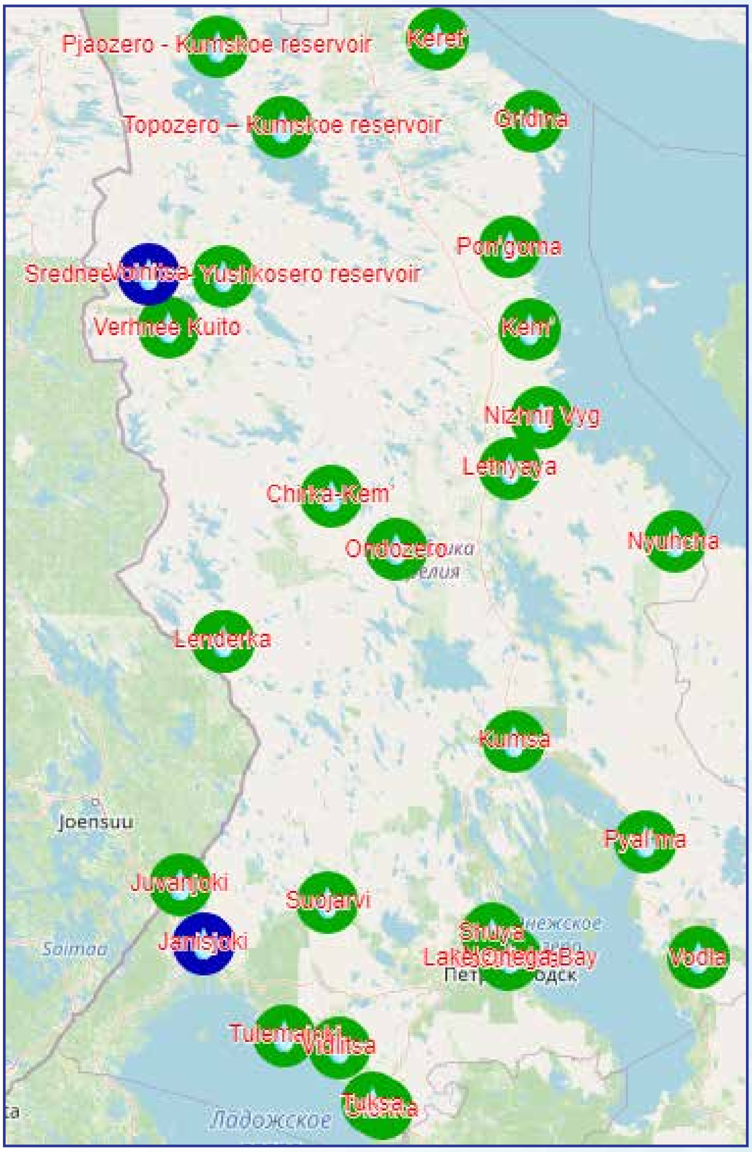


Fig. 2 Observation network in the Republic of Karelia.

Table 7

Waterbody	Name of the observation point	Coordinates	Sampling frequency	Monitored parameters
Keret'	bridge over the river	N66o16'53" E33o35'01"	4 times a year	Nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, phosphates, total phosphorus, gross phosphorus, organic phosphorus, silicic acid, total iron, calcium, sodium, potassium, magnesium, hydrogen carbonate, sulphates, chlorides, hardness, total dissolved solids, copper, lead, cadmium, chrome, BOD5, COD, color, oil products, anionic surfactant, suspended solids, pH, carbon dioxide, dissolved oxygen, oxygen saturation, transparency, smell, electric conductivity

Gridina	Gridino	N65°54’50” E34°38’6”	4 times a year	Nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, phosphates, total phosphorus, gross phosphorus, organic phosphorus, silicic acid, total iron, calcium, sodium, potassium, magnesium, hydrogen carbonate, sulphates, chlorides, hardness, total dissolved solids, copper, lead, cadmium, chrome, COD, color, oil products, anionic surfactant, suspended solids, pH, carbon dioxide, transparency, smell, electric conductivity
Pon’goma	Pon’goma	N65°19'49.1" E34°23'48.6"	4 times a year	
Kem’	Kem’	N64°56'39.3" E34°35'55.1"	4 times a year	Nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, phosphates, total phosphorus, gross phosphorus, organic phosphorus, silicic acid, total iron, calcium, sodium, potassium, magnesium, hydrogen carbonate, sulphates, chlorides, hardness, total dissolved solids, copper, lead, cadmium, chrome, BOD5, COD, color, oil products, anionic surfactant, suspended solids, pH, carbon dioxide, dissolved oxygen, oxygen saturation, transparency, smell, electric conductivity
Chirka-Kem’	Andronova Gora	N64°08'34.1" E32°22'54.9"	4 times a year	
Nizhnij Vyg	Belomorsk	N64°31’24” E34°44’51”	4 times a year	
Verhni Vyg	Ogorelyshy	N62°59'59.9" E35°41'36.8"	4 times a year	
Letnyaya	Letnij-1	N64°16'39.7" E34°23'21.6"	4 times a year	
Nyuhcha	Nyuhcha	N63°55'02.0" E36°13'55.2"	4 times a year	
Lenderka	Lendery	N63°25'23.8" E31°10'37.5"	12 times a year	
Juvanjoki	Vyartsilya	N62°10'51.8" E30°42'07.1"	4 times a year	
Tulemajoki	Salmi	N61°22’38” E31°52’01”	4 times a year	
Vidlitsa	Bol’shie Gory	N61°18'55.3" E32°28'26.3"	4 times a year	
Olonka	Olonets	N60°58’53” E32°57’10”	4 times a year	
Tuksa	Tuksa	N61°00'51.0" E32°50'31.9"	4 times a year	
Lososinka	Petrozavodsk	N61°46'53.0" E34°22'10.9"	12 times a year	
Neglinka	Petrozavodsk	N61°47'52.8" E34°22'06.6"	4 times a year	
Shuya	Shuya	N61°55'10.4" E34°11'58.7"	4 times a year	
Kumsa	Medvezh’egorsk	N62°55'09.8" E34°26'26.9"	4 times a year	
Pyal’ma	Pyal’ma	N62°24’4”, E35°53’46”	4 times a year	

Vodla	Pudozh	N61°47'28.5" E36°29'46.6"	4 times a year	
Pjaozero - Kumskoe reservoir	Zasheek village	N66°15'08.8" E31°06'10.2"	4 times a year	
Verhnee Kuito	Voknavolok village	N64°57'05.0"N 30°33'47.2"E	3 times a year	
Srednee Kuito – Yushkosero reservoir	Kalevala settlement	N65°11'41.2"N 31°11'17.5"E	3 times a year	
Ondozero	Ondozero village	63°52'30.6"N 33°06'59.5"E	3 times a year	Nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, phosphates, total phosphorus, gross phosphorus, organic phosphorus, silicic acid, total iron, calcium, sodium, potassium, magnesium, hydrogen carbonate, sulphates, chlorides, hardness, total dissolved solids, copper, lead, cadmium, chrome, COD, color, oil products, anionic surfactant, suspended solids, pH, carbon dioxide, transparency, smell, electric conductivity
Topozero – Kumskoe reservoir	Kesten'ga settlement	65°53'05.6"N 31°50'04.6"E	4 times a year	Nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, phosphates, total phosphorus, gross phosphorus, organic phosphorus, silicic acid, total iron, calcium, sodium, potassium, magnesium, hydrogen carbonate, sulphates, chlorides, hardness, total dissolved solids, copper, lead, cadmium, chrome, BOD5, COD, color, oil products, anionic surfactant, suspended solids, pH, carbon dioxide, dissolved oxygen, oxygen saturation, transparency, smell, electric conductivity
Lake Onega Bay	Petrozavodsk city	N61°47'27.1"N 34°23'17.9"E	4 times a year	
Suojarvi	Suojarvi town	62°05'03.9"N 32°21'03.5"E	4 times a year	

The main task of the pollution monitoring system is to inform about water quality for making management and environmental decisions. The greatest damage to the ecological state of water bodies is caused by emergency and salvo (and sometimes illegal) discharges of polluted wastewater. Untimely detection of different extreme situations, imprompt surveys and forecasting of the movement of the pollution load prevent the adoption of urgent water protection measures and lead to significant economic and environmental losses. Therefore in addition to traditional monitoring methods, automated remote measurement tools are becoming increasingly widespread globally. In case of automatic monitoring, measurement results can be immediately updated on websites online, making it possible to track the state of the water body in real time.

In Russia, automation of hydrochemical observations has not yet become widespread. To achieve the goals set by the project, one of the main objectives was to study modern monitoring methods, first and foremost the possibility of automating hydrochemical observations. As the results of the project have shown, they present a promising basis for ensuring the effective operation of the Russian-Finnish environmental monitoring system.

Besides improving the efficiency of obtaining primary data, the use of automatic stations minimizes errors related to the human factor and increases the accuracy of estimates of average concentrations over a long period of time.

To achieve the goals set by the project, one of the main objectives was to study modern monitoring methods, first and foremost the possibility of automating hydrochemical observations. As the results of the project have shown, they present a promising basis for ensuring the effective operation of the Russian-Finnish environmental monitoring system.

That is the reason why the project's efforts were primarily focused on studying and implementing automation of hydrochemical observations. As the results of the project showed, this is the perspective for ensuring the effective operation of the environmental monitoring system.

Table 8

Site where the equipment is installed: multiparameter sensors for control of the quality of surface natural water and data collection center

№	Complex	Site	Coordinates	Site description
1	AHCC 1	Hydrological post 1on the river Olonka, Verhovye	60°58′53″N, 32°57′10″E	Right bank of the Olonka river
2	AHCC 2	Hydrological post 1on the river Uuksunjoki in Uuksu village	61°30′11″N, 31°35′57″E	Right bank of the river Uuksunjoki
3	AHCC 3	Hydrological post 1 on the river Tulemajoki, Salmi settlement	61°22′38″N, 31°52′01″E	Right bank of the river Tulemajoki
4	Data collection and processing center	Karelian Center for Hydrometeorology and Environmental Monitoring		Communication center, 3 Varkaus str., Petrozavodsk

The sensors monitor the following parameters:

- pH
- oxygen saturation
- dissolved oxygen
- electric conductivity
- water temperature

Analysis of the results and convergence of average values obtained from multiparameter probe with the results of analyses of manual samples of natural surface water in KarCHEM lab revealed insignificant divergence of results for all five parameters listed above.

Implementation

During the implementation of the project, partners conducted a number of activities to enhance exchange of experience in joint sampling and inter-laboratory comparison tests (intercalibration). Partners got acquainted with devices analysis methods used. The Russian Federation and Finland, as a rule, use similar instruments for regular sampling.

Various types of equipment designed for automatic hydrochemical monitoring were considered and tested by KarCHEM experts. Equipment and software were offered by the following companies: EHP-Tekniikka Ltd, Endress+Hauser, SEBA Hydrometrie GmbH&Co and YSI inc, Hydrolab.

The KarCHEM project staff visited and got acquainted with the equipment of Poltraf LLC (https://poltraf.ru/) and Analit products LLC (http://analit-spb.ru/).

Even prior to procurement of equipment, a trial operation of the digital multi-parameter sensor provided by Poltraf LLC was conducted and a technical report was made on the testing performed.

In the training course in Finland in the Helsinki region, the KarCHEM specialists got acquainted with the on-line water quality monitoring station at the River Vantaanjoki. The station is equipped with s::can nitro::lyser sensor (www.s-can.at/products/spectrometer-probes), which was used to measure NO3-N, turbidity and organic carbon with hourly time step.

The water level was measured with a pressure sensor also with hourly time step. The positive experience of the Finnish colleagues was useful for the specialists of the KarCHEM and in the Russian Federation they found official distributors of s::can Messtechnik GmbH - LLC «Ecostroy-Project».

Fig.3 Sampling in Finland

Fig.4 Getting familiar with the equipment at Poltraf LLC

The supplier was invited to participate in the tender held as part of the ongoing project for the supply of automatic hydrochemical equipment.

On June 28, 2019, a tender was held for the purchase of automatic hydrochemical complexes (AHCC) for equipping 3 hydrological posts at largest tributaries of Lake Ladoga, located in the Republic of Karelia. The maximum contract price set by KarCHEM was 10,947,666.67 rubles. Applications for participation were submitted by two companies: Hydrotech-Engineering LLC and Poltraf LLC. Both participants were admitted to the tender. According to the results of the auction, the price reduction was 2,923,479.28 rubles. Winner of the auction was Hydrotech-Engineering LLC.

Following the contract signed, Hydrotech-engineering LLC has installed automatic hydrochemical complexes at hydrological posts HP-1 the Olonka river – the town of Olonets, HP-1 the Tulemajoki river - village of Salmi and HP-1 the Uuksunjoki river – Uuksu settlement. All equipment was installed in accordance with the provisions of the

Fig.5 Work meeting at Analyt products LLC

Fig.6 Preparation for the installation of the sensor

Fig.7 Sensor installation

contract. Power supply is provided from solar panels. Batteries and controllers are installed in a special container. Employees were trained in the maintenance of AHCC.

The stations are equipped with sensors for electric conductivity, pH, dissolved oxygen and water level manufactured by Seba Hydrometric GmbH&Co. KG, Germany. Every hour the data collection centre receives the following information from the hydrochemical probe:

- water level;
- water temperature;
- pH;
- electric conductivity;
- dissolved oxygen;
- oxygen saturation;
- salinity;
- water density;
- total dissolved solids.

Experts checked received data and control technical parameters regularly.

Fig.8 Conducting comparative measurements

Fig.9 Equipment installed in Finland at the monitoring station in Pitkäkoski, Vantaa

Fig.10 AHCC at the Olonka river – the town of Olonets

Fig.11 AHCC at the Tulemajoki river – village of Salmi

Fig.12 AHCC at the Uuksunjoki river – Uuksu settlement

Primary monitoring results

The installed equipment has been operating in a reliable manner since October 27, 2020. According to the technical requirements, monthly calibration of pH and oxygen sensors is required. In accordance with the observation program, quarterly manual sampling is performed at the sites where the equipment is installed. Comparative analysis of sensor data with data based on manual sampling in the 4th quarter of 2019 and in the 1st quarter of 2020, showed satisfactory convergence of results. Average values a represented in Table 9.

Table 9 Average values of measured parameters

		Measured parameter									
		pH		Oxygen saturation		Dissolved oxygen		Electric conductivity		Water temperature	
		pH unit	pH unit	%	%	mg/l	mgO/dm³	µS /cm	µS /cm	C°	C°
Data collection means											
		Multiparameter probe	Laboratory analysis	Multiparameter probe	Laboratory analysis	Multiparameter probe	Laboratory analysis	Multiparameter probe	Laboratory analysis	Multiparameter probe	Laboratory analysis
Hydrological post 1 the Olonka river – the city of Olonets											
1	Average values	6.4	6.4	83.0	80.0	9.0	10.0	43.0	40.0	24.0	23.5
Hydrological post 1 the Tulemajoki river – Salmi settlement											
2	Average values	6.4	6.4	85.0	74.0	9.6	9.0	49.0	49.0	8.0	8.0
Hydrological post 1 the Uuksunjoki river - Uuksu settlement											
3	Average values	6.0	6.2	83.0	80.0	10.0	9.5	2.3	31.0	12.0	11.9

In the 2nd quarter of 2020, the pH sensor needed to be replaced at hydrological site HP-1 at the Uuksunjoki river in Uuksu settlement. The sensor was replaced from set of spare parts, tools and accessories.

Data obtained from continuous on-line water quality measurements were compared with traditional laboratory results. The database for analysing the proximity (reproducibility) of results obtained is updated quarterly. Preliminary comparison results can be considered satisfactory.

In general, the installed automatic stations have proven to be reliable. The engineering solutions proposed by the designers during the technical re-equipment of observation points were discussed and approved as a long-term solution. Favourable conditions for the location of the device, include the presence of a land plot and the location of an operating state observation site. It is also important to ensure that the device is not subjected to vandalism. Operating experience has shown that maintenance of a hydrochemical probe and sensors is only possible during the ice-free period. Thus, during the winter period, the data received from the AHCC will require the introduction of correction coefficients, which can be calculated based on the results of a sufficient number of parallel observations.

During the observation period, there were no cases of high or extremely high pollution in the water bodies under study. However, based on the laboratory data, the COD, Mn and BOD5 indicators constantly exceeded maximum permissible concentration levels for the rivers Olonka, Tulemajoki, Uuksunjoki and Tohmajoki, which indicates that water is overloaded with organic substances.

Fig.13 Sensor calibration at HP-1 at the Olonka river in the city of Olonets

Fig.14 Sensor calibration at HP-1 at the Tulemajoki river in Salmi settlement

Measurements take place on a quarterly basis. Average values are presented in Table 10. In addition at all sites, maximum permissible concentration of total Fe and Mn is exceeded. But the excess of these ingredients is due to natural features and is typical for the territory of the Republic of Karelia.

According to the results of research and data from the AHCC, the level of dissolved oxygen in rivers is 10-12 mg/dm3, which indicates a satisfactory environmental condition of water bodies. However, human economic activity has a significant anthropogenic impact on the studied rivers, and it is necessary to constantly monitor the state of watercourses in order to preserve the ecosystem.

Table 10

Water-body	Location of the observation site	Average value of each variable and its exceedance of maximum permissible concentration (mpc) (how many times over mpc)							
		Total Fe		COD		BOD5		Mn	
		Average value (mg/dm3)	Exceedance	Average value (mgO/dm3)	Exceedance	Average value (mgO/dm3)	Exceedance	Average value (mg/dm3)	Exceedance
Olonka	Hydrological post (Olonets)	0.97	9.7	4.3	3.2	2.0	1.0	0.03	3.0
	Mouth of the Olonka river	0.45	4.5	35.0	2.3	2.4	1.2	0.03	3.0
Tulema-joki	Hydrological post (Salmi)	0.68	6.8	41.0	2.7	2.0	1.0	0.02	2.0
	Mouth of the Tulemajoki river	0.4	4.0	42.0	2.8	2.2	1.1	0.03	2.0
Uuksun-joki	Hydrological post (Uuksu)	0.85	8.5	35.2	2.3	2.0	1.0	0.025	2.2
	Mouth of the Uuksunjoki river	0.78	7.8	32.0	2.1	2.0	1.0	0.02	2.0
Tohmajoki	Hydrological post (Rytty)	0.5	5.0	50.0	3.3	2.2	1.1	0.04	4.0
	Mouth of the Tohmajoki river	0.4	4.0	40.0	2.6	2.0	2.0	0.02	2.0

Access to data for the population and experts

The modernization of the official website of the Karelian CGMS will make it possible to present data received from the AHCC on-line. Specialized software tracks parameters, and data on the site is presented in a convenient format that is accessible to a wide range of people. The colour display, which is formed depending on the quality of the water body, visualizes information content. If all the monitored parameters on the site have passed the quality control, the observation point is highlighted in green. If an adverse or extreme value occurs for any of the parameters tracked, the colour display will change to yellow and then red.

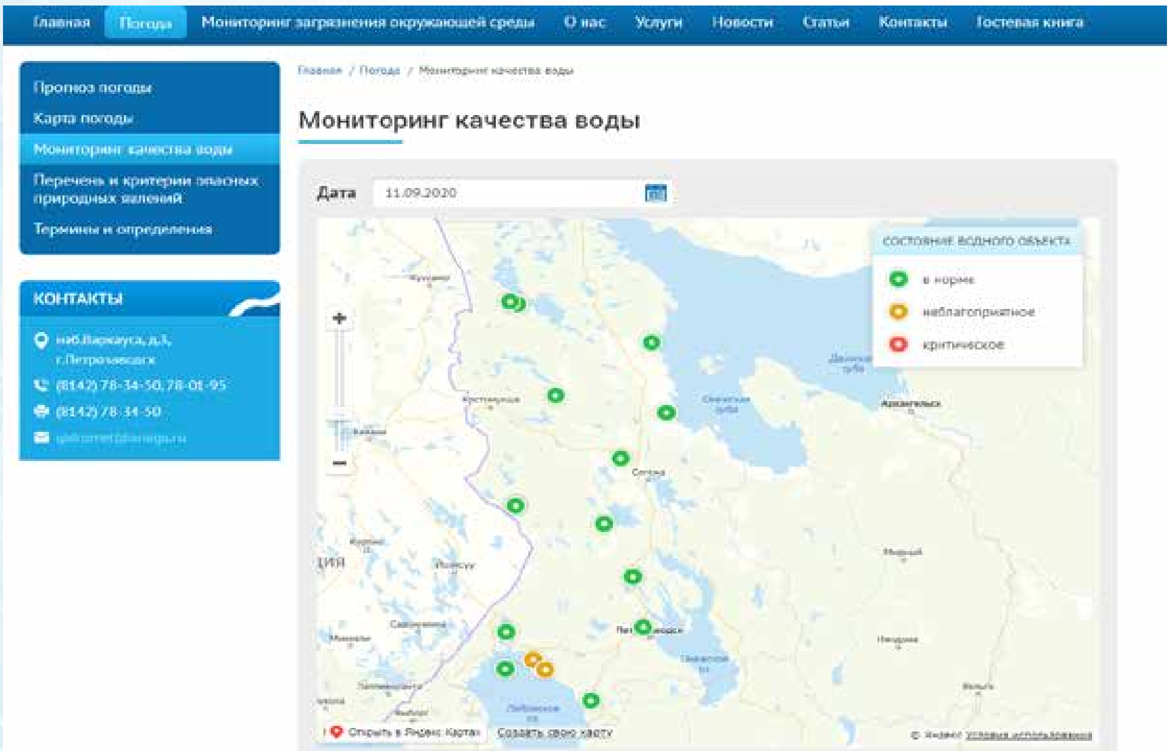
In addition, specialists will have access to monitoring databases obtained during the implementation of the project, containing information on all 36 elements that were monitored quarterly in the area of river mouths and in the locations of points of the state observation network.

In addition, Arbonaut OY specialists together with KarCHEM developed a «Web-based eco-monitoring information system» (based on OpenStreetMap), which will be available to specialists from Russia and Finland. This system is described in detail in section 1.2 of this publication.

Further development

At the moment, capabilities of automatic monitoring are still limited both in terms of the number of parameters and in terms of ensuring the proper functioning of stations, especially in the Northern conditions, during ice formation. It is in these situations when the amount of dissolved oxygen and diluting capacity is reduced, and it is especially important to control the quality of water composition. Many parameters cannot yet be measured continuously. Some devices are not suitable for measuring low concentrations of substances in natural waters.

Therefore, traditional hydrochemical monitoring cannot yet be replaced by automatic monitoring, but a wide range of analyses can already be monitored automatically. This type of monitoring is particularly relevant in



the locations of production facilities, with the inclusion of sensors aimed at detecting the concentrations of certain dangerous pollutants in the composition of hydrochemical probes. With regard to monitoring of transboundary water bodies, it is the use of automatic monitoring stations that will allow for the best possible unification of observations and ensure proper monitoring.

The project's preliminary study of the catchment areas of the Janisjoki and Tohmajoki watercourses already allows for a preliminary analysis, which can become the basis for the development of a transboundary monitoring system. On the territory of the Republic of Karelia there are many other transboundary water bodies, standardized assessment of which is also important for the development of good neighbourly relations.

The Karelian Centre for Hydrometeorology and Environmental Monitoring has gained experience in working with leading Finnish environmental monitoring institutions that will be used in the system not only for cross-border monitoring, but also for the expansion of regional hydrochemical and aerochemical monitoring systems.

1.1.3 Online phosphate phosphorus measurements on the Finnish side.

Background

Together with nitrogen, phosphorus is the main nutrient that restricts basic production and algal growth in water bodies. Therefore, phosphorus concentration is a good indicator of the eutrophication of a water body, and it is an important part of the overall monitoring of water quality. Excessive phosphorus and nitrogen entering the water body will lead to eutrophication of the waters. Eutrophication leads to changes in population structure of vegetation and animal species and increases biomass and thus e.g. oxygen consumption as this biomass decomposes.

Total phosphorus (Ptot) includes all phosphorus in the water, i.e. phosphorus bound to living and dead organisms as well as soil particles and phosphorus in dissolved form. The sources of phosphorus are shown in Fig. 15. In river waters, the Ptot concentration can vary largely depending on the amount of rainfall and the variation it causes in the leaching of nutrients from the catchment area. The season of the year matters, as the amount of leachable nutrients is typically highest outside the growing season.

Phosphate phosphorus (= dissolved inorganic phosphorus, PO4-P) is the main phosphorus compound used by algae. Therefore, it is important to know what proportion of total phosphorus is in soluble form. It is difficult to measure, in part because PO4-P concentrations are typically very low during the production season since the algae use efficiently the available phosphorus.

TP cannot yet be measured directly with

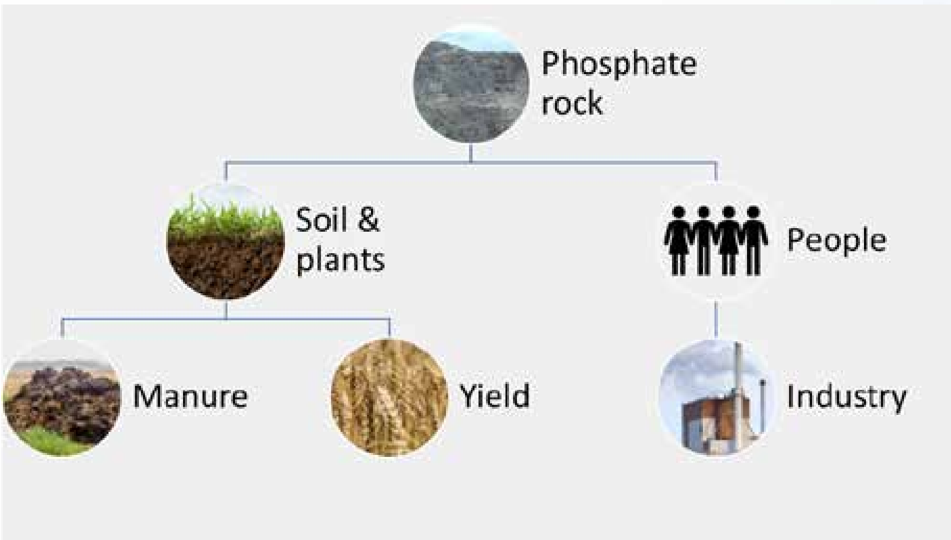


Fig. 15 Main sources of phosphorus

Fig. 16. The PO4-P device including the passive collectors (DGT, see also www.dgtresearch.com)

continuous water quality sensors. However, it can be calculated based on the turbidity measured by the continuous water quality devices, especially in catchments with clay soils.

Phosphate phosphorus (PO4-P) sensor

Eco-Bridge project tested a new passive filter method for PO4-P measurement. The measurement method does not produce continuous measurement, but the results are obtained, for example, as a 2-day average, which is considerably more than is usually obtained with water samples. A measurement period of PO4-P with this passive filter started in mid-March 2020. The device was leased from a Finnish equipment supplier Luode Consulting Oy (http://www.luode.net/en/). Measurements will continue four to five months over the summer 2020.

Measurement method

The method is based on the incubation of passive collectors (DGT) (Fig. 16 and see more www.dgtresearch.com). The collectors are nowadays well standardized, as well as laboratory determinations of the collected samples at the end of the measurement period. So far, the problem has been that exporting and retrieving the collectors is laborious. This problem was solved when a French company developed a device called THOË, which automatically changes the incubator at the desired intervals. The carousel of the device can hold 12 collectors. The advantage of collectors over automatic water sampling is that the collected substances are chemically bound in them and no longer change their form. Therefore, the collector analysis is in no hurry, unlike water samples. The final result is calculated as concentrations with a formula that takes into account the mean temperature of the measured period, the diffusion coefficient, the length of the period, the background concentration and the extraction coefficient.

Implementation

The equipment was installed on the Finnish side in the Kuonanjoki catchment area. Figure 3 shows the catchment area above the observation point. The size of the area is 73.5 km2, most of which is forest land (72%). Agricultural land covers only 3 % and lakes in the area cover 20% of the total area. In the area, there are a lot of moraine soils (mixed fraction soil) and some peat soils (Fig. 18). The measuring point (see Fig.17) is located in the outlet river of the Kuonanjärvi lake. The measurement site was selected because

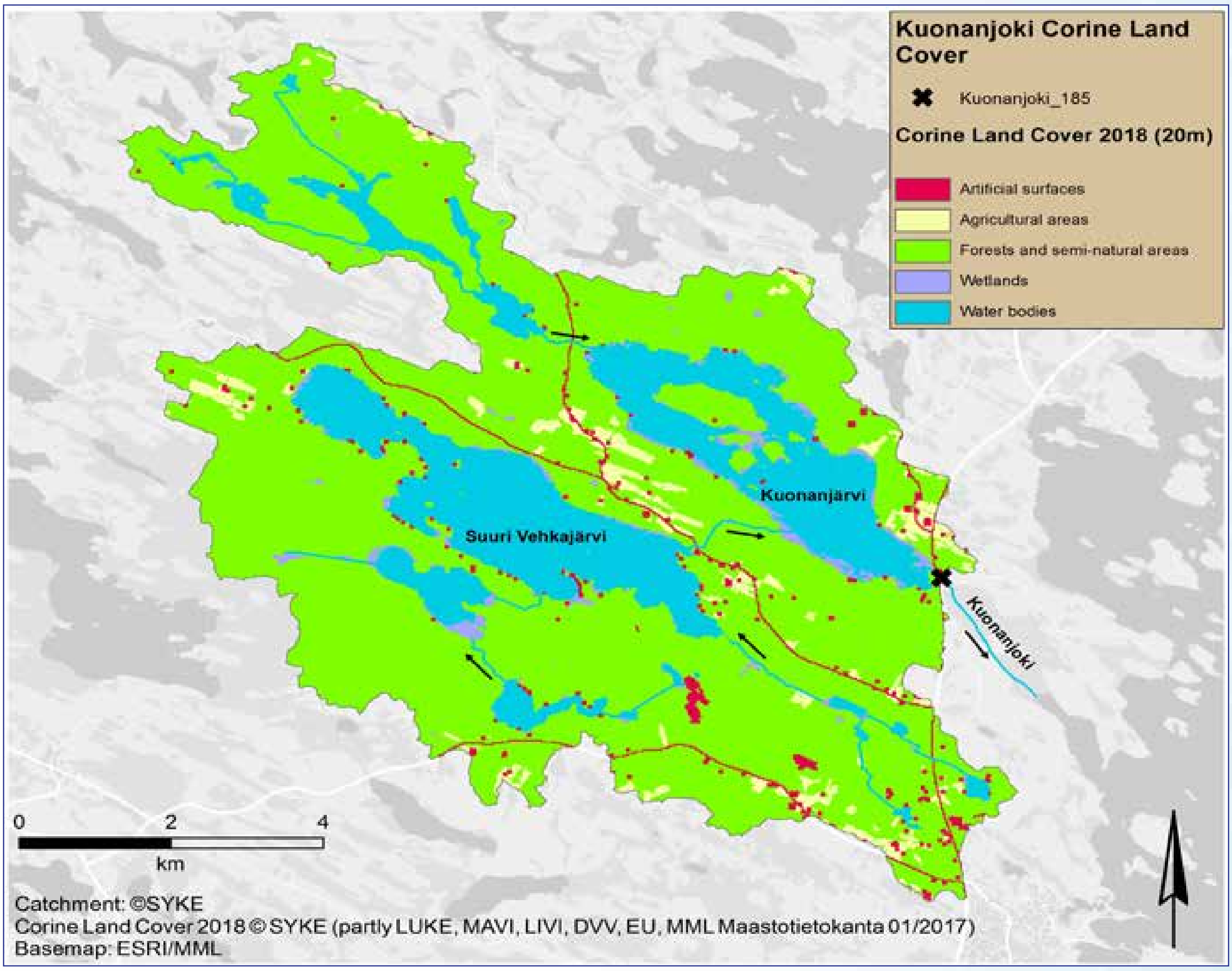


Fig. 17. Dominating soils in the catchment area.

an automatic water quality measurement was already underway in the framework of another project (https://www.luke.fi/en/projektit/operandum/) and it enabled a fast and still high-quality measurement to be carried out.

Results

At this measurement site, based on monitoring data the PO4-P concentrations are typically very low. Based on standard laboratory measurements of five water samples (5 March, 23 April, 14 May, 10 June and 23 June in2020), the average Ptot concentration was 34 µg/l. During the corresponding period, the mean PO4-P concentration was 1,9 µg/l. Therefore, the share of PO4-P averaged thus only 6% of Ptot. Because the detection limit for PO4-P varies between 2 and 5 µg/l, the measured concentration readings are very close to the limit of determination.

The new DGT-method could detect small variation during the spring measurement period, but the level was low throughout this period (see Fig. 19). At the end of May PO4-P concentration increased sharply, the maximum value being above 50 µg/l. In addition, there are a few periods of elevated concentrations in the summer results, the highest of which are at the same level (30–50 µg/l) as in the rivers of agricultural areas. On the other hand, all laboratory results based on manual sampling are rather low and these observations fit very well into a continuously

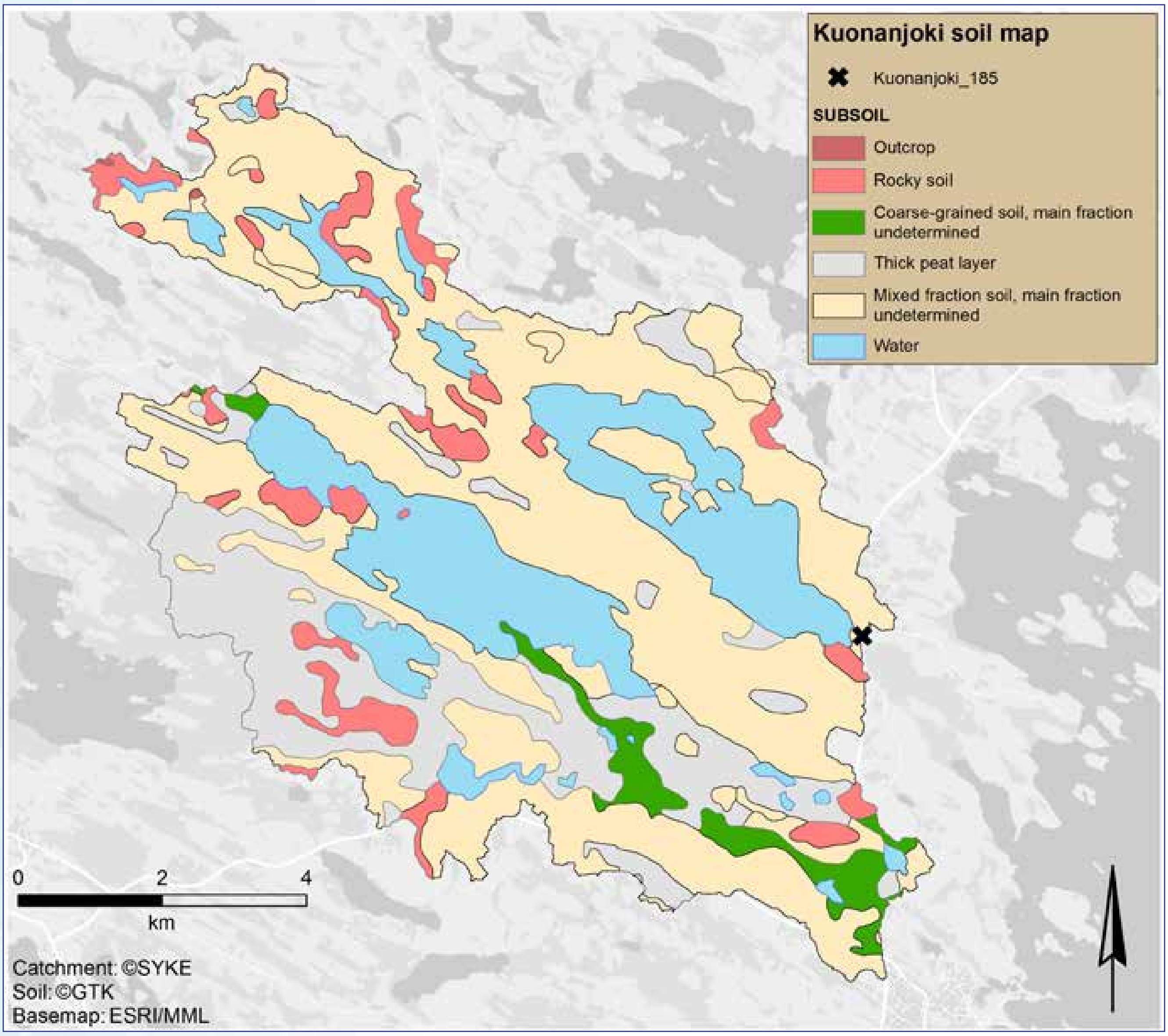


Fig. 18. The catchment area of the PO4-P station in the Kuonanjoki river and the land use in the area. The measuring station is located in the Kuonanjoki river just below the lake.

measured DGT time series. It can also be seen from Figure 5 that the increase in PO4-P concentration is not related to rainfall events.

Development needs

Technically, the measurements were successful. The equipment supplier took care of the maintenance and collectors' replacement, and their delivery to the laboratory. In our experience, the measurement method seems to be reliable and, in fact, the need for maintenance is low. Our measurement site was located just below the lake Kuonanjärvi, so probably the concentration level was influenced by the eutrophication processes of the lake itself. The PO4-P range for the whole period varied between 0,3–51 µg/l, so we practically did get a lot of variation in measured PO4-P levels. Therefore, the results showed that in the routed watershed such as the Kuonanjoki catchment, PO4-P concentrations seem to vary considerably.

In the future, it is good to select a measurement site with varying PO4-P concentration levels and the measurements should also be made not only in rivers but in eutrophic lakes as well. The measurement method should also be tested at different locations and throughout the spring and

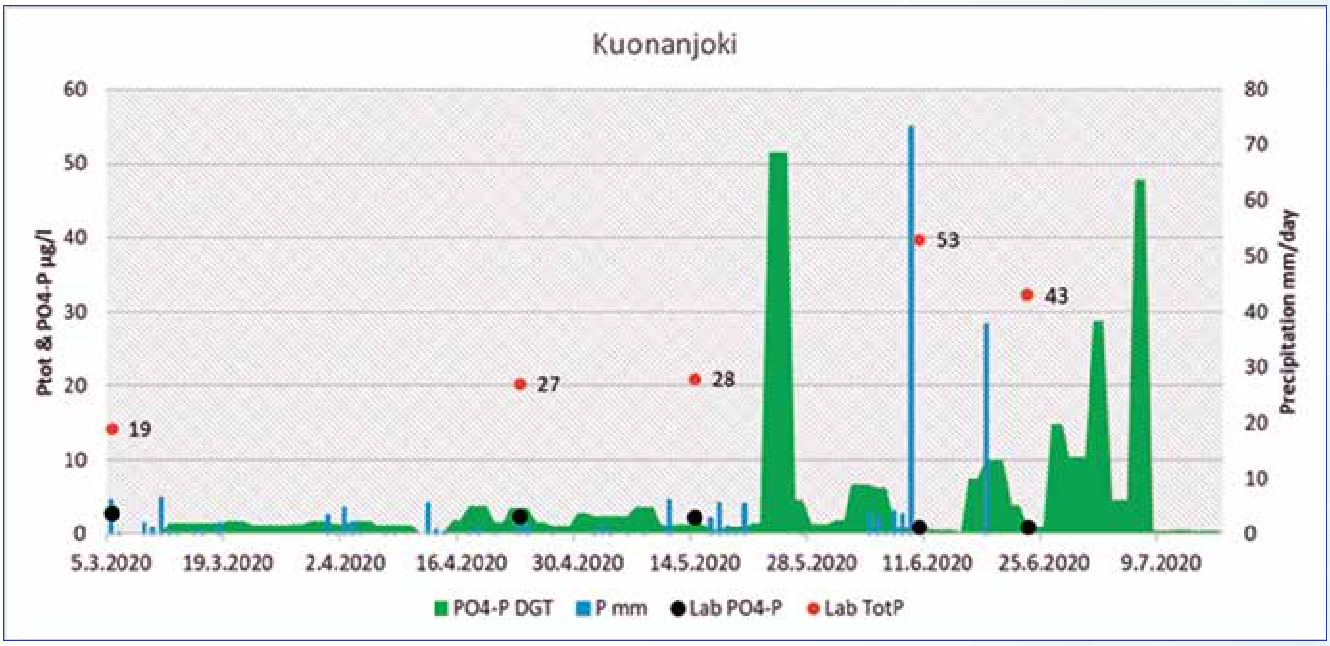


Fig. 19. Variation of PO4-P measured with the DGT passive filter sampler in the Kuonanjoki river between mid-March and mid-July. The figure also shows the variation of total phosphorus (Ptot) analysed from the water samples taken. The daily precipitation is also shown.

summer period to find out the temporal variation of PO4-P. It would also be useful to test the method for intensive livestock areas or in an area with, for example, industrial PO4-P emissions.

1.1.4 On-line air quality measurements on the Finnish side

The Finnish Meteorological Institute's (FMI) Ilomantsi-Potsonvaara air quality monitoring station (Fig. 20) was established in 1997, i.e. 23 years ago. The station infrastructure and instrumentation required essential upgrades to ensure the continuous operation of the station (Fig. 21). This is important as the station is, together with the Hietajärvi deposition collection site, the only air quality monitoring station in the county of North Karelia. As a matter of fact, it is the only background air quality monitoring station close to the Finnish-Russian border between Virolahti and Kuusamo. Situating in a background area with no local pollution sources the station can act as a regional clean air reference site not only in Eastern Finland but also in the Republic of Karelia. .

Project implementation – New measurement container for the Pötsönvaara air quality monitoring station

A new measurement container was procured (Fig. 22). It was installed to the Ilomantsi-Pötsönvaara monitoring station after making a gravel foundation for it. The new location is in the immediate vicinity of the old container. The old container was discarded and removed from the premises. A new electricity line was built to the station.

Project implementation – New air quality monitors

The procurement procedure of a sulphur dioxide monitor and an ozone monitor and their associated hardware and software was accomplished (Fig. 23). The ozone monitor is model 49i by Thermo Electron Corporation. The sulphur dioxide monitor model is model 43i-TLE also by Thermo Electron Corporation. The measurement computer is model ARK-3520P by Advantech Co., Ltd. The data collection and transmission software is Envidas Ultimate by Envitech Ltd. The uninterruptable power supply is model 9130i by Eaton® Corporation plc.

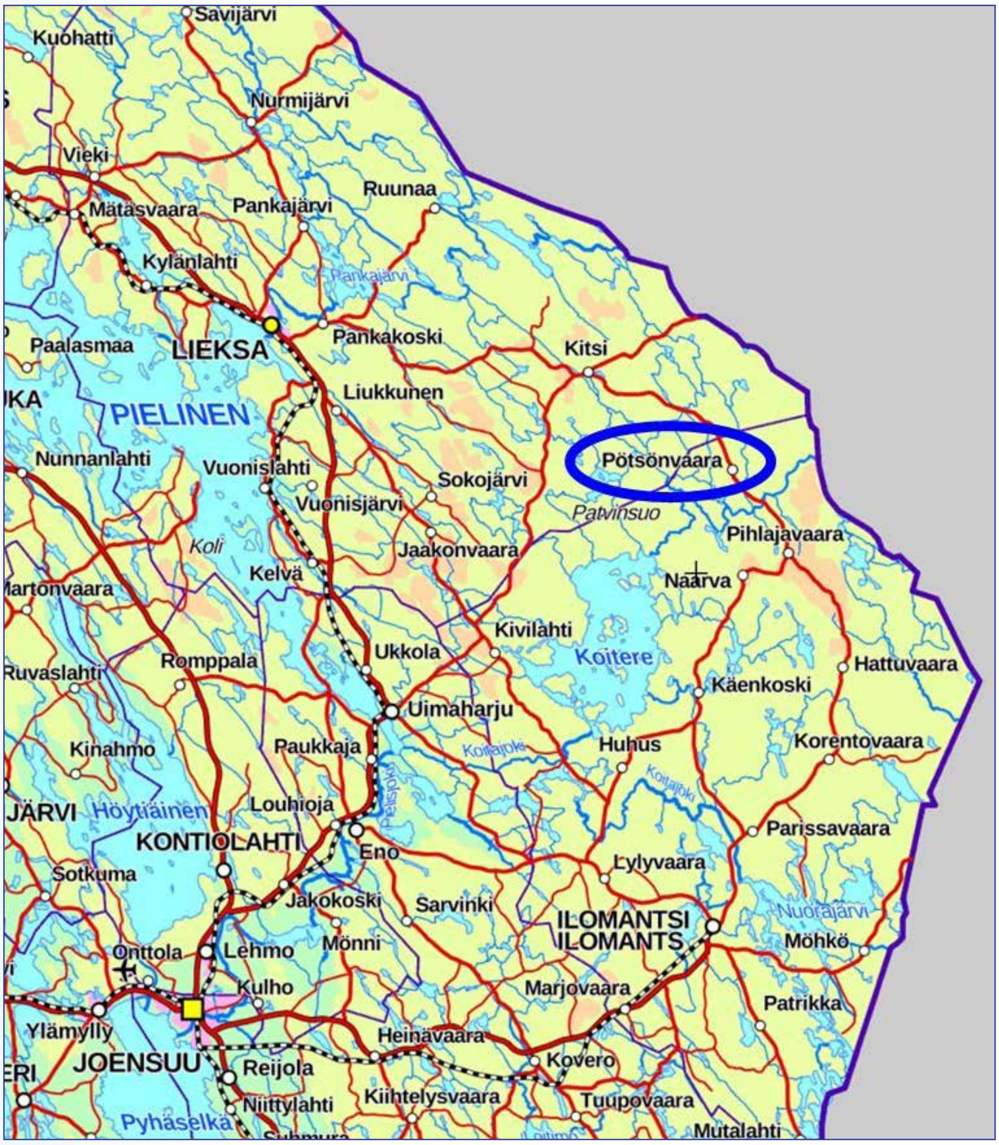


Fig. 20 Location of the Pötsönvaara air quality monitoring station (Map: National Land Survey, https://asiointi.maanmittauslaitos.fi/karttapaikka).

Project implementation – KarCHEM study visit to the FMI

A study visit by KarCHEM staff to the FMI Headquarters in Helsinki took place 23 May 2019 (Fig. 24). During the visit various FMI's activities related to air quality and radioactivity monitoring issues were presented.

Project implementation – Study visit to Pötsönvaara

Due to the Covid-19 pandemia and associated travel restrictions the planned KarCHEM study visit to Pötsönvaara air quality monitoring station had to be cancelled. Instead, the FMI is producing a video presentation about air quality monitoring in Finland with the following agenda:

Fig. 21. Old measurement container at the Ilomantsi-Pötsönvaara air quality monitoring station.

- Air quality monitoring in population centres
- Background air quality monitoring stations
- Laboratory measurements of aerosol and precipitation samples
- National reference laboratory for air quality issues
- Air quality assessment with dispersion modelling

Outcomes of the project

This project has been vital for the continuity of air quality measurements at Pötsönvaara. The old container was in a very bad condition. Water from rain and melting snow had penetrated into the container wall and roof structure causing a health risk to the station manager and service personnel due to microbial activity. The electricity system of the container was also in the end of its technical service life. The lack of air conditioning was hazardous for the instruments in the container because the temperature rose too high in summer. The ozone and sulphur dioxide monitors were rather old too and spare parts started to be hard to acquire.

As a result of the project the FMI has now an up to date station infrastructure at

Fig. 22 The new measurement container on its gravel foundation at the Pötsönvaara air quality monitoring station. The sample air inlet line can be seen close to the right-hand side back corner. An air-source heat pump, capable of cooling the container in summer, is beside the container door.

Fig. 23 Indoor view of the new measurement container. On the table from left to right a measurement computer, a sulphur dioxide monitor and an ozone monitor. In the corner under the table is an uninterruptable power supply (UPS).

Fig. 24 KarCHEM delegation at the main entrance of the FMI.

Pötsönvaara. The new electricity line to the station provides improved electrical safety and reliability. The new container gives a safe and pleasant working environment to the staff visiting the station. The improved temperature control in the container offers good conditions for the instruments. This will lead to improved accuracy of the measurements and better temporal data coverage as less instrument malfunctions occur. The electricity system of the container fulfills now all the current official technical and safety requirements. The new ozone and sulphur dioxide monitors should provide data for the next 5-10 years.

In addition to improved air quality monitoring infrastructure the project supports the development of air quality monitoring programmes in the Republic of Karelia by providing a regional clean air reference site and by the know-how transfer to the KarCHEM. This is important as the air pollutants don't respect national borders. In the future the FMI would be interested to continue these cross-border activities as the KarCHEM and the FMI face similar challenges in their atmospheric monitoring activities. One specific example of possible future cooperation is the monitoring of atmospheric radioactivity that both institutes are performing.

1.2 ELECTRONIC AND WEB-BASED TOOLS FOR DATA PRESENTING AND ANALYSES ON BOTH SIDES OF THE BORDER.

VESINETTI in Finland

Vesinetti has been developed under GISBLOOM-project (01/10/2010-30/09/2013) in cooperation with SYKE (Finnish Environment Institute) and other authorities, financed by the EU LIFE+ (Best LIFE Environment projects 2014, 48). Arbonaut was responsible of maintenance and development of the technology.

Vesinetti web-service integrates data and models for participatory river basin monitoring and management. As well it provides a platform for information sharing and exchange place between authorities and water management networks. It is used for observation and preservation of data about conditions of water systems. Vesinetti enables to facilitate the information sharing between the authorities, scientists and different kind of experts and professional users and citizens.

Currently in Finland, it combines nationwide data and models and is used to:

- manage, design and register data related to; algal blooms and eutrophication, climate, hydrology, hydrobiology, land-use, nutrient loads and water quality responses - estimate climate change in lakes and coastal areas

It is continuously used by ELY Centers and water protection associations to run LLR-model.

LLR (Lake Load Response) is browser-based modeling tool, developed by SYKE, to assess load effects. LLR assists in assessing the load reduction need and thus in the planning and management of river basin management. (Vesimuodostumakohtaisenkuormituksenvaikutus ja vähennystarpeenarviointi – LLR, SYKE, 2014).

Users can themselves produce and add data into the system and the containing information can be set either public or private. Of the information stored in the service, html-formatted pages can be created to able the "basic users" use the information as well. There are different levels of ID's which allows the users to carry out different levels of tasks: permission to edit the information, or visitor; data viewing, without the rights to do modifications it.

Web-based information system for eco-monitoring in Karelia and Finland

In Eco-Bridge project, new web-based information system was developed to allow data collection, monitoring, and delivery to end users in Russia. The system brings the environmental data accessible in one centralized database, allowing the comparison of the data obtained on both sides of the border in Russia and Finland, monitoring, and sharing the interested information for the public.

KarCHEM manages the user levels and provides user accounts according to the purpose of the use. They can regulate what data will be available for each user. Similarly, as in Vesinetti, there are different levels of ID's allowing the users to carry out different levels of tasks: to edit or to view the data.

Information from the monitoring stations.

The information system was created for collecting and visualizing data from new equipment - automatic water monitoring stations installed within the framework of this project will help to provide a wide range of people with information on the status of water, including water quality. The data, including pictures of the sites, from these three stations is automatically derived to the web system and allows up-to-date monitoring of the sites. The data include a set of parameters and indicators determined by KarCHEM and is presented in the form of graphs and tables. Quarterly, information on the status of the water objects will be manually added in the system after laboratory tests on 32 parameters.

On the Finnish side, there is an interface between this system and VESLA database run by SYKE. VESLA contains data from observation sites in Finland and information of the water samples can be viewed with the new system. (Pintavesientilantietojärjestelmä - vedenlaatu - ohjeitatiedontuottajille, Ymparisto.fi, 2018).

Maps and layers

The base map of the system is OpenStreetMap. There are different raster maps indicating rivers, lakes, and catchment areas. On the menu bar, it can be chosen which layers are wanted to be visible.

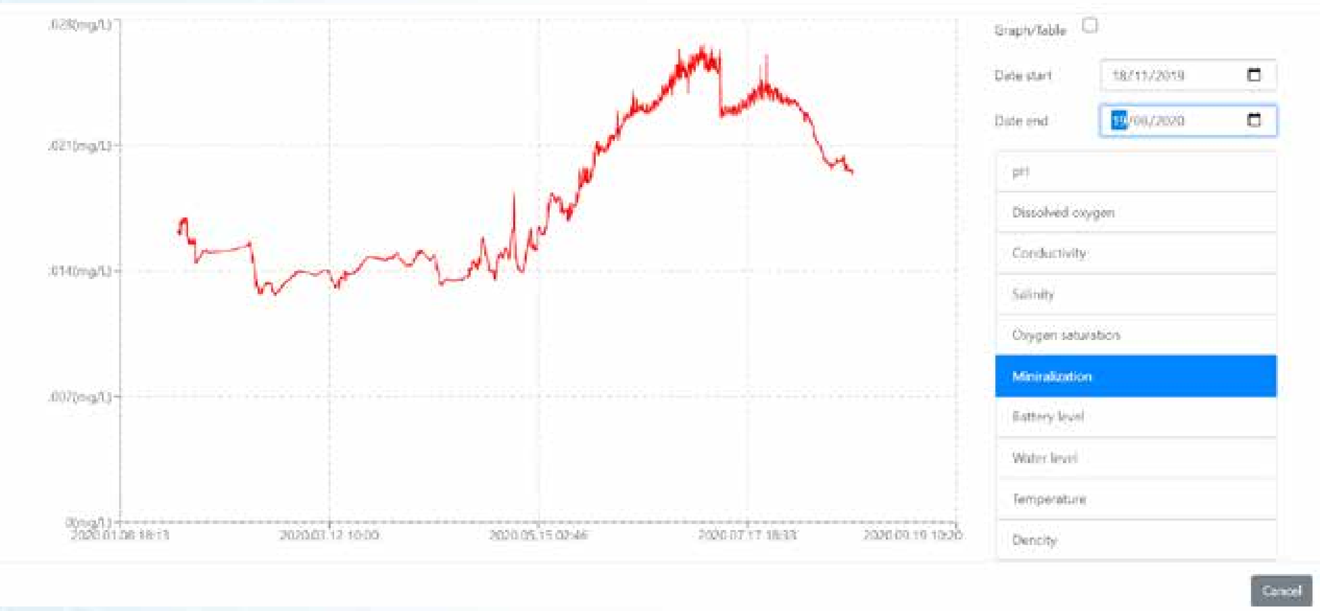


Fig. 25 Example of the data view of monitoring station in Uuksunjoki

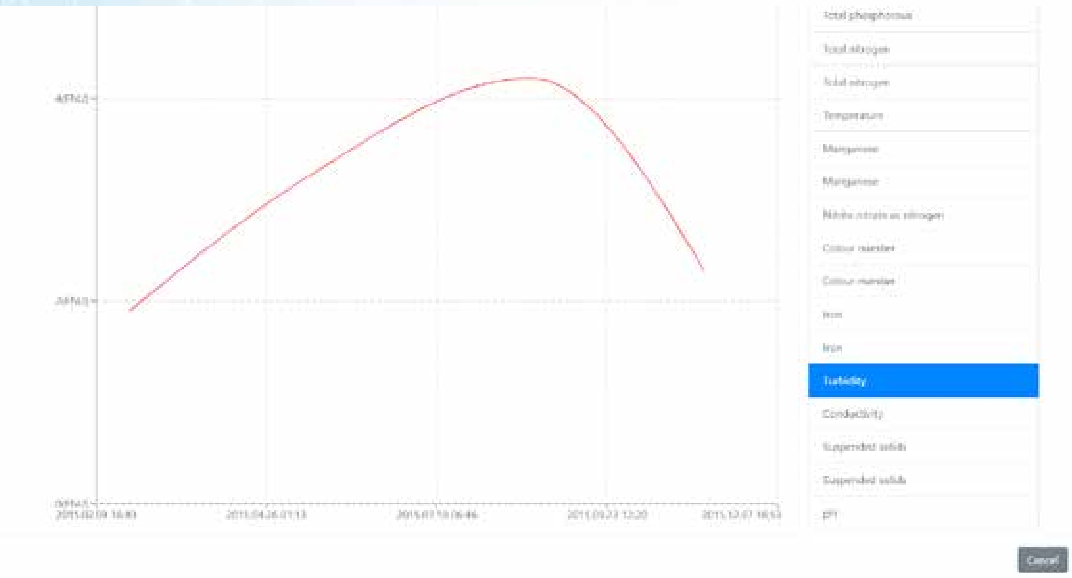


Fig. 26 Example of the laboratory data view of monitoring station in Kiteenjoki

Land cover maps

Below it is presented view of the land cover map in Finland, representing spatial information on different types of coverage of the Earth's surface. Legends on the menu indicate the type of land for each color.

Similarly, soil maps in Russia, indicate the type of the soil of the surrounding areas of Olonka, Tohmajoki, Tulemajoki and Uuksunjoki.

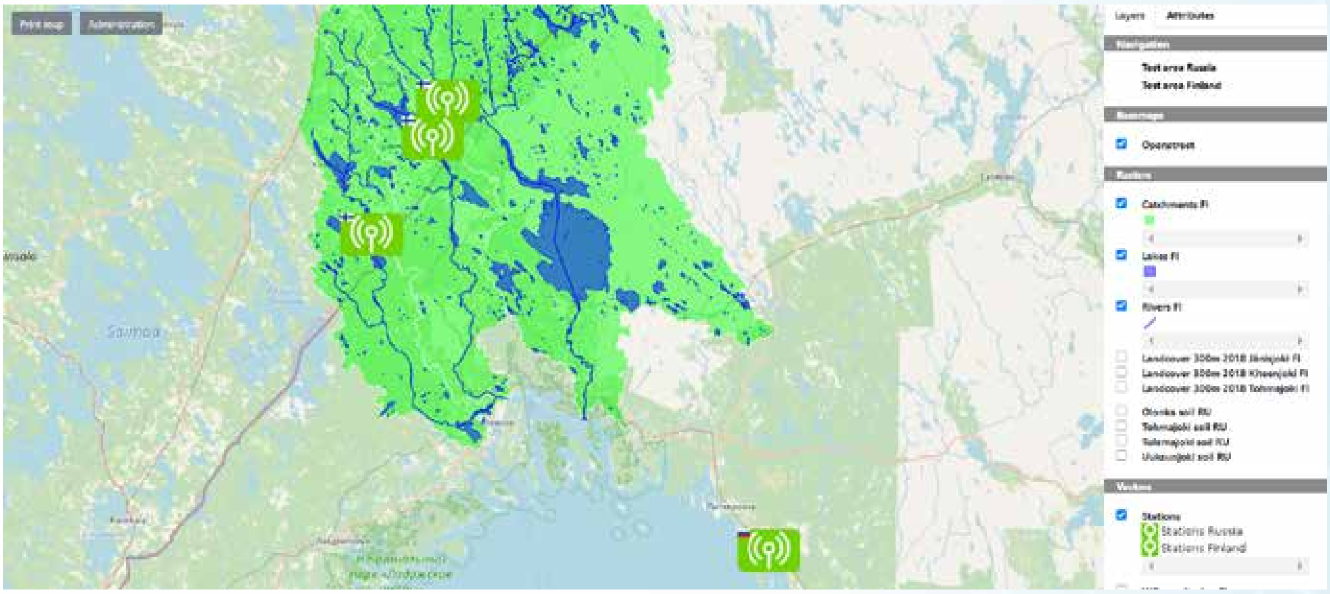


Fig.27 Example of the layer view (map source: SYKE) [1]

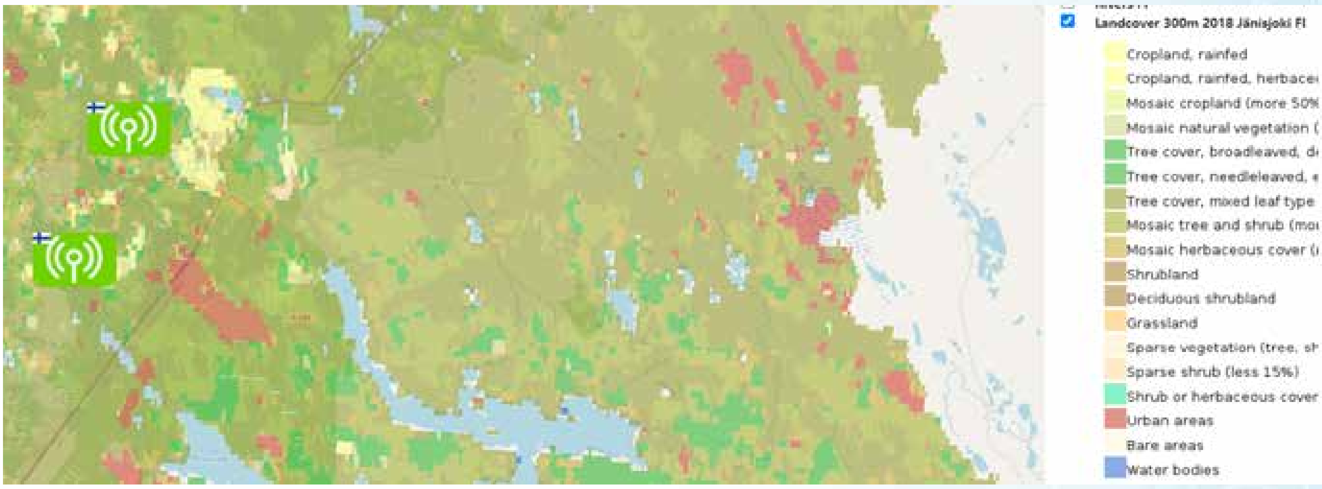


Fig. 28 Land cover of Jänisjoki [2]

[1]Source: SYKE
[2]Source: ESA Climate Change Initiative – Land Cover led by UCLouvain (2018) ESA. Land Cover CCI Product User Guide Version 2. Tech. Rep. (2017). Available:maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf

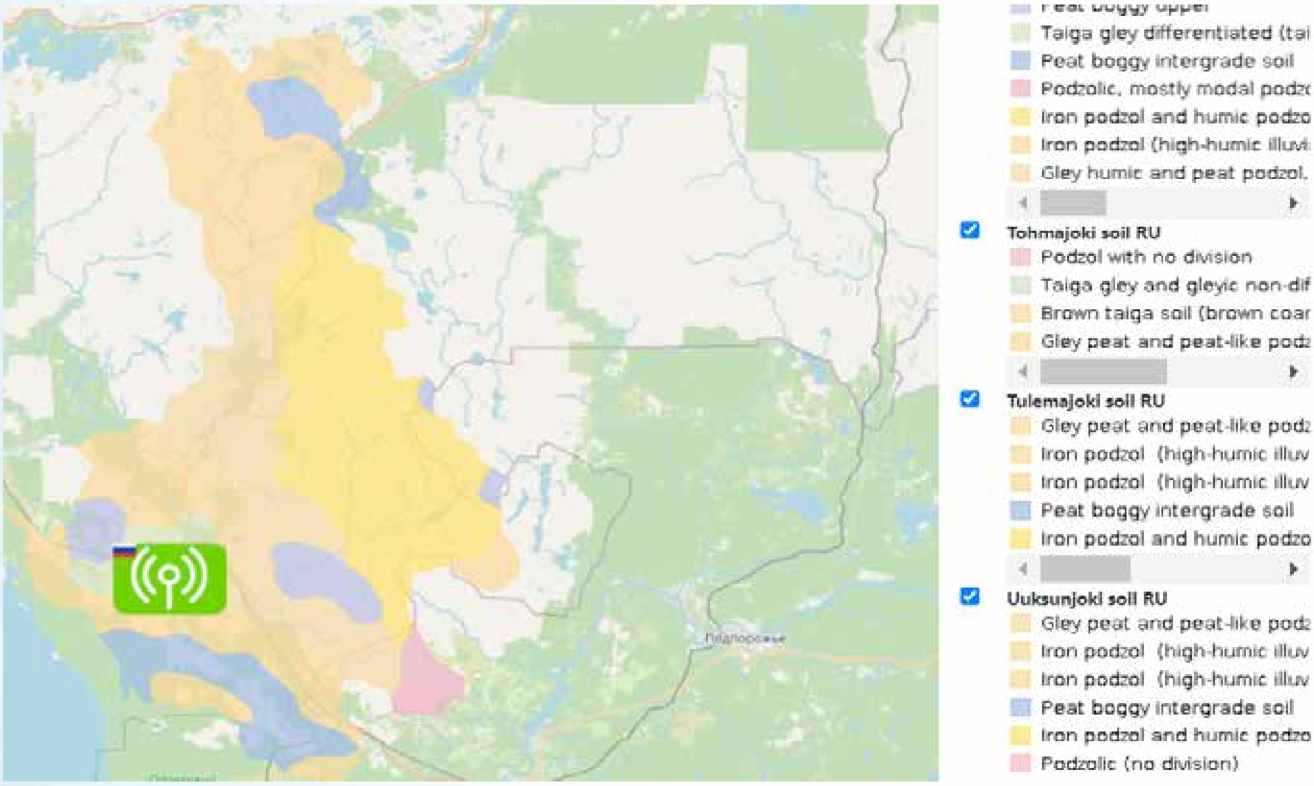


Fig. 29 Soil map of Olonka[3]

Manual sampling sites

Icons below are representing water quality manual sampling sites in Finland. Attributes present basic information of the site including amounts of samplings. The size of the icon changes accordingly, more samplings the bigger the icons.

Fig. 30 Jänisjoki alajuoksu sampling site [4]

[3] Source: Energy Efficiency Centre
[4] Source: Arbonaut, OpenStreetMap

Fig.31 Hydrological monitoring site - water level [5]

Other functionalities

There is an option to print the wanted maps or the views.

In addition to the automatic stations, new stations can be added, edited, and deleted manually. User can add basic information for the station including identifier, name, type, or add pictures.

KA5016 project sites, KarCHEM state network and transboundary state network points are presented on the map.

Fig.32 Ecological status[6]

Application on the Russian side

As part of the project implementation, Arbonaut has developed a specialized WEB-based information system. KarCHEM has a monitoring data collection center, which receives information from automated hydrochemical complexes (AHCCs). A

[5] Source: Arbonaut, OpenStreetMap
[6] Source: SYKE, ELY-centres, Luke

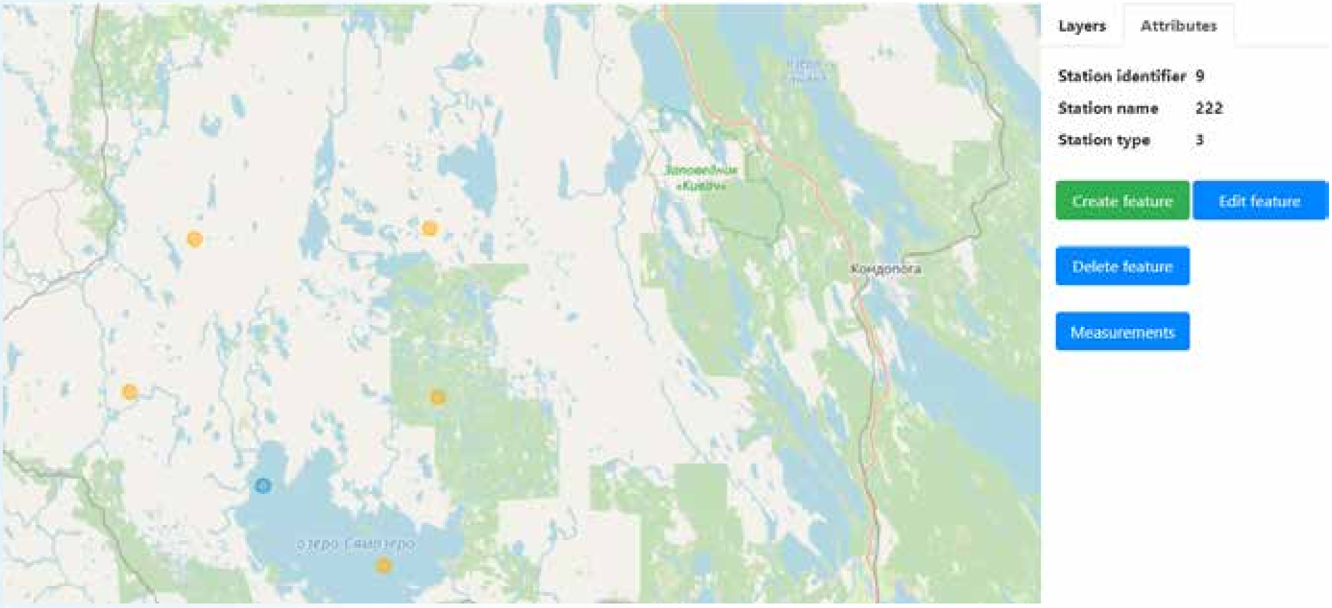


Fig.33 Example of the view when creating new station [7]

database is formed in the monitoring data collection center, which is accessed via the WEB interface or specialized software. KarCHEM employees can view and analyze information from automated systems that can be presented in the form of tables or graphs with the help of the monitoring data collection center.

Information from AHCCs is also present on an interactive map, on the website of the KarCHEM and is available to all users. The map shows the location of the AHCCs and displays daily readings from the sensors. In case the values of the measured parameters exceeded maximum permissible levels, the station marker is colored yellow or red.

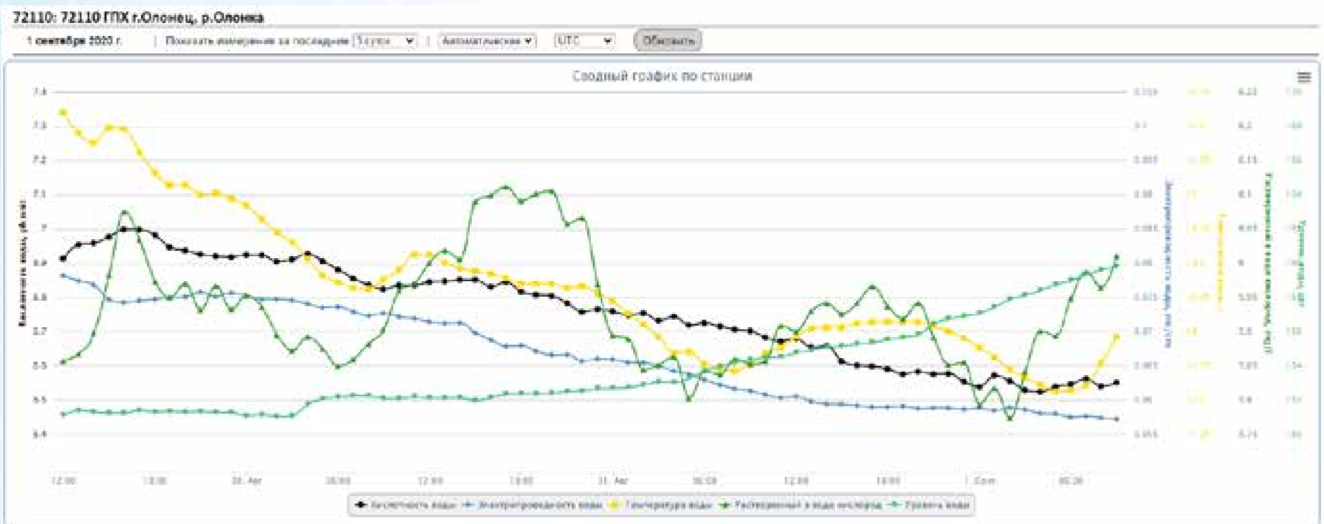
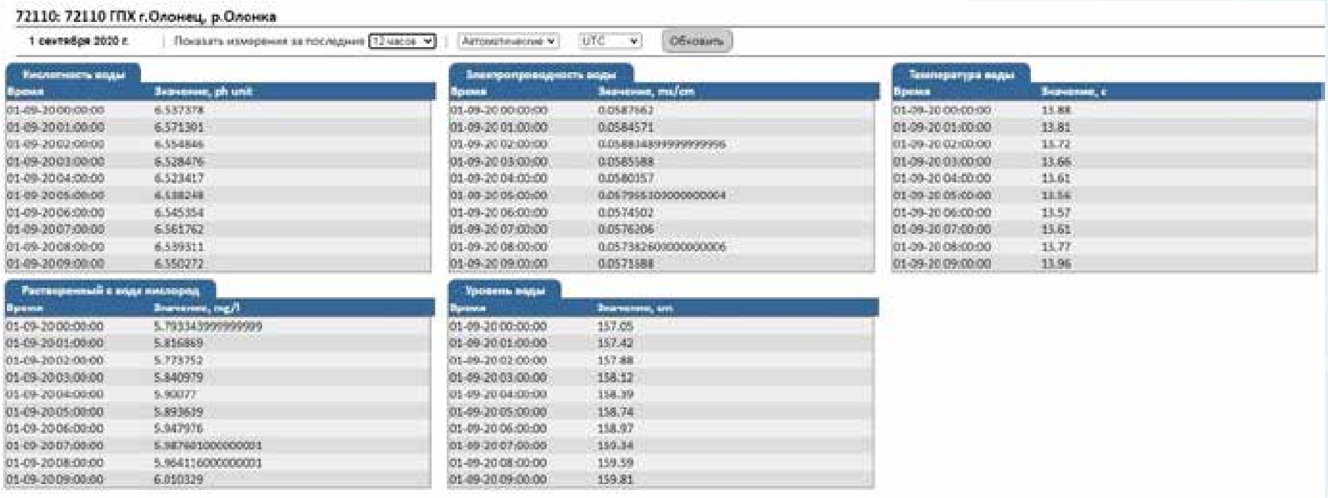


Fig.34 Thematic maps in Finland [7]

[7] Arbonaut, OpenStreetMap



72110: 72110 ГПХ г.Олонец, р.Олонка

1 сентября 2020 г. | Показать измерения за последние 12 часов | Автоматически | UTC | Обновить

Кислотность воды

Время	Значение, ph unit
01-09-2000:00:00	6.557378
01-09-2001:00:00	6.571301
01-09-2002:00:00	6.554846
01-09-2003:00:00	6.528476
01-09-2004:00:00	6.523417
01-09-2005:00:00	6.538248
01-09-2006:00:00	6.545354
01-09-2007:00:00	6.561762
01-09-2008:00:00	6.539311
01-09-2009:00:00	6.550272

Электропроводность воды

Время	Значение, ms/cm
01-09-20 00:00:00	0.0587662
01-09-20 01:00:00	0.0584571
01-09-20 02:00:00	0.058834899999999996
01-09-20 03:00:00	0.0585588
01-09-20 04:00:00	0.0580157
01-09-20 05:00:00	0.057965100000000004
01-09-20 06:00:00	0.0574502
01-09-20 07:00:00	0.0576206
01-09-20 08:00:00	0.057382600000000006
01-09-20 09:00:00	0.0571588

Температура воды

Время	Значение, c
01-09-20 00:00:00	13.88
01-09-20 01:00:00	13.81
01-09-20 02:00:00	13.72
01-09-20 03:00:00	13.66
01-09-20 04:00:00	13.61
01-09-20 05:00:00	13.56
01-09-20 06:00:00	13.57
01-09-20 07:00:00	13.61
01-09-20 08:00:00	13.77
01-09-20 09:00:00	13.96

Растворенный в воде кислород

Время	Значение, mg/l
01-09-2000:00:00	5.793343999999999
01-09-2001:00:00	5.816869
01-09-2002:00:00	5.773752
01-09-2003:00:00	5.840979
01-09-2004:00:00	5.90077
01-09-2005:00:00	5.893639
01-09-2006:00:00	5.947976
01-09-2007:00:00	5.987601000000001
01-09-2008:00:00	5.964116000000001
01-09-2009:00:00	6.010329

Уровень воды

Время	Значение, cm
01-09-20 00:00:00	157.05
01-09-20 01:00:00	157.42
01-09-20 02:00:00	157.88
01-09-20 03:00:00	158.12
01-09-20 04:00:00	158.39
01-09-20 05:00:00	158.74
01-09-20 06:00:00	158.97
01-09-20 07:00:00	159.34
01-09-20 08:00:00	159.59
01-09-20 09:00:00	159.81

Thematic maps in Finland

By combining spatial data sets, thematic maps can be made to provide an overall picture of the land use, soil type and topography of the area. Land use data makes it possible to map, for example, areas with a high nutrient load. Topography (DEM) information allows e.g. to delineate catchment areas, map flood-risk areas and calculate slopes of the fields and estimate their erosion risk. Potential use of soil data is to locate more accurately erosion-prone soils. Soil and land use data could be combined and, for example, fields on peat soils can be mapped.

Thematic maps combining water quality observation data, various classifications and even modelled data could be informative. Thematic maps are used e.g. to target water protection measures, such as buffer zones and wetlands, to places where they achieve the best benefits.

In Finland, map-based data is quite openly available (e.g. https://www.syke.fi/fi-FI/Avoin_tieto), but their use and analysis require knowledge on spatial data programs and currently the data is still underused. Still, easy-to-use map services are available for visual viewing of maps (e.g. the environmental map service maintained by SYKE). However, there is a need for thematic maps in which different materials are computationally combined and which can be further processed with other materials from environmental databases. Model results on nutrient and solids loads are also desired as map-based.

Figures 35-37 show some examples of thematic maps. Some of the maps do not have data on the Russian side. Since, for example, ecological classification is not done using the same method in Russia as in the EU countries.

At present, the consolidation of spatial data sets in transboundary river basins is difficult. Worldwide data are coarse in resolution which limits their use. Co-operation should promote the development of compatible spatial data sets. The classifications of soil maps are also different in the two countries and it would be good to harmonize the soil classes to make them easier to use. With regard to land use, it would be necessary to map the different land uses by field measurements in the Russian side in order to refine the accuracy of satellite observations. For example, a mapping of clear-cutting areas would be useful to do.

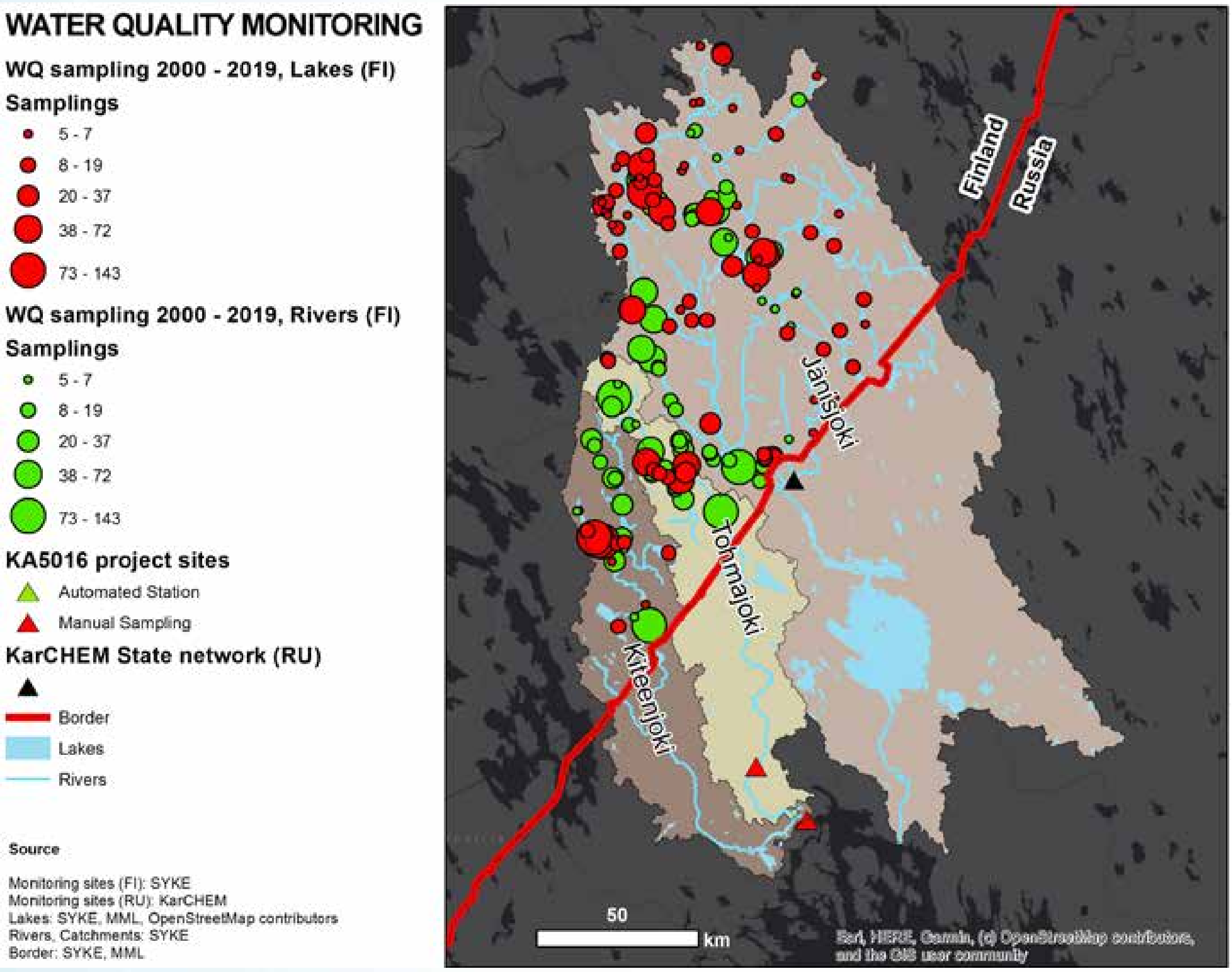


Fig. 35. The thematic map shows the number of water samples in both rivers and lakes in the three transboundary river basin districts. The figure also shows the observation stations in the Russian side.

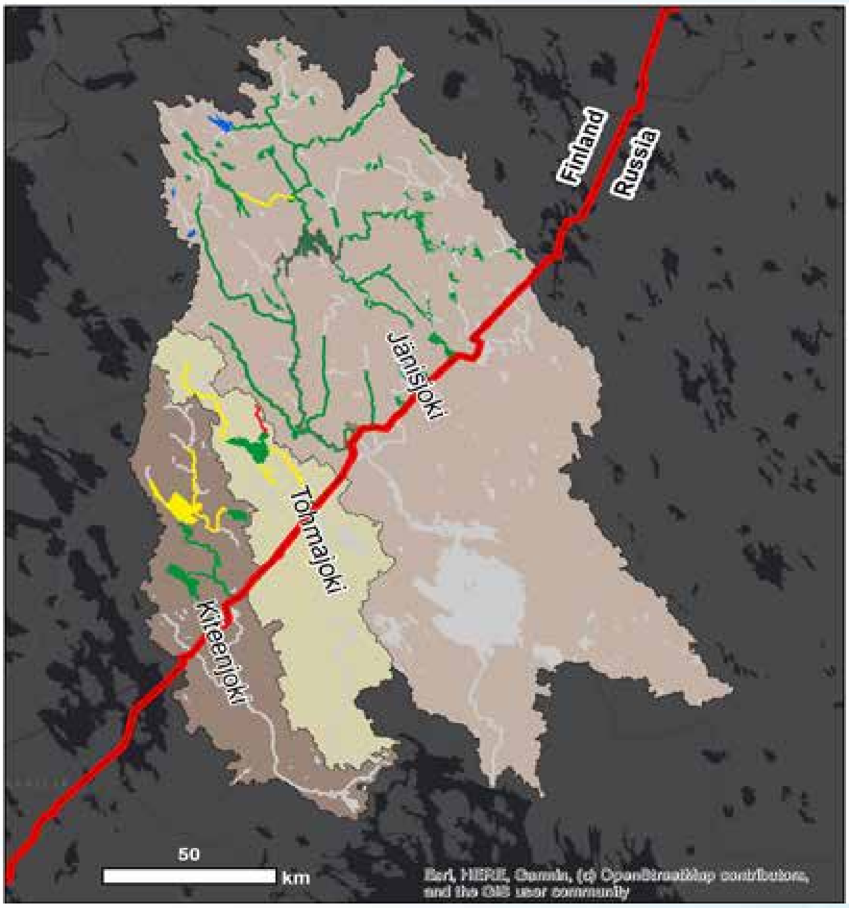


Fig. 36. The ecological status of the rivers and lakes in the Finnish side.

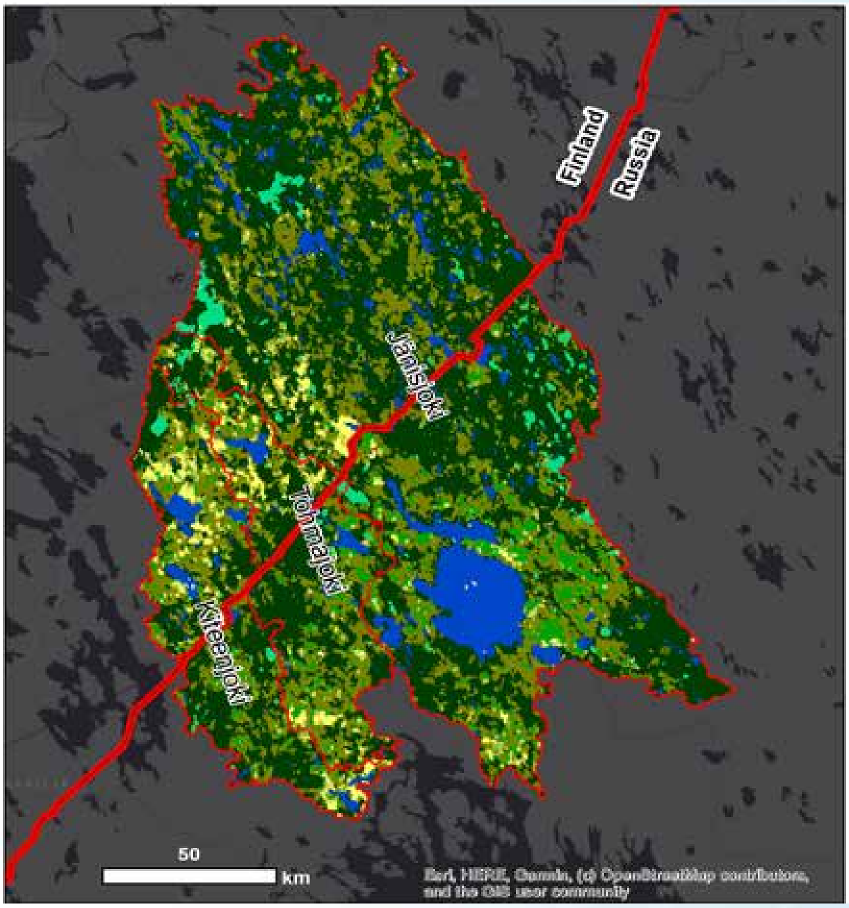


Fig. 37. The land use classes in the three transboundary river basins on both sides of the border.

2 PLANS FOR FURTHER IMPROVEMENTS

2.1 Spatial coverage and parameters.

The environment is subject to increasing anthropogenic impact. At the same time, the demand for high-quality water is growing and legislation on environmental pollution is being tightened. The policy of modern states in relation to the environment should contribute to the achievement of the goals of preserving, protecting and improving the quality of the environment, and the careful and rational use of natural resources. It is necessary to integrate the protection and sustainable management of water resources in all areas of the economy: energy, transport, agriculture, fishing and tourism. When planning action programmes, it is necessary to take into account the different conditions and needs of natural resource use, as well as regional and local conditions.

On the territory of the Republic of Karelia there is a significant number of cross-border Russian-Finnish water bodies, including the Saimaa-Vuoksi catchment area. Information about the largest water bodies located both on the territory of Karelia and on the adjacent territory of Finland, as well as information about the presence of sampling sites on these water bodies of the state monitoring network of Roshydromet is presented in the table.

№ п/п	Waterbody (water course)	Location		Presence of state observation points and observation type
1	the Olanga river (Oulanjoki, Oulankajoki)	originates from Finland	flows into Kumskoye reservoir (the river Kovda catchment area)	none
2	the Pistojoki river	arises from Finland (Lake Multijarvi)	flows into Lake Upper Kuito (the river Kem catchment area)	none
3	the river Voinitsa – Voinitsa settlement	arises from Finland (Lake Ala)	flows into Lake Ketojarvi	hydrology
4	the river Tula (Luzhma)	flows from Lake Tulos (the river Lieksa catchment area)	flows intoFinland	none
5	the river Lenderka – Lendery settlement	flows from Lake Sula (the river Vuoksi catchment area)	flows into Lake Pielinen in Finland	hydrochemistry and hydrology
6	the river Shaverko	flows from Lake Kusloksa	flows intoFinland	none
7	Lake Viksinselka	partly on the territory of Finland (the river Vuoksi catchment area)		none
8	the river Janisjoki – Hamekoski settlement	arises from Finland	flows into Lake Ladoga	hydrology
9	the river Tohmajoki	arises from Finland	flows into Lake Ladoga	none

10	the river Kiteenjoki	Lake Ladoga catchment area		none
11	Lake Pyhajarvi	mostly on the territory of Finland (the river Vuoksi catchment area)		none
12	Lake Korpijarvi	partly on the territory of Finland (the river Vuoksa catchment area)		none
13	Lake Tyrjanjarvi	partly on the territory of Finland		none
14	the river Juvanjoki	arises from Juvanlampi, flows through Finland and returns to Russia		hydrochemistry and hydrology
15	the river Asilanjoki (Hiitolanjoki, Kokkolanjoki)	arises from Finland (Lake Simpelejarvi)	flows into Lake Ladoga	none

The sequence of development of monitoring of transboundary water bodies should be based on long-term plans for the development of territories, as well as the vulnerability of ecosystems. The analysis of the strategy of socio-economic development of the Republic of Karelia until 2030 allows us to draw conclusions that the territories of Petrozavodsk-Kondopoga agglomeration, Ladoga region and Kostomuksha will be most actively developed. Thus, the focus of the development of water monitoring should be placed on water bodies located in these territories: the Janisjoki and Tohmajoki rivers, Asilanjoki and Kiteenjoki.

The river Olanga, Voinitsa, Pistojoki and Shaverka flow through sparsely populated territories with poorly developed infrastructure. The absence of industrial enterprises and agricultural production minimizes the risks of contamination of water bodies on the territory of the Republic of Karelia and monitoring of these rivers can be conducted for the purpose of background control. In this regard, transboundary water bodies are even less susceptible to anthropogenic impact from the Russian Federation, since access to them is limited.

The border territories of the Kostomuksha city district are promising areas for the development of the mining industry and, as a result, air quality monitoring may become the most popular direction for the development of international cooperation in this region.

In Finland, national water quality monitoring guidelines are followed in the North Karelia region. The monitoring network consists of rivers and lakes so that information is obtained on long-term changes in water quality for waters of different sizes and inherently different types. Under state monitoring, observation sites are located in areas that are not directly affected by pollution load, such as an industrial or municipal wastewater treatment plant. Monitoring includes a wide range of both hydrochemical (physico-chemical) variables as well as biological variables such as phytoplankton, aquatic plants, bottom fauna and fish. The sampling frequency for hydrochemical variables varies within a year from two to more than 12 observations depending on the variability of the water quality of the water body. Sampling points are rotated, which means that some areas are monitored annually and some areas every three or six years. Some sites are monitored even more seldom if the water quality is supposed to be unchanged. Water authorities plan all national monitoring programmes, but nowadays, sampling and analysis of samples has been outsourced and carried out by consulting companies.

The effects of polluting activities are monitored through obligation monitoring, which is paid for by the operator (e.g. company or municipality). This is also called local pollution control which includes monitoring of polluting discharges (quality and quantity) and observations in the receiving water body. The water monitoring program (observation sites, variables, time of sampling, etc.) depends on the load and the receiving water body. The monitoring program is planned usually by a consultant and should be approved by water authorities. The obligation monitoring is carried out by a consultant firm or a water protection association with proper facilities.

In both national and obligatory monitoring international standards are used in sampling and laboratory analysis. Sampling personnel are trained, and they are mostly certified which means that they have shown they ability to take samples properly. Laboratories are accredited by FINAS Finnish Accreditation Service. Accreditation or third-party recognition of competence is a procedure that is based on international criteria.

The hydrological catchment areas have been delimited and the land uses have been mapped, so it is possible to calculate the distribution of the water load to different land use types, such as agriculture and forestry. This makes it possible to target water protection measures correctly.

Remote sensing has proven to be a suitable technique in the study of spatial and temporal variations in water quality. However, there are a number of constraints that require precise considerations prior to conducting these techniques. Developed models from remote sensing data require adequate calibration, and validation using in situ measurements and can be used only in the absence of clouds in the case of optical sensors. The spatial, temporal, and spectral resolution limitations of many current optical sensors can limit the application of remotely sensed data to assess water quality.

In the future, the use of remote sensing data will increase and, in general, the use of various types of data should be promoted. This means e.g. assimilation of remote sensing data, traditional data, continuous water quality data and citizen observations. In addition, this requires the promotion of new assimilation techniques and efficient and open data systems, as well as good cooperation between different actors.

A nationwide network of continuous water quality stations would have many benefits. Finland is already a major player in the use of continuous water quality measurements, so the creation of a national network is the next natural step in this development. New stations should be established in three different aquatic environments: rivers, lakes and coastal stations.

2.2. Maintenance systems in on-line monitoring

SYKE

Although the measuring system is so-called automatic on-line monitoring, it always needs on-site maintenance. These include e.g. various cleaning measures as well as ensuring the power supply to the station. In connection with maintenance, the general condition of the station and the attachments of the measuring equipment are checked, and the equipment is cleaned. The sensors are always cleaned according to each sensor type.

Optical measuring devices always need maintenance, even if they had an automatic cleaning method. There are various automatic cleaning methods on the market, the most common of which are currently compressed air cleaning (Fig. 9) and various mechanical brushes and wipers. During maintenance, compressed air cylinders or compressors, valves and tubing as well as mechanical cleaning equipment used in addition to compressed air cleaning are inspected, maintained and replaced if necessary. Moreover, there may be chemical antifouling treatments to keep equipment sensors and optical windows clean. This method can extend the maintenance interval, but it does not eliminate the need for maintenance.

The maintenance interval for optical devices depends largely on the water environment to be measured and the season. The equipment becomes more sensitive to fouling in warm water during the growing season than during the cold season. In winter, the need for maintenance is therefore usually lower. After cleaning the device, the results must always be monitored for any changes in the measurement level due to the cleaning. If cleaning affects the results, it is usually a sign of a too long maintenance interval.

The maintenance of the device is a very important part of a successful automatic on-line monitoring and must be adequately invested in. The measurement results must also be quality controlled regularly, in some cases even daily, in order to immediately notice any problem situations on the devices (Fig. 10). The person responsible for quality assurance must be one who has knowledge of the behaviour of the measured variables in different water environments and in varying water situations such as during peak and low flow periods.

In the near future the continuous water quality measurements will increase, but their use will be planned in more detail than today. Now when more measurements are available, their benefits can be viewed more reliably. It is quite probable that, for example, more frequent water sampling will in some cases suffice to refine the nutrient loads. On the other hand, for example, the effectiveness of a water protection method can be better assessed with continuous monitoring.

In the development of nutrient leaching models, on-line devices will certainly be used more. They allow us to significantly improve the process descriptions of the models. On the maintenance side itself, development work will certainly continue, but we will hardly get rid of manual maintenance completely in the future either.

More information on maintenance and quality assurance can be found in the quality manual translated into Russian (Tattari et al. 2019).

KarCHEM:

A significant part of pollutants enters water bodies from catchments as diffuse

Fig. 38. This device uses automatic compressed air cleaning before each measurement. The figure shows that the hardware itself is dirty, but the optical window is clean (left hand figure). In the figure on the right, the device has been completely cleaned.

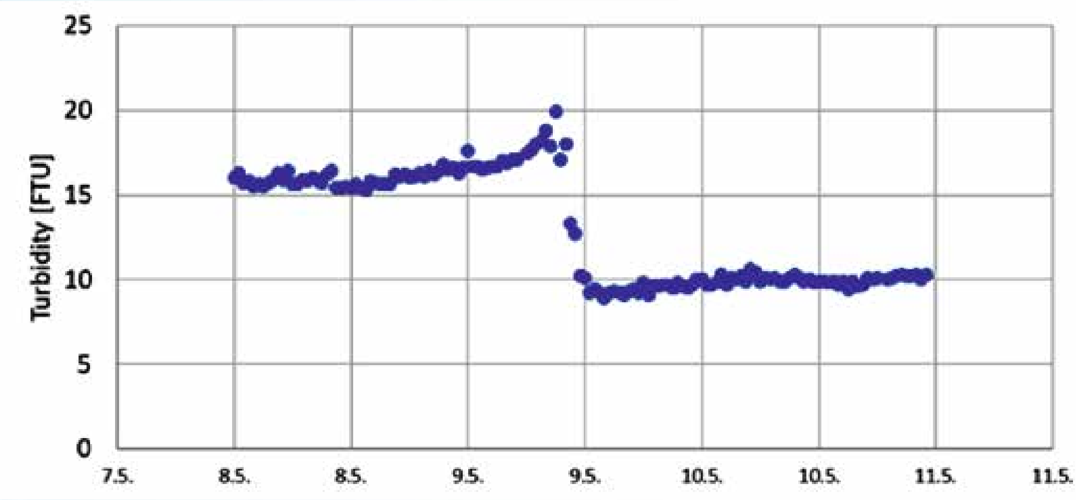


Fig 39. Example of a dirty optical lens. The level of turbidity rises and after the maintenance (9.5.) drops sharply.

load. In this regard, it is necessary to develop methods for assessing the volume and degree of negative impact caused by diffuse load from economically developed territories. With regard to river basins where water use is a common problem on both sides of the border, it is necessary to analyze the characteristics of the river basin and the possible anthropogenic impact on the river basin as a whole.

Since the current level of technological development of automatic monitoring systems does not allow controlling a large number of parameters, the priority components of monitoring should be based on the principle of prevention. This relies, in particular, on the identification of any potentially harmful consequences and on a scientifically based risk assessment. To prepare proposals containing a list of controlled ingredients, it is necessary to analyze widespread environmental pollutants, separately for each basin, as well as substances of concern.

To ensure consistent approach, an important step is to establish criteria for assessing the state of water, as well as standardizing monitoring and sampling methods.

The creation and development of the state information systems that provides public authorities and population information about the state of the environment and the sources of negative impact on it is a priority strategic direction in the implementation of state policy in the field of environmental safety of the Russian Federation. The specialized software developed in the framework of the project can be used as the basis for further development and digitalization of observation materials. The thorough modernization of the official website of the KarCHEM makes it possible to present monitoring data in real time and in the future can become a platform for presenting data from all new observation points.

2.3 Recommendations for monitoring water quality and quantity

Finland is an active member of many environmental organizations and is active in the environmental field. The information obtained during the project implementation on the monitoring system was used in the development of the territorial monitoring system of the Republic of Karelia, which is being developed by the KarCHEM under the instruction of the Ministry of natural resources and ecology of the Republic of Karelia in 2020. However, in order to ensure good water and air quality in border areas, it is necessary to coordinate the efforts of neighboring countries, which can only be organized within the framework of international cooperation.

Any attempt to evaluate water quality monitoring programmes should begin with the question Why do we monitor? This is stated e.g. by European Environment Agency that is collecting data from national monitoring programmes of its member states (https://www.eea.europa.eu/data-and-maps/figures/eea-member-countries-coverage). It is very important to be able to describe the purposes and objectives of monitoring as they create the background for the direct monitoring activities, i.e. the set-up of sampling networks, variables to be measured, sampling frequency, data storage and information utilization, including data analysis and reporting.

In Finland, the purpose of monitoring is generally laid down by laws or other regulatory actions (directives such as Water Framework Directive (WFD) and Nitrates Directive), water quality standards such as local pollution control, and action plans such as Baltic Sea Action Plan) and aim at assessing the environmental state and detecting trends. Often the same monitoring serves many different purposes.

There are many water policy instruments (see below) which also impose requirements for monitoring:

- Planning and long-term target setting - National water protection programmes - River Basin Management Plans (EU WFD)
- Legislation and enforcement
- Economic Instruments -Agri-environment subsidy - Water and waste water charges
- Information, education and research
- Financing - Rehabilitation of water bodies - Construction of wastewater and water supply networks
- International co-operation - Baltic Sea co-operation, transboundary waters, other activities - Financing water protection in the neighbouring areas

In addition, monitoring (mainly in short-term) is also carried out in research projects. At its best, research projects provide additional information on the implementation of monitoring and the introduction of new measurement methods.

In Finland, open access to environmental data is a common strategy and SYKE is a forerunner for that (syke.fi/opendatapolicy). SYKE maintains a national water quality database where is stored all national monitoring data, and data from local pollution control carried out by consultant firms and water protection associations. Some research data is also stored in this register. Open access makes it possible to combine different kind of data and thus increases the value of the data.

Finland and Russia have their own methods for water quality analyses and assessment (standards, laboratory practices, classification, norms, laws etc.). In this project we compared our methodologies and performed an intercalibration comparability test for basic water quality monitoring parameters to evaluate possible differences between results. This test gave us a lot of information and also visiting in SYKE's and KarCHEM's laboratories were brilliant ways to learn from each other and deepen our cooperation. SYKE invited KarCHEM to participate proficiency tests provided by SYKE's reference laboratory (syke.fi/proficiencytests).

SYKE monitors the state of the environment with the help of satellite technology and is a European forerunner in the efficient use of satellites (https://www.syke.fi/en-US/Current/Press_releases/Algal_rafts_water_temperature_ice_extent(58101). The TARKKA service (syke.fi/tarkka/en), which contains plenty of open data, can be accessed by anyone who wants to check on various natural phenomena and environmental changes, e.g. water temperature, ice-coverage, turbidity, Secchi disk transparency, chlorophyll concentration, algae blooms and humus absorption. In the TARKKA service it is also possible to find information from Russian side of the border and this could be used also by Russian people.

SYKE develops citizen science (syke.fi/citizenscience) to form informed and widely supported solutions for pressing environmental problems. Ordinary citizens, residents, pupils, amateur teams or NGOs are active agents creating new knowledge about environment in various fields. Citizen's voluntary contribution to research may include data collecting or processing, analysing and interpreting existing data. Citizen science plays a role in monitoring the impact of environmental policies and it raises debate about policy options.

The SYKE team proposes the following as areas for further development in the territory of the Republic of Karelia:

- a more precise delineation of hydrological catchments, especially transboundary catchments
- improvement of land use data
- land use shares in the catchment area above the observation point (agriculture, forest, bogs, point loads)
- mapping and monitoring of water quality in natural or near-natural areas in order to assess the impact of human activities in polluted water bodies
- re-evaluate the purpose of the monitoring
- check that the observation sites are correctly located
- evaluate the range of variables to be monitored
- consider rotation of monitoring sites in some areas
- examine the possibility of including biological variables in monitoring
- consider the possibility of including remote sensing products in water status monitoring
- updating the monitoring program
- testing of a continuous water quality measurement device on both sides of the border
- SYKE invited KarCHEM to participate proficiency tests provided by SYKE's reference laboratory
- in general, continuous analysis of results and response to change.