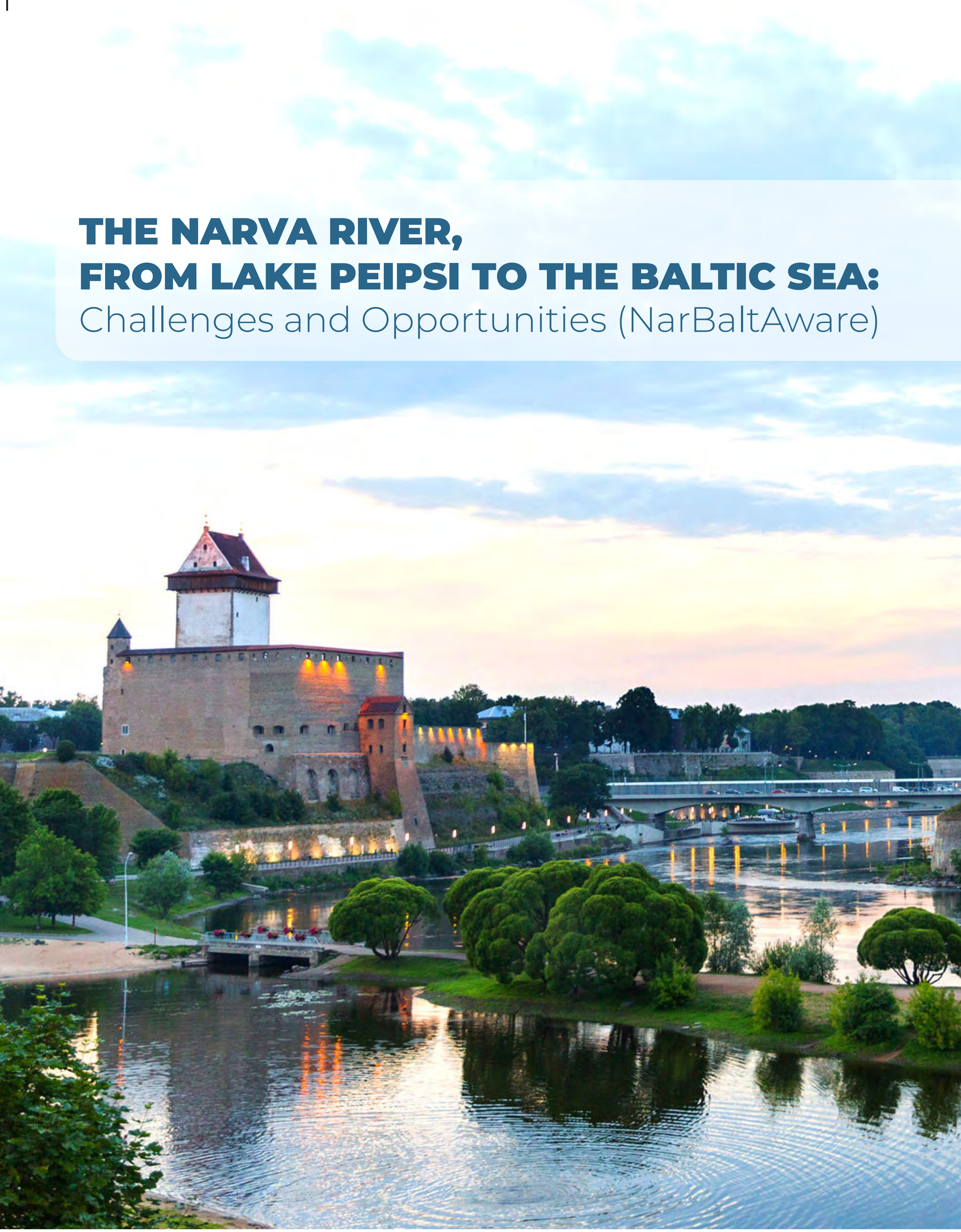
THE NARVA RIVER, FROM LAKE PEIPSI TO THE BALTIC SEA:
Challenges and Opportunities (NarBaltAware)



Booklet of Recommendations

TAL TECH

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HAZLESS

NARVA WATMAN

#ER101 Green Mind

European Union
European Social Fund

Leverage from the EU 2014–2020

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1 FOREWORD

The project "The Narva River, from Lake Peipsi to the Baltic Sea: Challenges and Opportunities" (NarBaltAware), implemented under the Estonian EU External programme 2014-2020 and co-financed by the European Union[1] strives to disseminate the results of the previously conducted projects: NarvaWatMan (ER25), Hazless (ER90), and GreenMind (ER101) while collaborating with the BBC1 (KS1699) project implemented under the South-East Finland-Russia CBC 2014-2020 programme.

All the projects were focused on the increasing resilience of the Baltic Sea region from the environmental point of view by conducting various events and research in the field.
The project partners of NarBaltAware, contributing to the dissemination of the aforementioned projects are Tallinn University of Technology, Peipsi Center for Transboundary Cooperation, and the National Institute of Chemical Physics and Biophysics in Estonia and the associate partner Mikkeli Development Miksei Ltd in Finland.

This booklet summarizes the results of the projects NarvaWatMan (ER25), Hazless (ER90), GreenMind (ER101), and BBC1(KS1699) for further dissemination among a wider audience. We also propose guidelines for combating environmental problems in the Baltic Sea region. Further, the findings of the projects and gained expertise are widely applicable to solving environmental issues in other similar areas.

2 INTRODUCTION

It is evident that environmental issues have become critical in every aspect of our lives. Increased greenhouse gas emissions lead to changes in weather patterns and thus climate change, which affects other parts of life, such as changes in water availability and quality. Also, enhanced industrial and agricultural activities driven by population growth put additional pressure on the valuable and finite natural resources on Earth.

European Union addresses these problems through its programmes that are created to fund projects focused on different aspects of environmental preservation.

The project NarBaltAware is a collaborative effort to disseminate the outcomes of the NarvaWatMan, Hazless, GreenMind, and BBC1 projects. The first three projects deal with environmental protection issues, particularly water-related problems and education, causes of water problems and work in the same Baltic Sea catchment area, while BBC1 deals with the acceleration of Business in Biotechnology and the Circular Economy in cross-border area, providing another point of view.

Thus, the collaboration enhances the emphasis on the above-mentioned issues and the importance of the solution to these issues. The projects intertwine in joint activities resulting in increased awareness of target population groups, new view angles, and approaches towards the environmental challenges and green technologies.

In this booklet we first summarize the results of the project GreenMind which focused on awareness-raising activities regarding Lake Peipsi, then describe the projects related to the environmental issues of the Narva River (NarvaWatMan) and the Gulf of Finland (Hazless) and end with the results of the project BBC1 regarding business aspects of biotechnology and circular economy in the cross-border region. Finally, we propose guidelines for future management of environmental issues in the area of Lake Peipsi to the Gulf of Finland.

3 ABOUT THE PARTNERS

3.1 PEIPSI CTC

NGO Peipsi Center for Transboundary Cooperation (Peipsi CTC, Tartu Estonia)[2] has worked since 1994 on environmental/global education and development cooperation issues. Our focus is on the Lake Peipsi region's multicultural communities while our mission is to preserve the natural/cultural heritage of Lake communities and educate people via interactive, innovative tools.

The NGO works with Estonian schools, youth centers, museums, and municipalities in Lake Peipsi region counties, to implement innovative educational activities (main topics: biodiversity, climate change, regional heritage), citizen science initiatives, etc. We have also been implementing development cooperation initiatives on environmental education, social entrepreneurship, and rural development in Eastern Partnership countries and elsewhere.

3.2 TALTECH

Tallinn University of Technology (TalTech, Tallinn, Estonia)[3] is the only technological university in Estonia. It was founded in 1918 and today is the most international one with more than 30 various degree programmes, including bachelor, master, and PhD levels.

The university implements new digital solutions for studying, research, and the entire university campus, using its TalTechDigital[4] initiative.

It also performs various research projects in the European Union and beyond in collaboration with other institutions and companies.

3.3 MIKKELI DEVELOPMENT MIKSEI LTD./MIKSEIMIKKELI

Mikkeli Development Miksei Ltd (Mikkeli, Finland)[5] is a business development company increasing business activity in the municipality of Mikkeli. We are a group of experts, providing business services as:

- growth and development services
- establishing a company and acquisitions
- sales-, marketing- and export services
- tourism productization and marketing
- invest in Mikkeli

MikseiMikkeli serves around 1000 clients each year and more than 40% of companies in the region are established with its help. The services range from start-up to growth financing and from employer services to regional development projects.

MikseiMikkeli actively participates in international projects, programmes, and selected networks, which involve partners from Europe and beyond. We are actively looking for partners within the EU programs such as Horizon Europe and Interreg. MikseiMikkeli is a reliable project partner with a proven track record, consisting of dozens of already finished projects and available references.

[2] https://ctc.ee
[3] https://taltech.ee
[4] https://taltech.ee/en/taltechdigital
[5] https://mikseimikkeli.fi/?lang=en

3.4 KBFI

The National Institute of Chemical Physics and Biophysics (KBFI, Tallinn Estonia)[6] is a public interdisciplinary research institute founded in 1979. Basic and applied research is carried out in the areas of Chemical Physics, Chemical Biology, High Energy and Computational Physics, and Environmental Toxicology. The partners of the project NarvaWatMan work in the area of Environmental Toxicology. The Laboratory of Environmental Toxicology at KBFI has a long-standing expertise in the evaluation of pollution from the oil shale industry in Northeastern Estonia and assessing the safety and hazards of novel materials (specifically nanomaterials) to the aquatic biota and the environment. In addition to basic research, the laboratory conducts ISO and OECD standard toxicity testing and analytical chemical measurements [7]. The laboratory adheres to the principles of 3R (Replacement, Reduction, and Refinement), and contributes to the aims of the EU's REACH policy.

4 RESULTS AND RECOMMENDATIONS

4.1 THE GREENMIND PROJECT

GreenMind project is implemented under the Estonian EU External programme 2014-2020 and co-financed by the European Union from 01.08.2019- 31.05.2022. The partners of the project are Pskov regional public organization "Lake Peipsi Project (Pskov)", The state budgetary institution of additional education of the Pskov region «Pskov regional center of the development of gifted children and youth», NGO Peipsi Center for Transboundary Cooperation, and Foundation Tartu Environmental Education Centre.

The project aimed to increase the green-oriented thinking of the society in the transboundary Peipsi/ Chudskoye region, to create environmentally oriented, energy-efficient, and attractive living conditions and recreation.

4.1.1 FORMAL AND NON-FORMAL ENVIRONMENTAL EDUCATION

Europe faces persistent problems in areas such as biodiversity loss, resource use, climate change impacts, and environmental risks to health and well-being. The continent continues to consume more resources and contribute more to environmental degradation than other world regions[8].

Thus, during the last decade, environmental education has gained importance globally as the "alarm clock" is ringing now really loud. Politicians and educators understand the urgent need to better educate young people on the complexity and interconnection of ecological, economic, political, cultural, etc. issues and develop creative problem-solving skills. This also requires new types of educational methods and teacher education.

Contributing to high-quality environmental education is one of the priorities of the Estonian Ministry of the Environment and its sub-agencies while cooperating in this field with the

[6] https://kbfi.ee/
[7] https://kbfi.ee/environmental-toxicology/services/?lang=en
[8] Europe Environmental Agency; https://www.eea.europa.eu/en/topics/at-a-glance/state-of-europes-environment#:~:text=Europe%20faces%20persistent%20problems%20in,degradation%20than%20other%20world%20regions.

Ministry of Education and Research. In order to increase environmental awareness and enhance the work in the field of environmental education, the state understands the need to create synergies also with universities, environmental education centers, and NGOs.

The recent research also suggests that non-formal and interactive approaches in environmental education are more effective than purely fact-based teaching, and thus there are several NGOs in Estonia that work with global/environmental education through innovative methods.

When formal education is provided in school settings then **non-formal environmental education** takes place outside of the classroom – in forests, parks, nature centers, lakeside, etc. Here, children experience more social and interactive play, hands-on activities, and self-discovery that help fuel the student's curiosity.

The lessons learned in this article are collected from the Interreg EstRus program project "Greenmind. Raising Environmental Awareness in Estonian-Russian Border Area", implemented during 2019-2022 but also our other environmental/ global education initiatives.

The Greenmind project tackled Lake Peipsi region's environmental challenges such as eutrophication, loss of biodiversity, waste management, etc.
Through our toolkits /various environmental education materials, and media messages we contributed to the improved quality of environmental education in the Lake Peipsi region and to the more environmentally friendly attitudes of the general public.

Deliverables such as the textbook on Peipsi ecosystems, on- and offline quizzes, crossword, LoqQuiz orientation game, educational videos, teachers' trainings, and creative workshops were of most interest among our target group.
The project partners developed innovative educational toolkits, tested new methods, educated educators, and increased environmental awareness efforts in transboundary Lake Peipsi region communities.
Some of the good examples of tools used and lessons learned are described below.

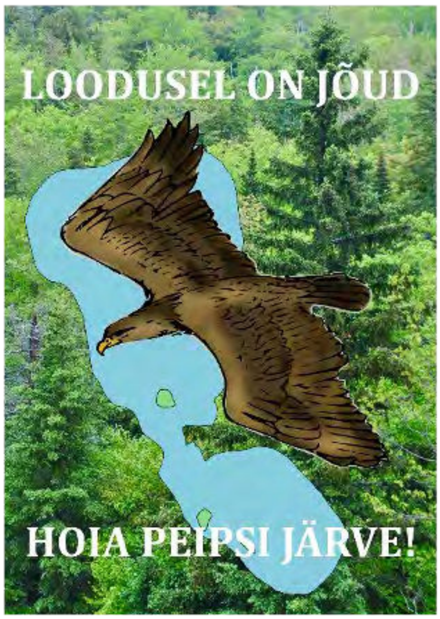

Figure 4.1.1 Art work for environmental advertisement contest

Creative methods

The use of art in the learning process promotes both the versatile empowermen t o f learners' intelligence and the integrated development of their personalities (Fragkouli, Koutsoukos, 2018[9]).

[9] Fragkoulis, Iosif, and Koutsoukos, Marios (2018), Environmental Education through Art: A Creative Teaching Approach. In: Education Quarterly Reviews, Vol.1, No.2, 83-88.
DOI: 10.31014/aior.1993.01.01.8

It is believed that self-expression, through being creative and playing with materials, and also with IT tools encourages a person's imagination and thinking processes. Promoting learners' creativity allows them to produce new understandings, experiencing the world from different perspectives.

Figure 4.1.2 Green Mind wall calendar with environmental messages


Figure 4.1.3 GreenMind eco-advertisement at Lake Peipsi beach

In 2021 we organised a competition on environmental artworks which was calling to act more environmentally friendly. We received different forms of self-expression, including posters, comics, videos, and animations. Some of the best works were printed as posters and presented in Lake Peipsi region public spaces, including beaches, etc.
In the Greenmind project, we also developed a multilingual wall calendar with inspiring drawings and environmental hints for each month.

<u>Live-Action Roleplay</u>

Educational Live-Action Role Play (EduLARP) as a non-formal learning method has long been known, but it has not been much practiced in Estonian educational institutions[10]. LARP is a form of spontaneous, co-creative, active learning. The unique experience of role-playing enhances student engagement, social skills, interest, and mastery of scholastic subject matter. In LARP participants physically embody characters within a fictional scenario for extended periods of time.

We have developed several LARPs and tested them in schools. For example, we created the scenario of UN Sustainable Development Goals an experience-based role-playing game Estonia 2121, that allows envisioning what life might look like when states do not pay enough attention today to environmental issues. The game creates laboratories with research groups, whose purpose is to study and map the current situation and start ecosystem restoration work.
The LARP game development and play with children is however rather demanding and time-consuming both for teachers and children.

DOI: 10.31014/aior.1993.01.01.8
[10] See also: https://ctc.ee/projektid/kaimasolevad-projektid/rohelineopilarp

Active /orienteering games

Outdoor environmental orienteering events require limited infrastructure and can be implemented at different times of the year. Orienteering provides both mental and physical challenges. The orienteering games can easily combine multiple subjects, e.g., Biology-math-history, and promote integrated learning concepts.

We have developed and tested environmental orientation games, aiming to introduce local biodiversity and ecosystem services, using the LoqQuiz app. Players need to find the spots and also answer the questions; to have more fun we were also using photos for augmented reality; creative tasks - such as making up a short poem, etc.

Educational videos

Videos have become an important part of different levels of education and are well-appreciated by learners and teachers.
It is believed that there are 3 main elements to be considered when designing educational videos (Brame, 2017 [11]). *The cognitive load* element should be taken into consideration as our working memory has two channels for information acquisition and processing: a visual/pictorial channel and an auditory/verbal-processing channel. The *student engagement* element guideline suggests that for maximizing student attention keep the video short and use a conversational style (personalization principle). *Active learning* suggests that we need to help students do the processing and self-evaluation through Interactive questions, making video part of a larger homework /group work assignment. The important thing to remember is that watching a video can be a passive experience but there are ways to make it more interactive.
Peisi Center for Transboundary Cooperation has published several bilingual videos (see also: https://ctc.ee/trukised/videomaterjal) e.g., on Peipsiland heritage plants, on famous Peipsi onions grown at old believers villages where the interaction is made between cultural heritage and environmental education. The video on Lake Peipsi and climate change can be used together with worksheets.

Online and offline Quizzes

Peipsi CTC has created around 10 multilingual quizzes on Lake Peipsi environmental issues, biodiversity, ecosystem services, cultural and historic heritage, etc. (available at: https://ctc.ee/quizzes).
The quizzes can be filled in online, but some are also available in PDF format /printed out.
The quizzes are a very engaging method both for children and adults to learn more about the home region's environmental challenges etc.

4.1.2 RECOMMENDATIONS

Our experience suggests that non-formal and narrative approaches in environmental education such as problem-solving exercises, role-plays, and storytelling can be more effective in the long run and engaging for the pupils than fact-based classroom teaching.
Here non-formal learning is characterized by learning by doing, as learners learn foremost from the specific situations they experience, while their attitudes and values would shape their future behavior. Also, environmental education should focus more on the importance of individual responsibility as well as the role of collective actions and networks in shaping energy transition processes.

[11] Cynthia J. Brame; Effective Educational Videos: Principles and Guidelines for Maximizing Student Learning from Video Content; Published Online: 13 Oct 2017 https://doi.org/10.1187/cbe.16-03-0125

It is very important to constantly work with educators, especially in rural areas, and smaller schools

4.2 THE NARVAWATMAN PROJECT

NarvaWatMan project is implemented under the Estonian EU External programme 2014-2020 and co-financed by the European Union from 15.03.2019 - 14.03.2022. The partners of the project are Tallinn University of Technology, Federal State Hydrological Institution, St. Petersburg City Government State Geological Unitary Company «Mineral» with associated partners Narva City Government, Department of City Maintenance; Administration of municipal formation «City Ivangorod Kingisepp municipal district of Leningrad Region».

Assessment of the river Narva water quality and water bodies in its basin according to Russian and Estonian estimation criteria are currently not comparable due to different resource (watershed data and time) requirements and sampling.
Chemical analyzing methodological approaches adopted in the national legislation are not comparable as well. In addition, there is no consensus in estimating the nutrient load carried with the river Narva flow to the Gulf of Finland, as well as in the allocation of this load between Russia and Estonia. Thus, the data provided to HELCOM (Baltic Marine Environment Protection Commission - Helsinki Commission) from both countries are not currently harmonized.
Addressing these issues individually in each country is impossible as it makes it difficult to offer common preventative measures to improve water quality for the conservation and sustainable management of shared water resources.
There is a lack of knowledge and information about actual flows and poor participation of the public and actors involved in assessing the quality of transboundary data in activities aimed at improving water quality in the region. The weak involvement of stakeholders hampers the expansion of international cooperation in the region and creates some bottlenecks for further cooperation in the field of environmental protection in general.

The goal of the project was the harmonization and sustention of the Narva River region. The main focus was on assessing the current methods of river discharge and pollution load estimation and producing new ones that would provide more precise data.

4.2.1 HARMONIZED METHOD FOR NARVA RIVER WATER RUNOFF ESTIMATION

Discharge (Q) is the volume of water that flows past a certain point in a stream over a specific period of time, usually expressed in cubic meters per second. Simply speaking, it can be computed by multiplying the area (A) of water in a channel cross-section by the average velocity (V) of the water in that cross-section.

In Estonia **Acoustic Doppler Current Profiler (ADCP)** is used for water discharge measurement, specifically the SonTek HydroBoard II (Figure 4.2.1). Using this tool, a reasonably accurate discharge measurement can be done in a fast and straightforward manner. The device uses the principles of the Doppler effect to measure the velocity of the water by sending a sound pulse into the water and measuring the change in the frequency of that sound pulse reflected back to the ADCP by sediment or other particulates being transported in the water.

Figure 4.2.1 SonTek HydroBoard II. [12]

Usually, river discharges can be manually measured several times a year and then the function Q=f(H) can be established for daily discharge calculation based on daily water levels (or stage), that are measured constantly. Here Q is the water discharge m^3/s and H - is the stage of the river in meters above the monitoring station zero.
This is also done for the Narva River and examples of the rating curves for 2018 and 2019 can be seen in Figure 4.2.2. To calibrate scattered points ice and vegetation coefficients are used.

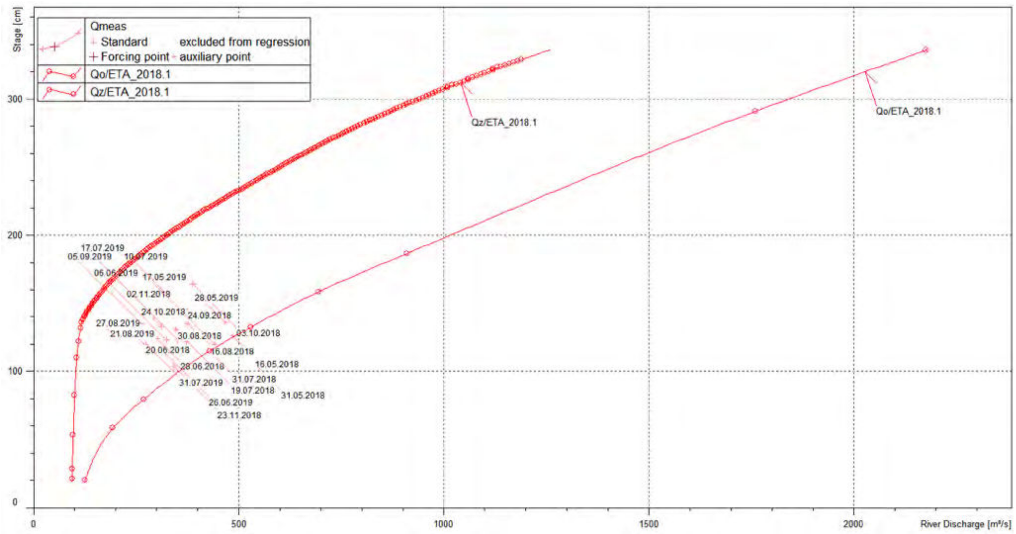

Figure 4.2.2 Narva River discharge curve constructed for 2018 and 2019.

However, additional circumstances are not considered: Narva River is relatively short, and the endpoint goes into the Baltic Sea (the Gulf of Finland), thus, sea level strongly affects the Narva River stage creating the affluent i.e., the backwater effect, making graphs points Q vs. H scattered off the curve.

In Russia, daily discharges of the Narva River are assessed by using the data on the amount of electricity produced by the Narva Hydroelectric power plant or Narva Hydroelectric generation station (HGS).[13]

[12] https://www.sontek.com/media/pdfs/hydroboard-web.pdf
[13] Feršel, A.-L., & Püttsepp, J. (2010). *The river Narva.* Tartu: Kuru.

The hydroelectric complex consists of three main structures: headwork, the derivation or supply channel, and powerhouse with appurtenant structures. The water dam is located 18.2 km from the mouth of the river. The regulation of the water regime of the river Narva is carried out by the system of structures by water passing through the derivation channel and the spillway dyke. The power plant's hydraulic performance is 760 m3/s. The total station capacity is 124.8 MW with a power factor of 0.8. During floods, the factor can be increased to 0,9 with a station capacity increased to 140 MW. [14]

According to Application 6 "Instructions for water flow assessment at the Narva HGS (HGS-13)" to the «Standard operating procedure for the operation of hydraulic structures of the Narva HGS», the volume of water flow through the HGS site is determined by the following components:

- outflow through hydraulic components turbines when working in active mode and at idle;
- outflow through the dam;
- outflow through the ice dam;
- outflow through the eel way.

For the daily discharge estimation at the station, the following values are measured and recorded:

- hourly:
  - headwater level;
  - upstream water level;
  - tailwater level;
  - gross head of the HGS (the difference between upstream and tailwater levels).

- at "0" hours daily:
  - readings of electric meters for each generator;
  - readings of a turbine flow meter.

- at "9" hours daily:
  - drop on the clear bar of each unit;
  - discharge according to the discharge indicator.

In addition to the listed above, the following is also recorded:

- the start and stop time of each unit and the duration of its operation per day;
- time, magnitude, and duration of the opening of each of the dam gates and ice passes.

As a result of processing the obtained data, the following quantities are determined:

- average daily headwater level;
- average daily tailwater level;
- average gross head for the turbines operating time;

[14] Zadonskaya, O., & Kobets, Y. (2019). *Report On Differences Between Estonian And Russian Methods And Results Of Water Runoff Estimation. Activity Output T1.2.1.* SHI. St. Petersburg: SHI.

- average head losses in gates clear bar for the turbines operating time;
- average net head for the turbines operating time (the difference between gross head and drop on the clear bar);
- average daily turbine discharge;
- average daily dam and ice pass discharge;
- average daily eel way discharge;
- average daily tailwater discharge;
- average daily residual flow discharge of the HGS.

Average daily turbine discharge, m^3/s, determined by the formula (1):

$$Q_{turb,\ avg} = \frac{\sum_1^3 V_{unit}}{T} = \frac{\sum_1^3 V_{unit}}{86400} \quad (1)$$

Where:

V_{unit} [m^3] – daily outflow through the unit (according to discharge indicator);
T=86 400 [s] – number of seconds per day.[15]

If the discharge indicator of any unit is taken out of operation for repair or because of a malfunction, the discharge through the unit is determined by its general-purpose operating performance (curves). The information on the Russian discharge estimation method is taken from the Report on differences between Estonian and Russian methods and results of water runoff estimation, performed by the Russian party.

As seen from the information above, the techniques of the two countries are radically different. Estonia relies on the mathematical method of establishing a discharge rating curve as recommended in various hydrological guidelines (WMO, etc.) while Russia solely relies on HGS data.

At first glance, it seems that in the case of Estonia discharge estimation, a lot of approximation takes place when making the curve. However, the Russian method leads to errors and mistakes due to equipment malfunctions and wearouts, considering that the plant was built in the year 1955.

The long-term discharge values difference between those derived from Estonia and Russia varies from 346 m^3/s (12/26/2009) to 861 m^3/s (04/15/2010) approximately.[15]

The agreed Russian-Estonian methodology for Narva River water runoff estimation

On the Russian side, the runoff is recorded at the Narva HGS, on the Estonian side - at the hydrometeorological gauge of the Narva River – Narva linn.

[15] Zadonskaya, O., & Kobets, Y. (2019). *Report On Differences Between Estonian And Russian Methods And Results Of Water Runoff Estimation. Activity Output T1.2.1.*SHI. St. Petersburg: SHI.

To assess the accuracy of river water runoff estimation at the Narva HGS and the monitoring station Narva River – Narva linn, as well as to develop a methodology for hydrometric estimation of the Narva River runoff, data from observations of water levels and water discharges for the multi-year period from 2003 to 2020 were used from the Estonian monitoring station at the Narva gauge and the Narva-Jõesuu river estuary gauge, data from observations of water discharges and levels at the Narva HGS (Russia), as well as observations and measurements obtained during joint Russian-Estonian experimental studies 2019-2020 on the section of the Narva River that lower than the Narva HGS.

To carry out experimental studies, the position of three gaging sections for measuring water discharges was chosen (gaging sections 1-3 in Figure 4.2.3): one − in the derivation (supply) channel; two - in the Narva channel (in the section of the Estonian monitoring station and between the fortresses), as well as a temporary level gauge equipped with an automated hydrological complex (AHC) is organized. The placement of the gaging sections is shown in Figure 4.2.3.

To substantiate the methodology, daily (average daily) and hourly data of observations of water stages at the following observation points were used:

- the tailwater of the Narva HGS;

- the temporary automated hydrological gauge of Federal State Budgetary Organization "State Hydrological Institute" (FSBO "SHI") (in the period from 31.07.2019 to 16.06.2020);

- the hydrological gauge of the Narva River – Narva linn;

- the hydrological gauge of the Narva River - the city of Narva-Jõesuu.

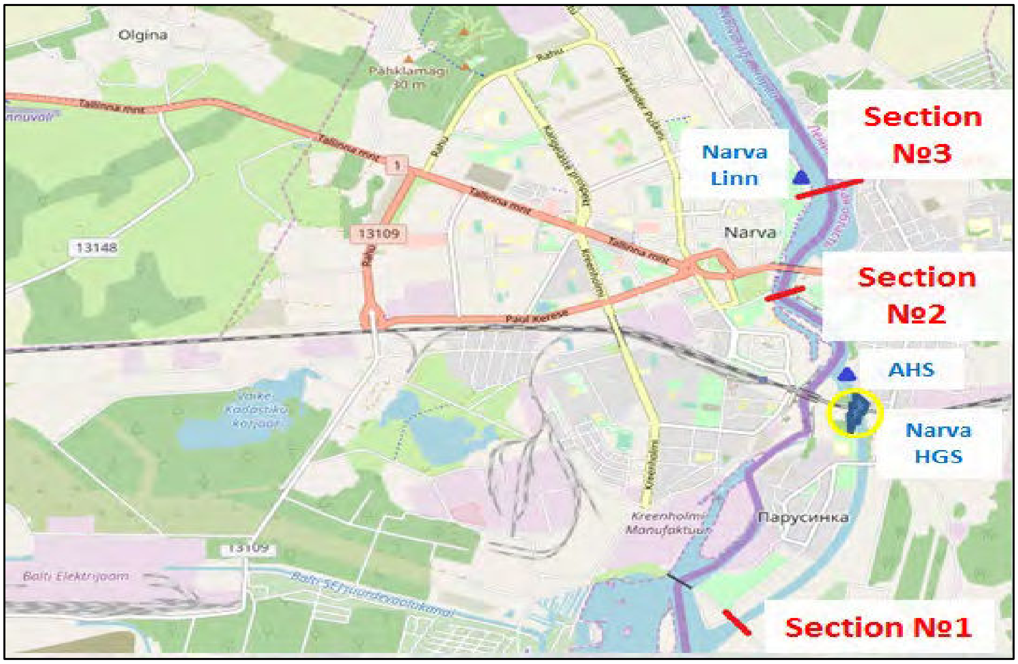

Figure 4.2.3 Hydrometric gauging sections on the Narva River below the Narva HGS.

Figure 4.2.4 Discharge measurements (Estonia)

To obtain the calculated dependencies of the river water runoff estimation methodology on the Estonian side, data from measurements of water discharges and water levels obtained within the framework of the project in 2019-2020 and water discharges measurements performed at the gauge of the Estonian monitoring station in the period from 2006 to 2014 were used. At the same time, for each water discharge measurement, the values of water levels observed at the time of discharge measurement at the Narva HGS tail water (Narva HGS/TW) and Narva – Jõesuu gauges were clarified.

To calculate water discharges, for the entire set of measurement data, the dependences of measured discharges on water levels Q(H) are obtained. During the development of the methodology, the dependencies obtained from the levels according to the data of three level gauges were compared: the level according to the AHC SHI $Q(H_{\text{AHC GGI}})$, the level in the tailwater of the HGS $Q(H_{\text{HGS(TW)}})$, and the level according to the gauge Narva linn $Q(H_{\text{Narva linn}})$.

As an additional variable reflecting the regimes of unsteady flow and variable backwater, the data of observations of the slope of the water surface in the sections: AHC SHI – Narva linn, HGS(TW) – Narva linn, AHC SHI – Narva Jõesuu, HGS(TW) – Narva Jõesuu, Narva linn – Narva Jõesuu were taken.

The quality of the approximation of the calculated dependence was evaluated by the following characteristics:

- the values of variance and mean square deviation of absolute (Dq и σq) and relative ($D_{\tilde{q}}$ and $\sigma_{\tilde{q}}$) regression residuals;

- estimates of the values of the mathematical expectation of the regression residuals, both absolute and relative ($q_{\text{cp}} \cong 0$; $\tilde{q}_{\text{cp}} \cong 0$).

The method uses the relative deviations of the MWD $\tilde{q}_и$ from the averaging dependence Q(H) or Q(H,I) as characteristics of the change in the flow capacity of the channel:

$$\tilde{q}_и = \frac{Q_и - Q(H_и I_и)}{Q(H_и I_и)} \quad (2)$$

where Q_m – MWD, m^3/s;

$Q(H_m, I_m)$ – the water discharge obtained from the dependence Q(H,I) for the H_m level and the slope I_m recorded during the measurement of water discharge Q_m, m^3/s.

For the water flow regime in the lower reaches of the Narva HGS, close to steady (stationary) flow, the best calculated dependence is obtained in the form of a multiple regression equation (3) using the following predictors:

- the water level at the Narva linn (Narva linn) gauge, expressed in m of the Baltic System;
- the square of the water level according to the gauge Narva linn ($H^2_{Narva\ linn}$);
- the slope of the water surface on the Narva River section from the tailwater of the Narva HGS to the Narva linn gauge (IHGS/TW – Narva linn), expressed in ppm (‰).

$$Q(H_{Narva\ linn}, I_{HGC(TW)\text{--}Narva}) = 46.9 + 241.3905 H_{Narva\ l} + 119.22152 H^2_{Narva\ l} + 732.105 I_{HGC(TW)\text{—}Narva\ linn}. \quad (3)$$

The equation has the following approximation quality characteristics:

$$\tilde{q}_{av} = 0.0,\ \sigma_{\tilde{q}} = 0.081$$

The dependence of water discharge on the water level at the Narva – Narva linn gauge and the slope of the water surface at the site downstream from the Narva HGS to the gauge Narva linn is shown in Figure 4.2.5.

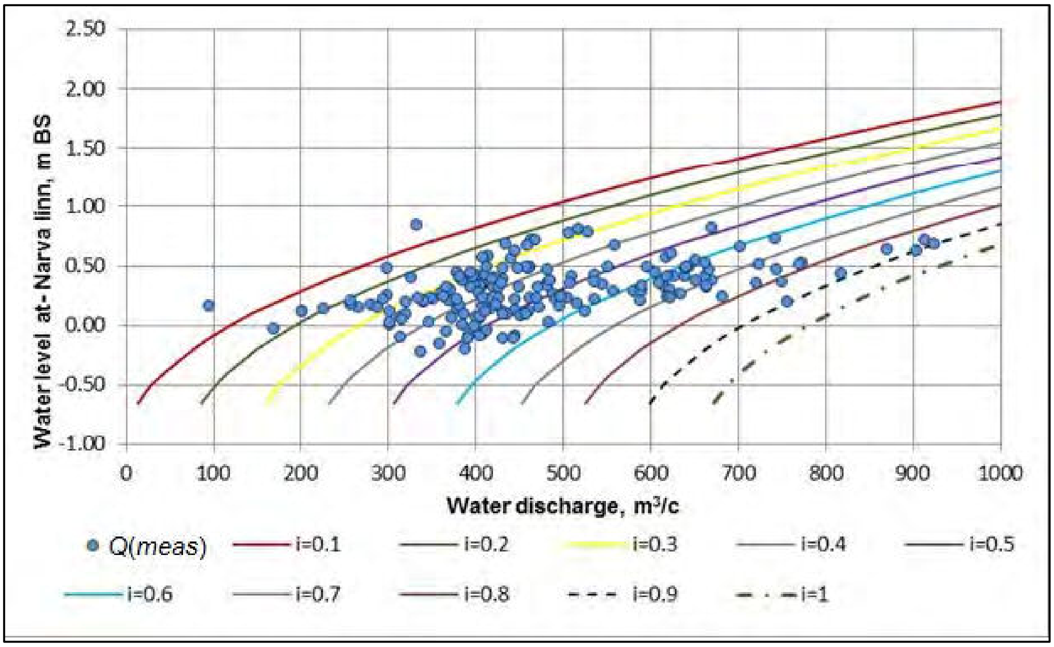

Figure 4.2.5 Dependence of water discharge on the water level of the Narva River – Narva linn gauge.

In accordance with the proposed methodology, the value of the average daily water discharge is calculated according to equation (3) using the average daily water level at the Narva linn gauge ($H_{\text{Narva linn}}$), expressed in m of the Baltic System, and the slope of the water surface at the site downstream from the Narva HGS to the gauge Narva linn gauge ($I_{\text{HGS/TW – Narva linn}}$), expressed in ppm (‰).

The slope of the water surface is calculated by the formula:

$$I_{HGS(TW)-Narva\ linn} = \frac{H_{HGS(TW)} - H_{Narva\ linn}}{L_{HGS(TW)-Narva\ linn}}, \tag{4}$$

where $H_{HGS(TW)}$ and $H_{Narva\ linn}$ – the average daily values of water levels in the tailwater of the Narva HGS and at the Narva linn post, respectively, in m of the Baltic System;

$L_{\text{HGS-Narva linn}}$ – the distance from the level gauge in the tailwater of the Narva HGS to the Narva linn gauge in km, assumed to be 1.95 km.

In conditions of pronounced unsteadiness of the flow in the tailwater of the Narva HGS, the calculation of river runoff should be carried out according to hourly observations of water levels and slopes of the water surface.

To estimate the unsteadiness of the flow, the parameter is used:

$$\chi = \frac{|\Delta I|}{I_{st}}, \tag{5}$$

where $|\Delta I|$ – the modulus of the difference in the slopes of the water surface: the observed I_m and the slope of the steady flow I_{st}.

The slope of the water surface of the steady flow at the site downstream from the Narva HGS to the gauge Narva linn is determined from the level of downstream HGS ($H_{HGS(TW)}$) in the formula (6), Figure 4.2.6.

River flow downstream of the Narva HGS should be considered to be steady if the value of the parameter χ does not exceed the value of 0.05: $\chi \leq 0.05$.

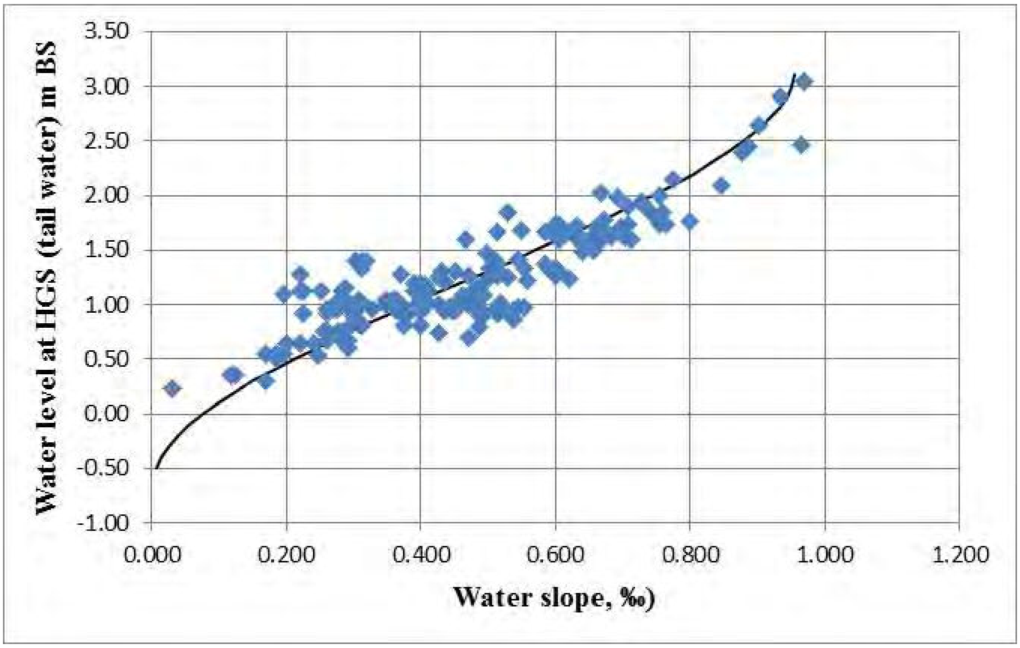

Figure 4.2.6 Dependence of the slopes of the water surface on the water levels in the conditions of steady flow at the site downstream from the Narva HGS to the gauge Narva linn.

The dependence of the slopes of the water surface on the water levels in the conditions of steady flow is approximated by the equation:

$$I_{st} = 0.0763 + 0.21345\, H_{HGS(TW)} + 0.1286 H^{2}_{HGS(TW)} - 0.0342 H^{3}_{HGS(NW)} \quad (6)$$

To calculate water discharges during periods of intensive daily regulation with pronounced unsteadiness of the flow ($\chi > 0.05$), the Jones formula should be used in the following form:

$$Q_p = Q_{st}\sqrt{\left|1 + \frac{\Delta I}{I_{st}}\right|}, \quad (7)$$

where Q_{st} and I_{st} are water discharges and slope of the water surface of steady flow, respectively;

$\Delta I = I - I_{st}$, I is the observed slope of the water surface.

The dependences of the steady flow Q(H) are also obtained for the level gauge of the lower Narva HGS, approximated by equation (8) and presented in Figure 4.2.7.

$$Q(H_{HGS/TW-}) = 100.52 + 264.7608H_{HGS/TW} + 33.676H^2_{HGS/TW}. \quad (8)$$

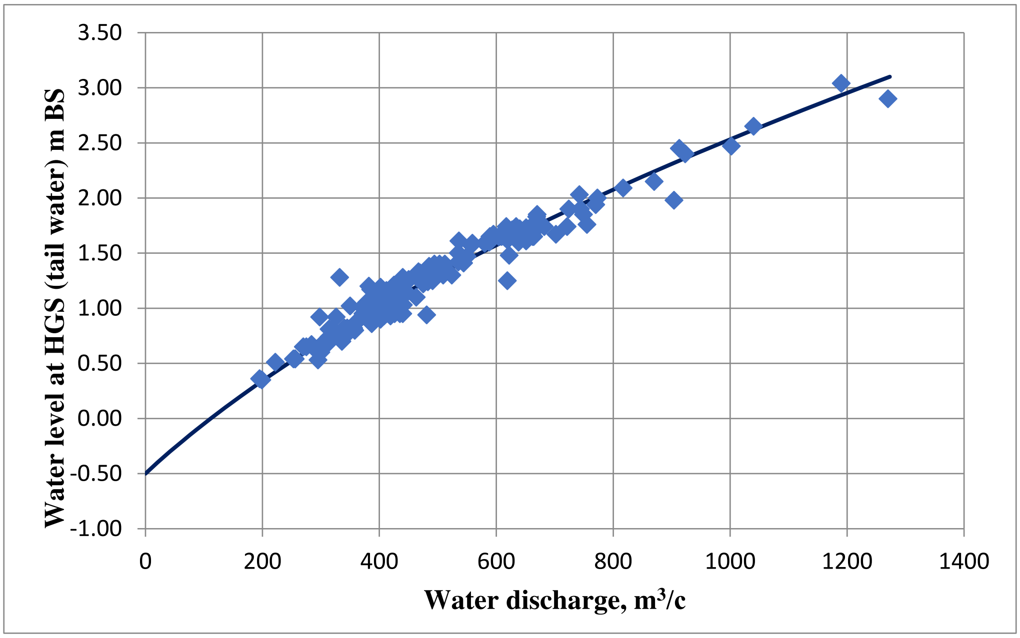

Figure 4.2.7 Dependence of water discharges on water levels of steady flow.

The values of Q_{st} and I_{st} in formula (6) are determined from hourly observations of the water level according to dependencies (7) and (5). The values of ΔI are determined from hourly observations of water levels in the tailwater of the Narva HGS and at the Narva linn post.

When calculating water discharges according to urgent hourly observations of water levels, the average daily value of water discharge is calculated as an arithmetic mean of the sum of hourly discharges divided by 24.

The average monthly water discharge is calculated as the arithmetic mean of the sum of the average daily discharges divided by the number of days in the month. The calculation is performed only if there are numerical values of the average daily discharge for all days of the month.

The average annual discharge is calculated as an arithmetic average of the sum of the real numerical values of the average daily discharges divided by the total number of days in the year.

In order to obtain the average annual discharge of the Narva River agreed between Russia and Estonia and submit it to international organizations (for example, to HELCOM), the average annual (monthly, daily) values of water discharge calculated according to the calculation formulas at the Narva HGS and according to the hydrometric river runoff estimation method for the Estonian gauge of the Narva river – Narva city are averaged through the arithmetic mean.

In order to improve the accuracy of water discharge measurements and calculations of the runoff of the Narva River in the future, it is necessary to implement a number of recommendations related to the graduation of the Narva HGS, the opening of an additional level gauge on the Estonian side, etc. Detailed recommendations are presented in a separate document.

4.2.2 HARMONIZED METHOD FOR NARVA RIVER POLLUTION LOAD ESTIMATION

Methods used for pollution load calculations

Various methods for pollution load calculation recommended by HELCOM Guidelines[16] were considered. They can be divided according to the frequency of concentrations and river discharge measurements. They also vary whether hydrological and chemical measurements are made at the same station. Three methods from HELCOM Guidelines[16] were used in order to test their applicability.

1. The first method is based on daily water flow and daily concentration. If on the day t measurements were not taken, daily water flow (Q_t) and concentration values (C_t) can be interpolated linearly between days.

Annual pollution load is calculated using the formula:

$$L = 0.0864 \sum_{i=1}^{n} (Q_t C_t)_t \tag{9}$$

n is the number of days;

L is annual load [kg];

C_t is concentration on day t ([mg/l] for nutrients, and [μg/l] for hazardous

substances);

Q_t is water flow [l/s].

The estimate in the equation is multiplied by 0.0864 for a nutrient to obtain the daily loads that are summarized in the equation over the whole year and by 0.0000864 for hazardous substances.

2. The second method uses a mean monthly concentration and monthly river flow. Monthly river flow is calculated as water flow multiplied by the number of seconds in a month.

Annual pollution load is calculated using the formula:

[16] HELCOM. (2019). HELCOM Guidelines for the annual and periodical compilation and reporting of waterborne pollution inputs to the Baltic Sea (PLC-Water).

$$L = 1/1000 \sum_{i=1}^{12} W_i C_i \quad (10)$$

L is annual load [kg];

W_i is a volume of monthly river flow [m^3] in a month i;

C_i is a mean monthly concentration [mg/l] in a month i;

When concentration is in [µg/l] (hazardous substances) the equation must be divided by 1,000,000.

3. In the third method, daily water flow and daily concentration regression are used. The calculation using daily regression should only be applied if there is a good relationship between the specific compound and the daily river flow.

Pollution load is calculated using the formula:

$$L = \mathrm{m} \sum_{i=1}^{n} Q_i C_{ri} \quad (11)$$

Where concentration is calculated from regression by the formula:

$$C_{ri} = \frac{a}{Q_i} + b + cQ_i \quad (12)$$

where

L is annual load [kg];

Q_i is a daily water flow in a day i (measured) [l/s];

C_{ri} is the regression value of the concentration for a day in [mg/l];

m is a conversion factor of units (0.0864 with a concentration in [mg/l] (nutrients) and 0.0000864 with a concentration [µg/l] (hazardous substances);

a, b, c are coefficients typical of each quality parameter, observation station, and time series;

n is the number of days per year.

However, the third method based on daily concentration regression is not applicable for the given data as there is no statistically significant relationship between the pollutants' concentrations and the daily water discharges.

4. There is also one additional method, which was considered in the study, that is called "flow-normalized". It uses mean monthly concentrations and flow in a day of concentration measurement. This method has the advantage that the influence of water discharge is eliminated. Intermediate data of flow-weighted concentrations can be used for additional analysis. The technique is not included in HELCOM guideline[16], but before the trend analysis, it is suggested to apply normalization first[17]. This means that the elimination of the effect of the hydrological conditions is mandatory anyway.

Thus, the first, second, and the "flow-normalized" further referred to as the third method were left for calculations of analyzed parameters: BOD – biochemical oxygen demand (BOD5); COD – chemical oxygen demand; NH4 – ammonium nitrogen; NO3 – nitrate; Ntot – total nitrogen; PO4 – orthophosphate; and Ptot – total phosphorus.

The comparison of methods

The visual analysis of the result graphs (Figure 4.2.8 - Figure 4.2.11) shows that the general tendency for each of the stations is that the II and III methods give very close results while the method I almost for every year gives the result that differs from the other two methods.

The comparison of methods is done by such statistics as standard deviation and z score. Standard deviation is one of the most common measures of data dispersion. The more spread out a data distribution is the greater its standard deviation. It was used for comparing the difference in results of pollution load calculation obtained by three methods. Standard deviation is measured in the same units as the original data. For this, it is more easily compared to the mean and other statistics that are measured in the same units as the original data[18].

Standard deviation is calculated by the formula:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \quad (13)$$

Where:

s is the standard deviation;

x_i is a value, for which the standard deviation is calculated;

$\bar{x}$ is a mean value;

n is a number of methods.

While these statistics compare each year and each pollutant separately, in order to make a conclusion about the method results as a whole, such statistics as the z score was used. It measures the number of standard deviations away from the mean a value is located. The mean value of the three methods by which pollution load is calculated is assumed to be the most probable value[18]. z-score is calculated by the formula: $z = (x - \bar{x})/s$,

[17] HELCOM. (2015). Updated Fifth Baltic Sea pollution load compilation (PLC -5.5). Baltic Sea Environment Proceedings No. 145.
[18] James, G. (2017). An Introduction to Statistical Learning: with Applications in R. Springer.

Where z is the z-score;

x is a value, for which the z-score is calculated;

$\bar{x}$ is a mean value; and

s is the standard deviation.

Table 4.2.1 Standard deviation of pollution load calculated for Narva linn station on the Narva River.

Quality indicator	Standard deviation				
	Average	Maximum		Minimum	
	t	t	Year	t	Year
BOD_5	806.99	1308.57	2012	88.27	2004
COD	7598.2	13562.36	2014	2271.39	2010
NH_4	11.96	22.54	2006	3.48	2007
NO_3	87.09	154.56	2004	24.9	2016
N_{tot}	323.28	740.91	2011	3.42	2010
PO_4	10.91	22.12	2005	2.68	2016
P_{tot}	22.15	71.78	2011	4.38	2015

The average z-score for Narva city station based on the I method is 1.14, the II method – 0.61, and the III method – 0.55. In Table 4.2.1, the average, maximum, and minimum standard deviations, and the years when they occurred during the period of observations are shown for each water quality indicator.

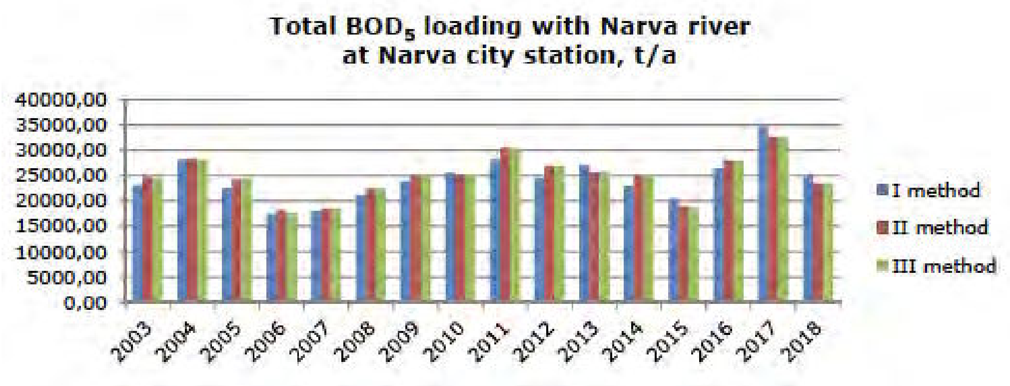

Figure 4.2.8 Total biochemical oxygen demand input with Narva River at Narva city station calculated by three different methods.

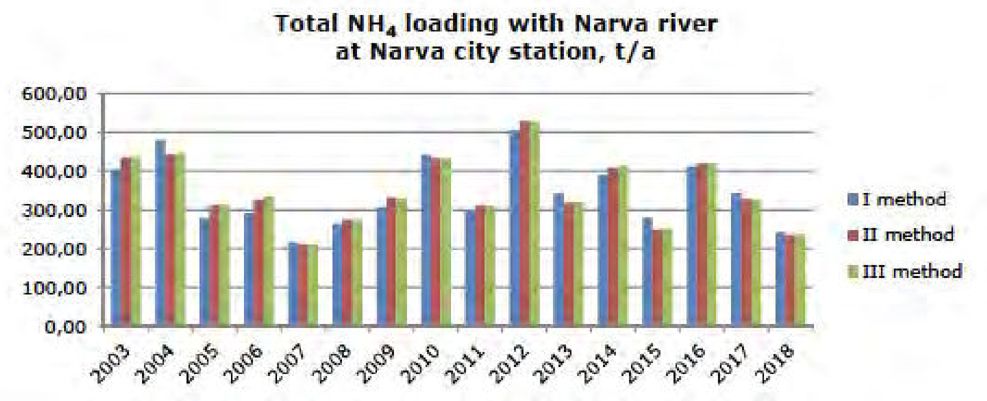

Figure 4.2.9 Total ammonia input with Narva River at Narva city station calculated by three different methods.

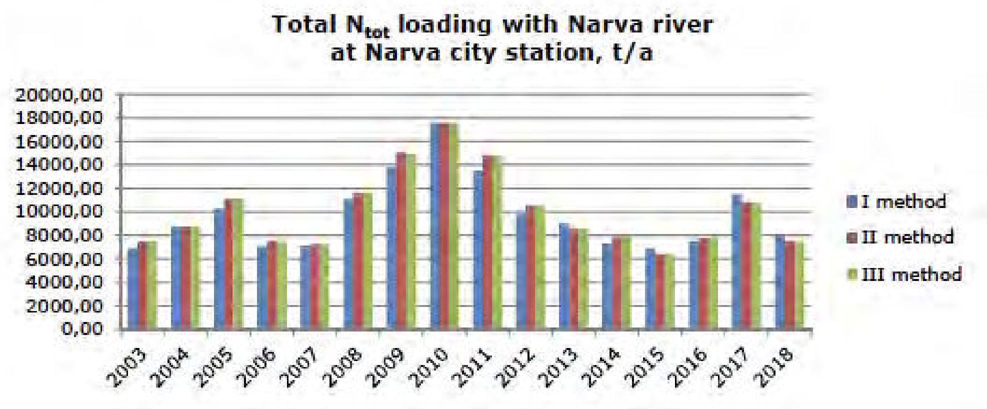

Figure 4.2.10 Total nitrogen loading with Narva River at Narva city station calculated by three different methods.

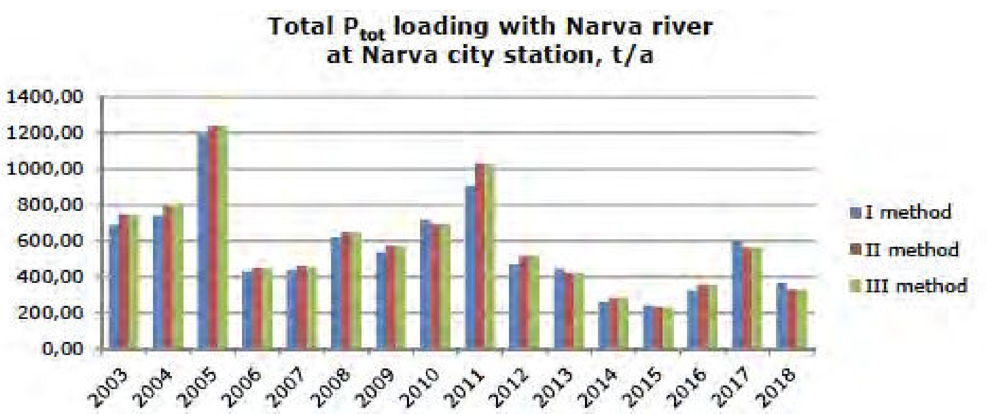

Figure 4.2.11 Total phosphorus input with Narva River at Narva city station calculated by three different methods.

Based on statistical analysis, it was concluded that the III “flow normalized” method gives the closest to the most probable result. Taking into account that this method is quite simple to apply, it was assumed that it is the best method to calculate the pollution load and to use as a “common”, or “harmonized” method.

4.2.3 JOINT WATER QUALITY INDEX (WQI) METHODOLOGY

Water Quality Index (WQI) is a tool for assessing water quality. WQI summarizes the selected water quality information into a single number that is easily understandable to the public and decision-makers. Currently, water quality evaluation in Estonia is based on the Estonian WQI method. However, it is quite simple and uses either the annual average value (Ntot, Ptot, etc.) or a certain percentile value of the quality indicator. Thus, it doesn’t consider the number of measurements and how many times an indicator exceeded or not the limit values. Therefore, the new WQI was developed.

There are many WQI models available and for the evaluation of water quality in the NarvaWatMan project, the Canadian Water Quality Index (CCME WQI) approach was chosen[19] as a single number that is easily understandable to the public and decision-makers.

CCME WQI is based on a combination of three factors (F): Scope (F_1), Frequency (F_2), and Amplitude (F_3). These factors are combined to produce a single value between 0 and 100 that describes water quality. The higher the index, the better the water quality. After testing different variations of WQI, some modifications to the original CCME WQI model were made during the NarvaWatMan project.

Modified Water quality index (MWQI) is calculated by the following equation:

$$WQI = \frac{F_1 + F_2 + F_3}{3} \quad (14)$$

Factors F1 and F2 are calculated as follows:

F_1 – <u>Scope</u> - represents the percentage of parameters that do not meet their guidelines at least once during the time under consideration (“failed parameters”), relative to the total number of parameters measured. 0,5 is a reducing coefficient that is used to make weights of the factors (F_1, F_2, F_3) more appropriate.

$$F_1 = 100 - \left(\frac{Number\ of\ failed\ quality\ parameters}{Total\ number\ of\ quality\ parameters}\right) * 100 * 0.5 \quad (15)$$

F_2 – <u>Frequency</u> - represents the percentage of individual tests that do not meet guidelines (“failed tests”)

$$F_2 = 100 - \left(\frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests}\right) * 100 \quad (16)$$

[19] CCME Water, 2017. *Canadian Environmental Quality Guidelines, Canadian Council of Ministers of the Environment.* https://ccme.ca/en/res/wqimanualen.pdf

F_3 – Amplitude - represents the amount by which failed test values do not meet their guidelines. F_3 is calculated in three steps:

Step 1: calculation of *excursions* - the number of times by which an individual concentration is greater than (or less than, when the guideline is a minimum) the guideline value.

In the case when the test value must not exceed the guideline value

$$excursion_i = \left(\frac{Failed\ test\ value_i}{Guideline\ value_i}\right) - 1 \quad (17)$$

In the case when the test value must not fall below the guideline value

$$excursion_i = \left(\frac{Guideline\ value_i}{Failed\ test\ value_i}\right) - 1 \quad (18)$$

Step 2: calculation of *normalized sum of excursions* (nse) – this is the collective amount by which individual tests are out of compliance. It is calculated by summing the excursions of individual tests from their objectives and dividing by the number of failed tests.

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{nr\ of\ failed\ tests} \quad (19)$$

Step 3: *F_3* is calculated by an asymptotic function that scales the normalized sum of the excursions from guidelines (nse) to yield a range between 0 and 100.

$$F_3 = 100 - \left(\frac{nse}{0{,}01 * nse + 0{,}01}\right) \quad (20)$$

Once the factors have been obtained, the index itself can be calculated as an arithmetical average from the three factors according to the above mentioned equation (WQI), and the water quality is classified into one of the following categories proposed within the Project (Table 4.2.2):

Table 4.2.2 Classification of WQI values into quality classes.

WQI value	0-54	55-64.99	65-79.99	80-89.99	90-100
Quality class	Bad	Poor	Moderate	Good	Excellent

Calculations and the results of the water quality index

The number and origin of the quality parameters can be chosen to fit the purpose of the need, but it is recommended to have at least 4 and in later recommendations at least 8 parameters included into the calculations. For the calculations of the joint WQI finally, 10 quality parameters were chosen: pH, Dissolved oxygen saturation, conductivity, BOD_5, COD, total nitrogen, ammonium, nitrate, total phosphorus, and phosphate. Limit values were chosen by experts from both countries, and these are presented in Table 2. Limit values depend on the type of river. Rivers were classified according to the organic (humic) substance content, which is evaluated as a long-term COD_{Mn} 90th-percentile value. According to the data analyses:

- River Type A – dark waters with high humic substance content, COD_{Mn} > 25 mgO/l
- River Type B - light waters with low humic substance content, COD_{Mn} < 25 mgO/l
- The Narva River belongs to a separate class.

In Table 4.2.3, parameter's limit values for WQI calculations are presented. In the table, COD values are given in two forms – COD_{Mn} and COD_{Cr}. The reason is the determination of different forms of COD in national river monitoring Programmes: COD_{Mn} in Estonia and COD_{Cr} in Russia.

Table 4.2.3 Parameter limit values for WQI calculations.

Nr	Parameter	Proposed limit values from NarvaWatMan partners		
		River type **A** (Waters with high humic substance content)	River type **B** (Waters with low humic substance content)	**Narva river**
1	**pH**	6.5-8.5	6.5-8.5	6.5-8.5
2	**O_2;** % Winter (Dec-Apr)	60	70	70
	Warm time (May – Nov)	70	80	80
3	**Conductivity;** µS/cm	620	420	350
4	**BOD_5;** mgO_2/l	2.3	2.3	2.0
5	**COD_{Cr};** mgO/l	61	29	34
	COD_{Mn}; mgO/l	40	19	22
6	**N_{tot}**; mgN/l	1.6	1.6	1.0
7	**NH_4^+**; mgN/l	0.2	0.2	0.1
8	**NO_3^-**; mgN/l	1.0	1.0	0.3
9	**P_{tot}**; mgP/l	0.06	0.07	0.05
10	**PO_4^{3-}**; mgP/l	0.04	0.02	0.02

On the Estonian side, rivers under the national monitoring program flowing into and out of Lake Peipsi were selected for the study (Table 3). All water quality data is originating from the national river monitoring program. On the Russian side not only the data of national monitoring but also rivers under departmental monitoring (Agency for Water Resources) were included. The full list is presented in Table 4.2.4.

Table 4.2.4 List of river chemical monitoring stations in the Narva River catchment area on the Estonian and Russian sides.

Estonian river gauges	River type	Russian river gauges	River type
Emajõgi_Kavastu	B	Velikaya-Vyaz (AWR)	B
Emajõgi-Kvissental	B	Velikaya-Pskov (AWR)	A

Emajõgi-Rannu	B	Velikaya-Pskov	A
Piusa-Saatse mnt	B	Piusa-Gorodishe (AWR)	B
Võhandu-Räpinast av	B	Piusa-Pechory	B
Avijõgi-Mulgi	A	Vyada (AWR)	A
Alajõgi-Alajõe	A	Sinaya (AWR)	A
Kullavere	B	Utroya (AWR)	A
Rannapungerja-Mustvee mnt	A	Lzha (AWR)	A
Mustajõgi-Mustajõe	A	Cherma (AWR)	A
Narva Narva	Narva	Gdovka	A
Narva_Vasknarva	Narva	Zhelcha-Nizovitsy (AWR)	A
		Zelcha-Yamm	A
		Narva-Ivangorod (1)	Narva
		Narva-Ivangorod (AWR)	Narva
		Narva-Ivangorod (2)	Narva
		Narva-source (AWR)	Narva
		Narva-Stepanovshina	Narva
		Narva-mouth (AWR)	Narva
		Plussa-Slantsy (AWR)	A
		Plussa-Slantsy	A

Initially, three-year data (2017–2019) were used to calculate WQI for all river monitoring stations. An example of the calculation is shown in Figure 4.2.12.

Emajõgi Kavastu	pH	O2, %	EC	BOD5	CODMn	Ntot	N-NH4+	N-NO3-	Ptot	P-PO43-				
	6.5	70	420	2.3	19	1.6	0.2	1	0.07	0.02				
	8.5	80												
2019														
03/01/2019	8.0	97	491	2.2	12.0	1.80	0.180	1.000	0.052	0.014				
04/02/2019	7.8	84	503	1.6	12.0	1.80	0.250	0.980	0.045	0.020				
04/03/2019	7.8	90	485	1.6	16.0	5.70	0.110	4.100	0.038	0.011				
01/04/2019	7.9	86	357	1.7	22.0	4.50	0.028	3.600	0.034	0.010				
02/05/2019	8.2	85	440	1.9	14.0	2.20	0.057	1.700	0.051	0.004				
03/06/2019	8.4	100	430	3.0	13.0	1.50	0.010	0.830	0.064	0.018				
01/07/2019	8.2	88	395	3.5	11.0	1.50	0.024	0.260	0.093	0.015				
06/08/2019	8.1	92	391	3.0	11.0	1.00	0.027	0.130	0.056	0.014				
04/09/2019	8.2	81	394	2.7	11.0	0.94	0.055	0.085	0.047	0.014				
01/10/2019	8.3	86	422	2.1	9.9	1.10	0.012	0.300	0.047	0.015				
05/11/2019	8.0	89	476	2.6	17.0	3.10	0.140	2.400	0.088	0.019				
02/12/2019	8.1	93	489	1.9	19.0	2.90	0.290	2.100	0.054	0.017				
											10			
F1											**65.0**	> par	SUM	>gr
F2	0	0	8	5	1	7	2	5	2	0	**75.0**	**30**	**120**	7
F3			0.17			0.13								
			0.20			0.13	0.25							
			0.15			2.56		3.10						
					0.16	1.81		2.60						
			0.05			0.38		0.70						
			0.02	0.30										
				0.52					0.33					
				0.30										
				0.17										
			0.00											
			0.13	0.13		0.94		1.40	0.26			sum e	nse	
			0.16			0.81	0.45	1.10			**60.7**	19.42	0.6475	
WQI 2019	**66.9**	moderate									66.9			

Figure 4.2.12 Example of WQI calculation for Emajõgi – Kavastu, 2019.

The result of the Water quality Map is shown for 2019 (Figure 4.2.13).

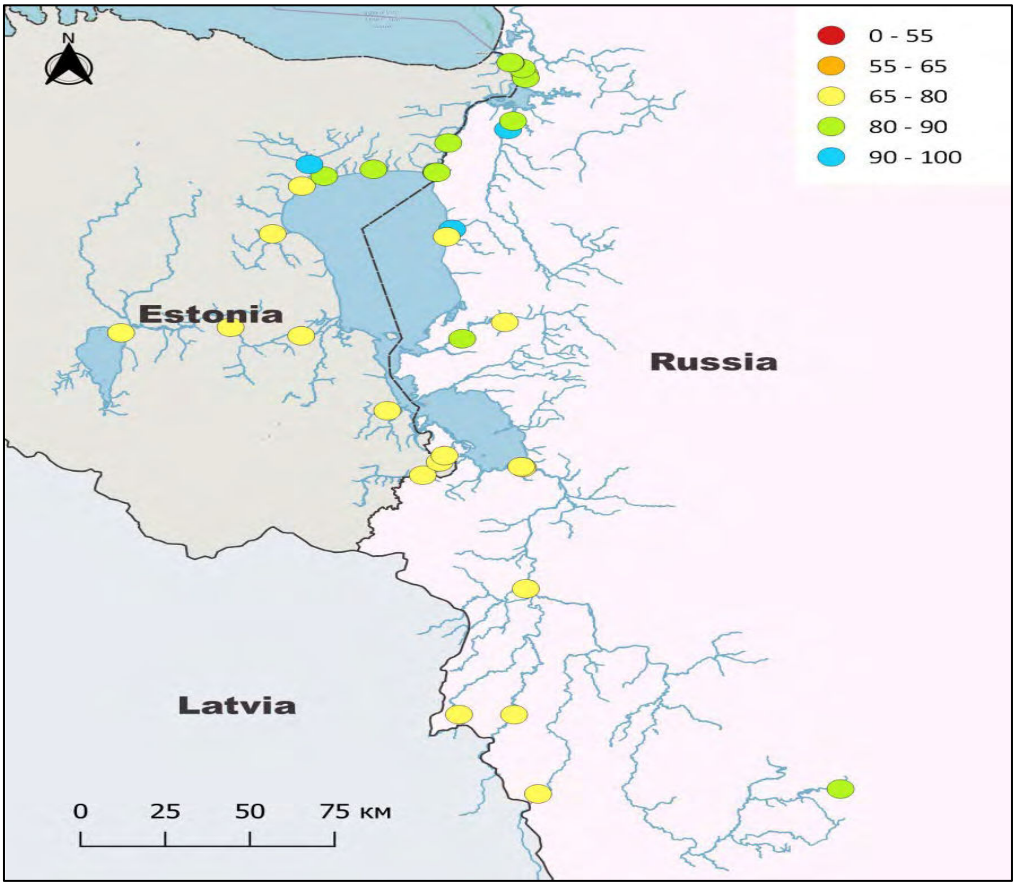

Figure 4.2.13 WQI in Estonian and Russian rivers, 2019.

To test the model over time, WQI calculations for selected river monitoring stations were performed for the period 2003-2019. The test results obtained with the modified WQI calculations for the long-term period are logical and showed an improvement in the quality of water bodies in the Narva River basin. These positive changes are also confirmed by the observed monitoring data.

4.2.4 RECOMMENDATIONS AND SUMMARY

Hydrological and hydrochemical monitoring i.e., monitoring of the water quantity and quality is crucial for environmental management, as it helps to assess the state of the water bodies and hence to come up with appropriate preventive or mitigative measurements. For instance, knowing the amount of biological matter or other indicators in water, we conclude if additional restrictions or regulations should be implemented in agriculture, wastewater treatment, and so on.

As was shown above, it is quite important to make the hydrological monitoring precise (time and place) as there are lots of factors that can distort its results, deeming them not useful, or worse, some important signs of ecological problems can be overlooked. It is necessary to consider local specificities, such as the backwater effect of the Narva River.

The NarvaWatMan project succeeded in developing a harmonized and common methodology for the Narva River discharge and pollution load estimation as well as the improved WQI. The developed techniques will help to eliminate previous discrepancies in hydrological data and therefore increase the resilience of the Baltic Sea region.

4.3 THE HAZLESS PROJECT

The Hazless project is implemented under the Estonian EU External programme 2014-2020 and co-financed by the European Union from 01.04.2019 - 31.08.2022. The partners of the project are Tallinn University of Technology, Zoological Institute of the Russian Academy of Sciences, Institution of Russian Academy of Sciences Saint-Petersburg Scientific-Research Centre for Ecological Safety, with the associated partner - Finnish Environment Institute.

The project was focused on the adaptation and implementation of uniform biological indicators for the assessment and control of environmental quality in the eastern Gulf of Finland where exchange of information regarding the evaluation of pressures, joint attempts to fill in gaps regarding HELCOM GES descriptors and boundaries, joint development of monitoring programs were needed. The project achieved success in both developing and harmonizing marine monitoring and environmental status assessment practices among countries that share a common sub-region (Figure 4.3.1).

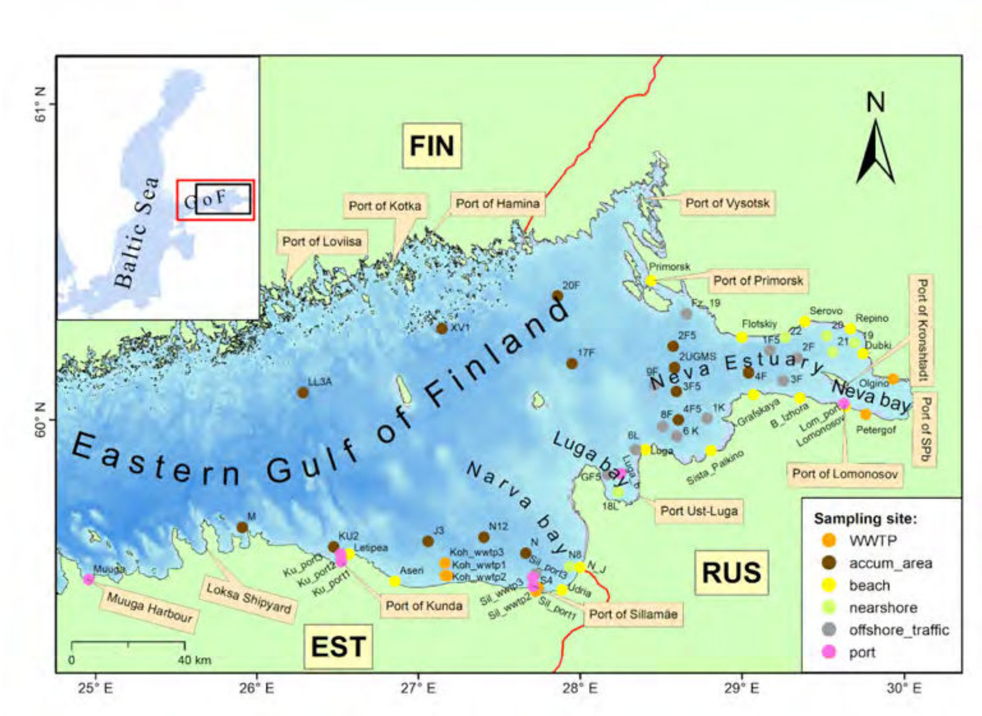

Figure 4.3.1 Study region, map of sediment sampling locations during 2019-2020 fieldworks, the classification of sampling sites is presented by colored dots (WWTP - vicinity of a wastewater treatment plant, accum_area - sediment accumulation area, beach - shallow coastal beach area, nearshore - area near the shore, offshore_traffic - the route of heavy marine traffic, port - area next to port). The red frame around the Gulf of Finland on the small panel of the Baltic Sea indicates the extent of the domain of the high-resolution nested model setup[20].

4.3.1 SAMPLING OF SEDIMENTS, WATER, BIOTA

Utilizing research vessels and employing various samplers for water, sediment, and biota, we conducted visits to numerous locations in the eastern Gulf of Finland (Figure 4.3.2). However, the initially proposed quantity of biota samples for chemical analysis could not be attained due to the insufficient availability of required material caused by the scarcity of benthic invertebrates at the stations visited.

[20] Kuprijanov, I., Väli, G., Sharov, A., Berezina, N., Liblik, T., Lips, U., Kolesova, N., Maanio, J., Junttila, V., Lips, I., 2021. Hazardous substances in the sediments and their pathways from potential sources in the eastern Gulf of Finland. Mar. Pollut. Bull. 170, 112642. https://doi.org/10.1016/j.marpolbul.2021.112642

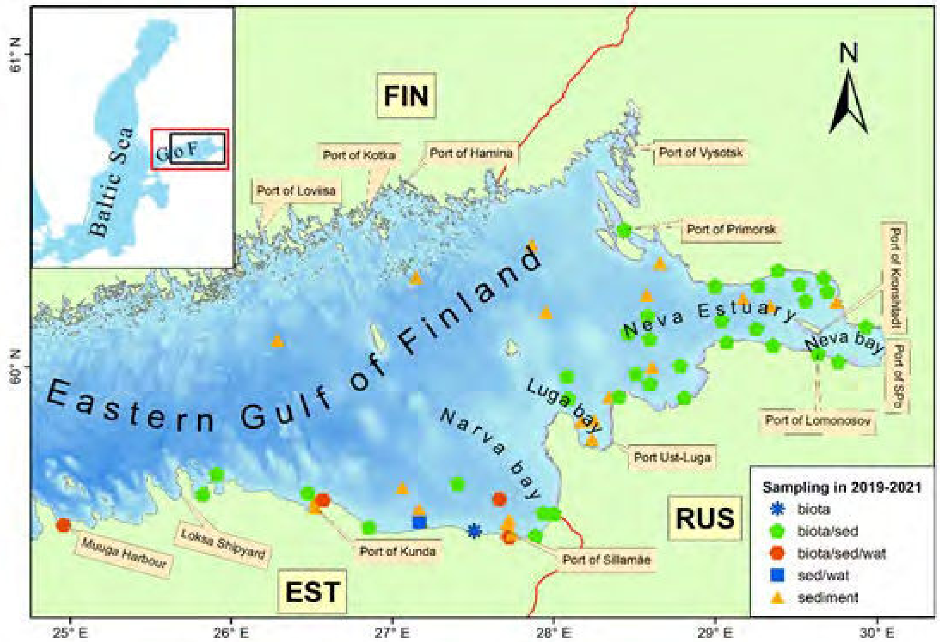

Figure 4.3.2 The study region's sampling stations have been organized based on the specific environments sampled.

The stations where biota and sediments were collected predominated, accounting for 33 stations or 52% of all visited stations (Figure 4.3.3).

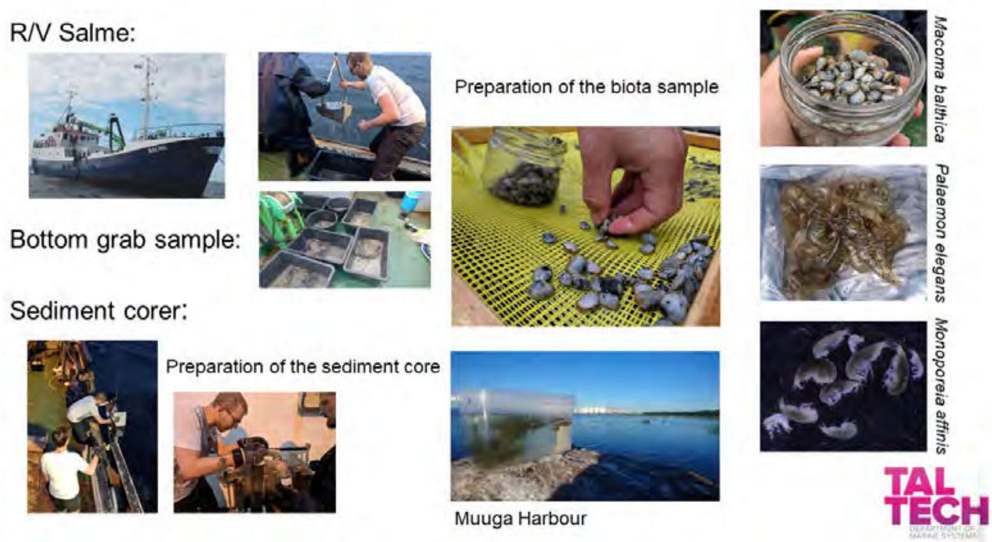

Figure 4.3.3 Sampling during the fieldworks in Estonian territorial waters (2019-2021).

Water

The overall recommendation for the sampling in the water environment might include the following aspects. The sampling campaign should consider water layers on the surface and near the bottom, as during resuspension processes (e.g., from water circulation due to currents) in the deeper areas along the shipping routes (including harbors) and estuaries, the water layer near the bottom might contain a higher concentration of pollutants. Chemical analyses conducted in the frames of the Hazless indicated that degradation products of tributyltin (TBT) might be found in the bottom water over the TBT polluted sediments near the shipping docks (at Muuga harbor) and at the offshore sediment accumulation areas (as in the case of Narva Bay). Whereas the extent of contamination by organic pollutants in the water column often depends on the contamination level of the underlying sediments.

Biota

Within monitoring activities, the sampling of filter-feeding mollusks must be preferred over other organisms where possible. These sessile macroinvertebrates efficiently accumulate all kinds of pollutants from the surrounding environment, though in comparison to suspension-feeding species, deposit feeders tend to highly accumulate polycyclic aromatic hydrocarbons (PAHs)[21]. However, some PAHs tend to degrade over time after exposure event due to physiological processes within the organisms[22]. It is worth mentioning that invertebrates have a lower metabolism capacity and relatively higher PAH concentrations in the body compared with fish[23].

The heavy metals (HMs) and persistent organic pollutants (POPs) accumulate in the bodies of aquatic animals characterizing the chronic contamination from diffuse or point sources nearby. Mobile animals (crustaceans, fishes) and macroalgae might be used in environmental monitoring, but with some reservations. Algae may accumulate HMs to some extent but for accurate assessment critical to consider rates of bioaccumulation from water/sediment (including sediment pore water). Thereby samples from different environmental matrices have to accompany the biota samples. Finally, the bioconcentration factor has to be calculated preferably, and sampling sites have to be intercompared [24].

The different fish species are effectively used in biomonitoring to collect information about the distribution and impact of hazardous substances in the aquatic environment. The high mobility of these organisms suggests migration over small/large areas, depending on the species and its migratory behavior. Therefore, it is often complicated to localize the contamination source

[21] Hickey, C.W.; Roper, D.S.; Holland, P.T.; Trower, T.M., 1995. Accumulation of organic contaminants in two sediment-dwelling shellfish with contrasting feeding modes: Deposit- (Macomona liliana) and filter-feeding modes: Deposit-(Macomona liliana) and filter-feeding (Austrovenus stutchburyi). Arch. Environ. Contam. Toxicol. 29, 221–231.

[22] Honda, M., Suzuki, N., 2020. Toxicities of polycyclic aromatic hydrocarbons for aquatic animals. Int. J. Environ. Res. Public Health 17. https://doi.org/10.3390/ijerph17041363

[23] Dsikowitzky, L.; Nordhaus, I.; Andarwulan, N.; Irianto, H.E.; Lioe, H.N.; Ariyani, F.; Kleinertz, S.; Schwarzbauer, J., 2016. Accumulation patterns of lipophilic organic contaminants in surface sediments and in economic important mussel and fish species from Jakarta Bay, Indonesia. Mar. Pollut. Bull., 110, 767–777.

[24] Gubelit, Y., Polyak, Y., Dembska, G., Pazikowska-Sapota, G., Zegarowski, L., Kochura, D., Krivorotov, D., Podgornaya, E., Burova, O., Maazouzi, C., 2016. Nutrient and metal pollution of the eastern Gulf of Finland coastline: Sediments, macroalgae, microbiota. Sci. Total Environ. 550, 806–819. https://doi.org/10.1016/j.scitotenv.2016.01.122

precisely, though the involvement of these vertebrate animals in the surveys is essential from the human consumption safety perspective (Food safety authority of Ireland, 2009). The POPs and HMs accumulate readily within species of bottom-dwelling (e.g., flatfish) and species with a high-fat content (e.g., salmonids, river lamprey), while biomagnification is responsible for the elevated level of chemicals in the areas of chronic pollution, specifically in the vicinity of port areas, where pollutants end up in the marine environment from various diffuse sources. According to previous studies, in Narva Bay, organotin compounds were elevated in herring near the port of Sillamäe, and in Muuga Bay, polychlorinated biphenyls (PCBs) in flounder near the Muuga Harbour[25].

The latest biomonitoring of commercially important fish species also revealed the high content of PCBs and dioxins within the salmon analyzed from the Narva-Kunda basin[26]. The cadmium (Cd) content in the river lamprey samples from the Narva River exceeded the threshold level established by the national quality guidelines[26]. When collecting samples from fish, it is important to consider that some POPs might accumulate more intensively in specific organs than in others (e.g., PFOS bioaccumulate mainly in the liver). The uneven bioaccumulation and uncertainty about the spatial distribution of pollution under investigation might lead to a situation where alternative approaches might be implemented. The indicators of health or biological effect indicators (including PAH metabolites and multibiomarker approach) might substantially support the conventional biomonitoring data.

Large benthic macroinvertebrate species accumulate HMs directly from the surrounding environment and by biomagnification across a food chain[27] [28]. The mobile benthic organisms might host microorganisms that facilitate the biodegradation of oil products [29], subsequently, the estimation of the abundance of hydrocarbon-oxidizing bacteria in the digestive tract might be one of the methods applied in the assessment of pollution effects. However, the effectiveness of this microbiological approach has to be evaluated systematically on different species with ecologically relevant laboratory and field effect studies.

Small crustaceans from the order *Amphipoda* are widely used in bioassay studies[30]. The application of sediment biotests with multiple eco-physiological endpoint measurements might be a suitable tool for pollution monitoring (Figure 4.3.4). Species of infauna or burrowing

[25] Järv, L., Kiviranta, H., Koponen, J., Rantakokko, P., Ruokojärvi, P., Radin, M., Raid, T., Roots, O., Simm, M., 2017. Persistent organic pollutants in selected fishes of the Gulf of Finland. J. Mar. Syst. 171, 129–133. https://doi.org/10.1016/j.jmarsys.2016.10.002

[26] EKUK, 2020. Saasteainete sisaldus Eestis töönduslikult püütavates Läänemere kalades. Aruanne, Eesti Keskkonnauuringute Keskus, Tallinn. https://www.envir.ee/sites/default/files/saasteainete_sisaldus_kalades_21.09.2020.pdf

[27] Lozano, G., Herraiz, E., Hardisson, A., Gutiérrez, A.J., González-Weller, D., Rubio, C., 2010. Heavy and trace metal concentrations in three rockpool shrimp species (Palaemon elegans, Palaemon adspersus and Palaemon serratus) from Tenerife (Canary Islands). Environ. Monit. Assess. 168, 451–460. https://doi.org/10.1007/s10661-009-1126-z

[28] Munoz, G., Budzinski, H., Babut, M., Lobry, J., Selleslagh, J., Tapie, N., Labadie, P., 2019. Temporal variations of perfluoroalkyl substances partitioning between surface water, suspended sediment, and biota in a macrotidal estuary. Chemosphere 233, 319–326. https://doi.org/10.1016/j.chemosphere.2019.05.281

[29] Polyak Yu.M., Demchuk A.S., Sharov A.N., Gubelit Yu.I., Berezina N.A. Hydrocarbon-Oxidizing Bacteria in the Digestive System of Fish as an Indicator of Coastal Pollution // Doklady Biological Sciences, 2020, Vol. 491, pp. 71–74. DOI: 10.1134/S001249662002009X

[30] Lehtonen, K. K., Ahvo, A., Jørgensen, K. S., Schultz, E., Berezina, N., Breitholtz, M., ... & Strand, J. (2018). Sediment biotesting in the Baltic Sea: The CONTEST Project. Nordic Council of Ministers.

amphipods, when used in controlled exposure studies or collected in situ under field conditions, suit well for investigating the “cocktail effect” of multiple pollutants.

Figure 4.3.4 Sediment biotest with amphipods. Test organisms: *Monoporeia affinis, Pontogammarus robustoides.*

However, littoral amphipods might be successfully used in ecotoxicological exposure studies, where the impact of a specific chemical compound is in the scope of the investigation (Figure 4.3.5.).

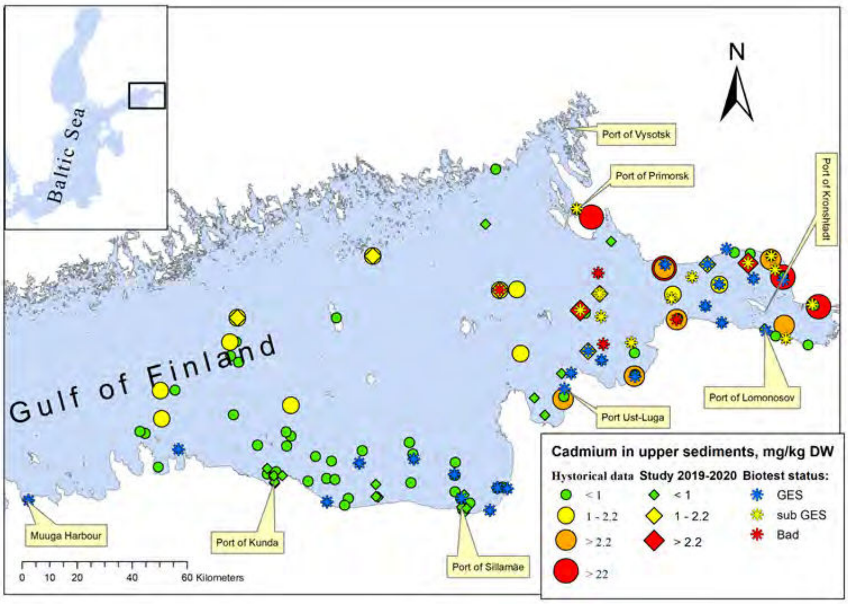

Figure 4.3.5 Correspondence between assessment according to sediment biotest with amphipods and cadmium content found in the upper sediments (GES - good environmental status acc. to % of survival of amphipods: GES ≥ 70%, Sub-GES 50-69%, bad < 50% acc.)[31].

Sediments

Several important aspects must be considered during the sampling campaign of the bottom sediments for chemical monitoring. The variation of sediment properties might be strongly related to the capacity of the bottom environment to bind and store the contaminants.

[31] Berezina, N. A., Strode, E., Lehtonen, K. K., Balode, M., & Golubkov, S. M. (2013). Sediment quality assessment using Gmelinoides fasciatus and Monoporeia affinis (Amphipoda, Gammaridea) in the northeastern Baltic Sea. Crustaceana, 86(7-8), 780-801

Therefore, areas of possible sediment erosion or accumulation must be identified in the study area. Fine-grained sediments (e.g., with high content of clay fraction) usually contain a higher concentration of organic matter, measured typically as the ratio of organic carbon, and are prone to developing poorer oxygen conditions in the bottom water layer, as compared to coarse-grained sediment erosion areas. The level of oxygen content, in turn, determines the temporal extent of preservation of some organic pollutants (e.g., organotins, PAHs), as aeration leads to degradation of these compounds on usually less harmful derivatives.
The application of appropriate sampling methods is also essential to consider during the planning of the sampling campaign. There was no considerable difference between the results of chemical analyses (including trace metals, TBT, PAHs) derived from sediment surface samples collected by sediment corer and bottom grab at the offshore accumulation area in Narva Bay except total content of PCBs, which was found to be 10 times higher from bottom grab sample (Figure 4.3.6). The latter might indicate significant variability in the availability and accumulation of this pollutant in the bottom sediments within even a small area. However, corer enables estimation of the historic contamination pattern by sequestering the core sample on separate layers with subsequent dating analyses. In coastal areas with shallow water, it is possible to use a sampling cylinder, which is a perfect tool when visually distinguishable contamination occurs, specifically by oil products.

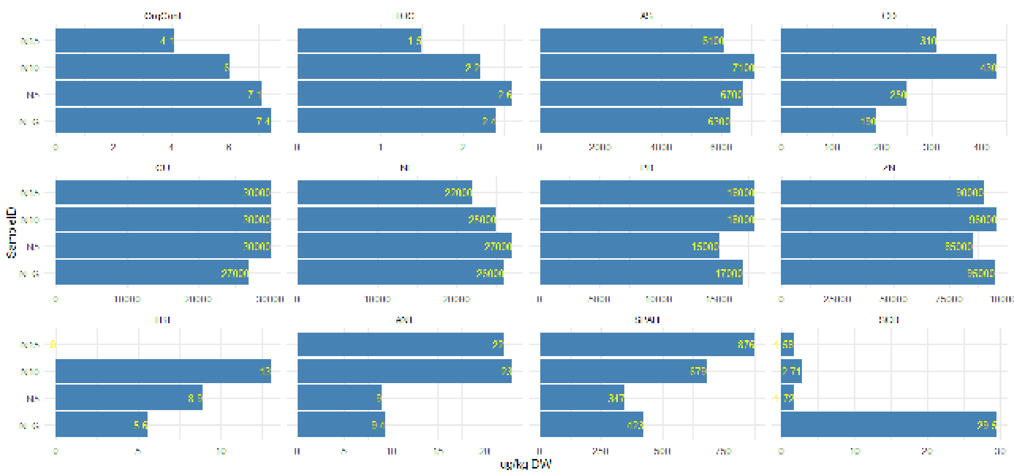

Figure 4.3.6 The results of analyses obtained from sediment surface samples collected using both a sediment corer and a bottom grab in Narva Bay (water depth 35-37 m). In this context, N_G refers to a bottom grab sample, while N5-N15 corresponds to distinct layers of a core sample, each taken at a depth of 5 to 15 cm from the sediment surface. The abbreviations OrgCont, ANT, SPAH, and SCB represent the total organic content, PAH compound anthracene, total content of PAHs (16 EPA), and total content of PCBs, respectively.

The current study showed that some POPs in accumulation areas and around centers of maritime activities in the eastern Gulf of Finland can be slightly below or manifold exceed the suggested good environmental status (GES) thresholds for the Baltic Sea[20]. Moreover, the high risk of contamination for the offshore eastern Gulf of Finland area and the outer Neva Estuary is confirmed by the calculated potential ecological risk index.

According to our assessment, there is evidence of continuous fresh input along the ship traffic routes and probably restricted TBT degradation at deep sediment accumulation areas. The content of TBT exceeded the GES threshold value at 60% of the sampled stations. The overall distribution pattern of TBT differs from distributions of PAHs and heavy metals, likely depending on the presence of specific diffusive sources related to maritime activities. The highest contamination by PAHs was found near the port areas, where compounds released during incomplete fuel incineration processes are likely prevailing. The situation with PAH contamination indicator in sediments – anthracene, raises the overall concern as it was detected at 52% of samples and at 29% exceeded the GES threshold, reaching extremely high values near the port areas. The spatial pattern of anthracene (ANT) distribution in the study area clearly differed from distributions of organotins and heavy metals and might be related to the point-source pollution from certain objects situated near the coast (e.g., oil storage reservoirs at the ports or harbors).

The potentially toxic heavy metals cadmium (Cd) and lead (Pb) are still traceable in significant amounts in the Neva Estuary and deep offshore areas of the eastern Gulf of Finland, while it is not a concern along the northern Estonian coast (Figure 4.3.7). The Pb content did not exceed the GES threshold in the study area, while Cd in sediment samples exceeded the threshold at two stations. The content of copper (Cu) in the bottom sediments may show a warning sign as its concentrations exceed (in the Neva Estuary) and approach the suggested provisional threshold levels in multiple locations across the study area. Overall, the high ecological risk of sediment contamination by heavy metals for the offshore eastern Gulf of Finland area and the outer Neva Estuary was identified from the calculated potential ecological risk index. The heavy metals had a specific distribution pattern in the study area as atmospheric deposition and waterborne inputs in different proportions are the main sources of these elements in the aquatic environment of the eastern Gulf of Finland. The simulated accumulation pattern indicates the most probable zones of riverine origin HS accumulation. Depending on the settling velocity, HS might disperse along the shoreline in the eastern Gulf of Finland much further from the initial release locations within the river estuary systems. Sedimentation of the medium size particles shows amounts growing from the outer part of the Neva Estuary to the east, highlighting the threat of increasing amounts of contaminants that are also visible from the available observations on heavy metals. This modeled gradient should be considered when planning monitoring activities in the eastern Gulf of Finland. The evidenced occurrence of periodically oxygen-depleted sediments can partly explain the presence and preservation of studied organic pollutants at the observed levels in the region. The increase of deoxygenated zones over time becomes the factor contributing to the sustainment of long-standing environmental issues regarding HS in the future as well.

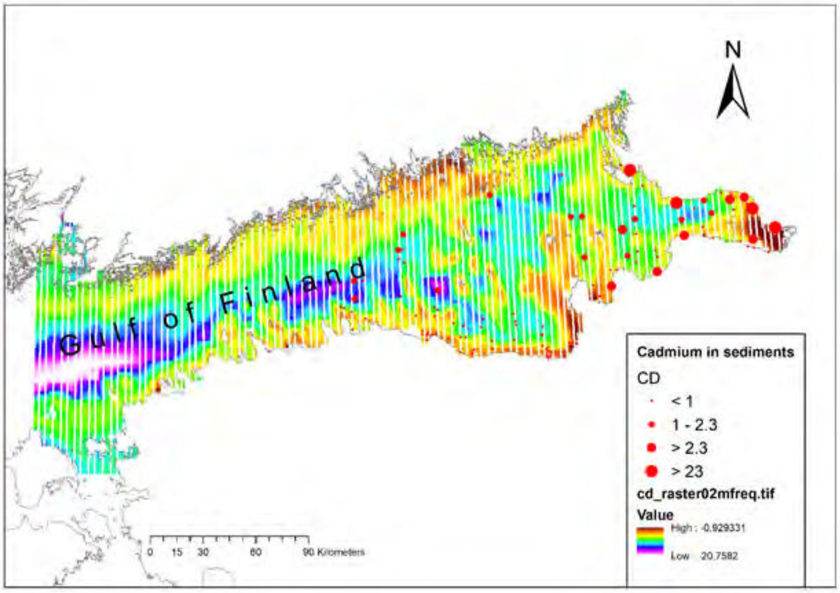

Figure 4.3.7 The simulated accumulation pattern is indicating the most probable zones of riverine origin cadmium accumulation, while red dots show element content found from sediment samples collected between 2005-2020 (in µg/kg dw).

The following surveys in the eastern Gulf of Finland have to focus on deeper nearshore stations for the HMs trend assessment. In addition, caution has to be taken when interpreting the results from samples taken at shallow beach areas. The continuous disturbance of the bottom surface by waves and the absence of fine sediments for pollutant accumulation might hinder the objectivity of marine pollution assessment due to high dispersion and, subsequently, low contaminant concentration. The designated polluting sites are still present in the eastern GoF basins, including the Neva estuary and Narva Bay, where most of the gulf's active municipal, industrial, and agricultural hotspots release polluting substances, probably until technological changes are applied to fulfill the critical requirements for achieving GES in the marine environment[32].

4.3.2 SURVEY OF BIOLOGICAL EFFECTS

Reproductive disorders in amphipods

We have studied the embryonic development of the sediment-dwelling amphipod *Monoporeia affinis*, which is sensitive to contaminant exposure. Therefore, the frequency of embryo aberrations in gravid females and the proportion of females carrying more than one aberrant embryo are used to detect the biological effects of chemical exposure in the Baltic Sea sediments. During the Hazless project, deep water (*M. affinis*) and shallow water (*Gammarus spp.*) amphipods were collected and analyzed for aberrated embryos. Collected data was added to the already existing dataset and used to evaluate the indicator applicability in the GoF (for *M. affinis*). The calculation of preliminary thresholds of indicators for the GoF is based on

[32] HELC OM 2013, The Baltic Sea Joint Comprehensive Action Programme (JCP): Implementation of Hot Spots Programme, 1992 -2013, Final Report (2013), pp. 1-44

available data. "Reproductive disorders in amphipods" is a supplementary indicator within the list of HELCOM biological effect monitoring indicators. During the project, we found that this indicator is applicable to the Estonian coastal waters. Specifically, based on the availability of *M. affinis*, stations N8, N12 (Narva Bay), and M (Käsmu Bay) are the most suitable for the eastern part of the GoF (however, due to the ice cover it could be difficult to collect at station N8). Shallow water stations at Udria, Eru, and Käsmu coastal waters can be considered for collecting littoral amphipods. According to the data from 2020 – the GES is not achieved for the eastern GoF. Reproductive disorders data collected during the Hazless project was also provided to HELCOM during the data call and used in HOLAS 3 assessment.

We suggest applying, for the representative assessment of the studied area, both deep water species *M. affinis* and littoral amphipods with an extent of at least 3 years of data within a 6-year period. In addition to already investigated sites in the Estonian part of the eastern GoF, we propose to consider the Kunda area for sampling littoral amphipods to provide an even spatial coverage of the sampling sites. We also propose systematic intercalibration of the measurements of this indicator to ensure the quality of the assessment in the future.

Multibiomarker approach

The so-called legacy persistent contaminants (e.g., PCBs or organotins) degrade slowly in the environment and continue to exert pressure on biota. Subsequently, the diversity of genetic characteristics in exposed species is prone to decline; they experience disruption in functionality and production, and persistent cumulative pressure on higher trophic levels through biomagnification is evident. There has also been registered a shift from high concentrations of a few chemicals to low concentrations of many in the last decades[33]. With the increasing knowledge of the mixture toxicity (or "cocktail") effects observed at relatively low levels of multiple contaminants, the reliability of environmental assessments based exclusively on chemical measurements is highly questionable.

In the last decades, the ecosystems of the Baltic Sea have experienced the impact of many emerging chemicals with low concentrations. However, priority contaminants continue to affect organisms on the different levels of biological organization. Within monitoring programmes conducted in the GoF, only a few biological effect indicators are implemented regularly. Both Finland and Estonia apply white-tailed sea eagle productivity monitoring. In addition, Finland assesses lysosomal membrane stability (LMS), while most other biological effect methods are implemented only on a project basis.

Based on multiple ecophysiological experiments conducted during the Hazless, it is reasonable to conclude that for reliable environmental assessment, chemical measurements should be accompanied by the estimation of the biological effect that HS contamination might trigger at the population level. The latter should be provided by the studies of the "early warning"

[33] Wang, Z., Walker, G.W., Muir, D.C.G., Nagatani -Yoshida, K., 2020. Toward a Global Understanding of Chemical Pollution: A First Comprehensive Analysis of National and Regional Chemical Inventories. Environ. Sci. Technol. 54, 2575 –2584. https://doi.org/10.1021/acs.est.9b06379

systems for the mixture effects of contaminants implementing the multibiomarker approach[30]. However, the application of biochemical health indicators is related to several considerations. Firstly, the effect of contaminants on the subcellular level is species-specific, e.g., it is impossible to compare the enzymatic activity rates of acetylcholinesterase (AChE) in fish liver and mussel digestive gland on the same scale. Secondly, within the battery of biomarkers, some might more generally indicate the probable influence of multiple specific compounds on the biochemical response. For example, the glutathione s-transferase (GST) activity rate is mostly related to the processes of removal of harmful metabolites from the cell and, therefore, might indicate the metabolization of large spectra of toxic HMs and/or POPs. However, seasonally occurring unfavorable environmental conditions such as hypoxia might modulate the enzymatic activities and change the biomarker response in the exposed biota at a similar pattern[34], which might complicate the interpretation of the survey results.

The abrupt declines in abundance of the study organisms (as happened with mussels due to the invasion of round goby in GoF[35]) might distract the long-term monitoring. The application of caging might compensate for the problem of the absence of suitable organisms for biological effect study. Utilizing the caging approach is possible to translocate organisms from supposedly unpolluted sites to the areas where contamination monitoring is necessary and, after deployment, conduct the analyses to reveal the exposure consequences.

Figure 4.3.8 Installing the cage with mussels and the cage with bioindicator organisms underwater.

[34] Woo, S., Denis, V., Won, H., Shin, K., Lee, G., Lee, T. K., & Yum, S. (2013). Expressions of oxidative stress -related genes and antioxidant enzyme activities in Mytilus galloprovincialis (Bivalvia, Mollusca) exposed to hypoxia. Zoological Studies, 52(1), 1-8.
[35] Nõomaa, K., Kotta, J., Szava -kovats, R., Herkül, K., Eschbaum, R., Vetemaa, M., 2022. Novel Fish Predator Causes Sustained Changes in Its Prey Populations 9, 1–12. https://doi.org/10.3389/fmars.2022.849878
[36] https://biocircularbusiness.com/

4.4 BBC1

BBC1 (Business in Biotechnology and Circular Economy)[36] project is implemented under the South-East Finland-Russia CBC 2014-2020 programme from 01.09.2019 – 31.12.2022. The partners of the project are Mikkeli Development Miksei Ltd and South-Eastern Finland University of Applied Sciences (Xamk). Until March 2022, the project consortium also included the Association for Environmental Partnership (ASEP) and ITMO University "ITMO".

The project focused on increasing cross-border sustainable economic growth by supporting entrepreneurship and business cooperation in the areas of biotechnology and circular economy. In these fields, the interface of research and business needs special attention and approach.

It aimed to attract companies to invest, locate, and operate in the Southeast Finland - Russia CBC region. The project aspired to improve sustainable economic growth in the cross-border region by supporting entrepreneurship and business cooperation in the field of biotechnology and circular economy. The project aimed to increase cooperation between companies and the capacity to create new businesses and commercialize scientific research results. In general, the objective was to improve the skills and competitiveness of Finnish and Russian companies and actors in the biotechnology and circular economy sector to enable them to succeed in cross-border markets.

4.4.1 ACTIVITIES

The activities were targeted at companies, university students, researchers, and experts in biotechnology and circular economy sectors in Finland and Russia. They were implemented between two strategic Finnish-Russian alliances:

- The universities ITMO and Xamk
- The business development organizations MikseiMikkeli and AsEP

Figure 4.4.1 BBC1 participated in the exhibition of the SEFR CBC Annual Event on 11.12.2019 in St. Petersburg.

The project consortium worked smoothly together - the universities provided courses, competitions, hackathons, lectures, and acceleration programs for students and businesses, improving their business skills and stimulating new innovations. The business development companies supported the growth and internationalization of new and existing companies, provided up-to-date market information, created important networks and contacts for businesses by organizing sector-specific webinars, seminars, trade fair participations, and visits, and developed the digital EcoSairila platform[37] to make the EcoSairila concept internationally more usable as a testing, piloting, and learning environment.

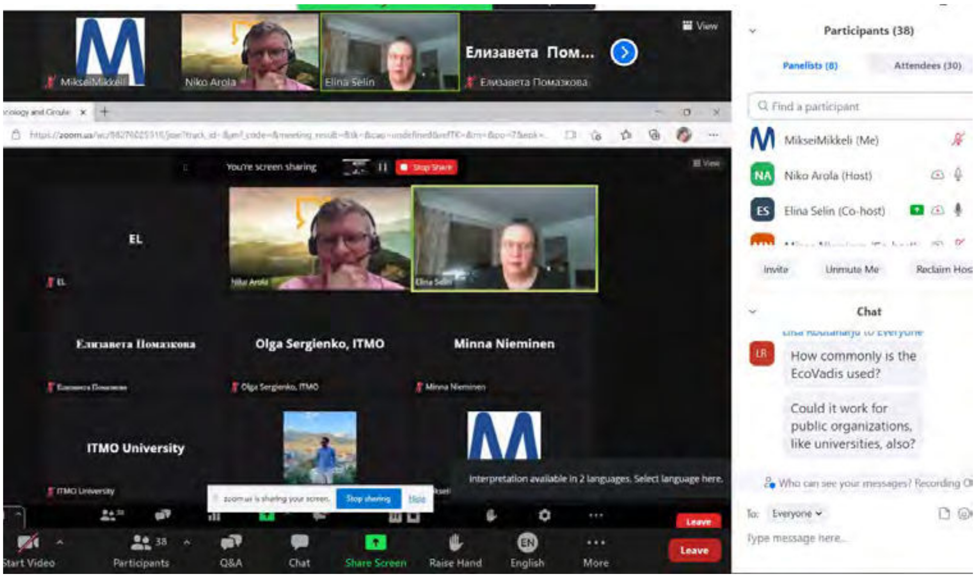

Figure 4.4.2 BBC1 webinar for Xamk and ITMO University students on the future prospects for biotechnology and the circular economy in an international context 15.2.2022.

The business development organizations organized a large number of match-making events for Finnish and Russian companies and represented companies at the EBC exhibition in St. Petersburg. They also promoted active cooperation with other projects and major players in the sector. Thanks to the awareness-raising activities and organized visits to EcoSairila, the EcoSairila concept e.g., the digital EcoSairila platform became a significant international platform for circular economy activities and communication in the South Savo region, which continued to operate after the end of the project. Generally, public awareness of the circular economy was widely promoted, for example through cooperation with educational institutions.

As the political situation changed significantly in the spring of 2022, the duration of the project and the measures had to be reassessed. The project remained with the Finnish project partners MikseiMIkkeli and Xamk. Central Asia became the new target area and the geographical scope of the project was also extended within Finland outside South-East Finland. Cooperation with Estonian actors was also started. A comprehensive and concrete market survey of the Central

Asian biotechnology and circular economy market opportunities and specificities was prepared and published for the use of companies. The project objectives were achieved, in a different geographical area than planned.

Figure 4.4.3 A roadshow of the Finnish delegation to Uzbekistan on 31.10.-3.11.2022 to find out whether the work previously done in the projects to Russia could be utilized in the Central Asia market.

One of the main outputs of the project is the digital EcoSairila platform[37]. It is a hub of regional material cycles, with a strong profile in various water treatment technologies. The platform has a combination of a vast array of public entities, RDI, educational organizations, and companies creating a unique innovation ecosystem. The EcoSairila provides a full-service innovation ecosystem for companies that would like to settle in the area, exploit the plant's side streams, and develop or test their solution in the RDI space. They can carry out development work on their own or alongside production activities.

Figure 4.4.4 A visit of BBC1 and Cata3Pult project groups to the wastewater treatment plant in Mikkeli City 10.12.2022.

[37] https://ecosairila.fi/; ENG: https://ecosairila.fi/en/home/

In order to reach as many Finnish companies as possible, the market survey of the Central Asia circular- and bioeconomy market and their opportunities was conducted and performed in the form of a big publication[38].

Mikkelin Kehitysyhtiö Miksei Oy

Markkinakartoitus: Keski-Aasian kierto- ja biotalousalan markkinat ja niiden mahdollisuudet suomalaisille yrityksille

Julkaisu toteutetaan osana
"Bisnestä bioteknologiasta ja kiertotaloudesta" -raja-alueyhteistyöhanketta, jota toteuttaa Mikkelin kehitysyhtiö Miksei Oy yhteistyössä Kaakkois-Suomen ammattikorkeakoulu Xamkin kanssa

Mikkeli 16.11.2022

Figure 4.4.5 Picture of the cover of the 155-page publication in Finnish language (https://ecosairila.fi/wp-content/uploads/2023/01/ca-marketing-report_16.11.2022_final_fin.pdf).

[38] https://ecosairila.fi/tiedotteet/keski-aasian-markkinakartoitus-kierto-ja-biotaloudessa/

5 DISSEMINATION OF PROJECT RESULTS

Under the frame of the NarBaltAware project, the results of the projects NarvaWatMan (ER25), Hazless (ER90), GreenMind (ER101), and BBC1 (KS1699) are introduced to the scientists, students, regulators, and industry representatives from the Baltic States and nearby regions at the following events and activities:

- The present booklet, that includes the summary of the projects, i.e., a description of activities and events, results, recommendations, and guidelines for future research and activities.
- NarBaltAware seminar, which will take place in Mikkeli, Finland on 19 – 20 September 2023. The seminar will take place in a hybrid format and will involve, in addition to the project partners, experts, representatives of small and medium-sized enterprises (SMEs) from Estonia and Finlan,d and other interested parties so the results of the projects can be presented and discussed, and future collaboration plans can be set up.
- International conference EcoBalt 2023 "Chemicals & Environment"[39], in Tallinn, Estonia on 9 – 11 October 2023 (Nordic Hotel Forum), organized by the KBFI partner. The event will be an opportunity for ecologists, environmental scientists, analytical and organic chemists, material scientists, toxicologists, and risk assessors to discuss the current trends and topics related to the environment. Specifically, for the NarBaltAware project a special session "The Narva River, from Lake Peipsi to the Baltic Sea: Challenges and Opportunities" will be organized on 10 October 2023 at the conference.
- Under the framework of the NarBaltAware, Peipsi CTC organizes outdoor lessons for school children of the Ida-Virumaa region of Estonia with the purpose of educating them on environmental issues. An online quiz on the Narva River was also developed[40].

[39] https://ecobalt2023.kbfi.ee/
[40] https://drive.google.com/file/d/1BXGWanTFc3jK3lKWGJ3fOmjQsRvOZhbu/view

6 SUMMARY

It is known that current environmental challenges require an integrated approach, i.e., various aspects and target groups should be addressed at the same time. The NarvaWatMan (ER25), Hazless (ER90), and GreenMind (ER101) projects implemented under the Estonian EU External programme 2014-2020 and co-financed by the European Union, and the BBC1 (KS1699) project implemented under the South-East Finland-Russia CBC 2014-2020 programme had different goals, but the same purpose of increasing prosperity and resilience of the Baltic Sea region.

Environmental education is vital due to global challenges like biodiversity loss, resource consumption, and climate change. The urgency of these issues has led to an increased focus on educating young people about ecological, economic, and cultural matters. The GreenMind project successfully utilized innovative approaches to enhance environmental education and awareness in the Lake Peipsi region. Non-formal and interactive methods proved effective in engaging learners and shaping their attitudes towards environmental issues. It addressed environmental challenges in the Lake Peipsi region through innovative toolkits, educational materials, and media messages. These efforts improved environmental education and public attitudes.

On the other hand, the NarvaWatMan project emphasized the importance of hydrological and hydrochemical monitoring, i.e., water quality and water quantity of the Narva River. The precise data on the river runoff and pollution load is crucial for establishing appropriate preventive, mitigative, and adaptation measures in the Baltic Sea region, as the river has its mouth in the Gulf of Finland, thus carrying its waters to the Baltic Sea, directly affecting its environmental status. The project succeeded in developing reliable and harmonized methods for assessing river discharge and pollution load, as well as improved the Water Quality Index (WQI) to assess the overall river state more thoroughly, considering a broader range of factors affecting its quality. The approach could also be applicable to other rivers in Estonia and beyond.

The **Hazless project** outcomes include the successful harmonization of marine monitoring and environmental assessment practices in the Gulf of Finland, i.e., the Baltic Sea region. Recommendations were made for improved water sampling techniques, such as considering both surface and bottom layers to account for pollutant distribution. The significance of assessing biological effects alongside chemical measurements was highlighted, as both legacy and emerging contaminants could represent a continued threat to individual organisms, population, and communities across aquatic ecosystems and trophic levels. The importance of multibiomarker approaches for understanding mixture toxicity effects was emphasized. Challenges like declining organism abundance and shifting ecological dynamics were noted, with suggestions to employ caging methods and translocate organisms to address these issues. Overall, the Hazless project findings provide valuable insights and recommendations for future monitoring and assessment efforts in the eastern Gulf of Finland, contributing to a better understanding of the region's environmental health status.

Lastly, the BBC1 project engaged Finnish and Russian universities and business development organizations to provide courses, competitions, hackathons, and acceleration programs for students and businesses with a focus on biotechnology and circular economy. The EcoSairila platform emerged as a central output, promoting business and education to utilize regional material cycles and water treatment technologies. The platform fostered innovation through collaboration between public entities, educational organizations, RDI, and companies. As geopolitical shifts occurred in 2022, the project's scope adapted. The focus expanded to Central Asia, and cooperation with Estonian partners was initiated. In summary, the BBC1 project successfully promoted cross-border economic growth through biotechnology and circular economy collaboration, creating innovative platforms and insights that extended its impact beyond its original geographical scope, whilst still contributing to increasing the resilience of the Baltic Sea region.

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