Nitrogen and phosphorus load reduction approach within safe ecological boundaries for the Nordic-Baltic region
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POLICY BRIEF NO. 2

NORDBALT ECOSAFE

Monitoring water quality with sensors

Based on experiences from streams in Northern Europe

Changes in land use and climate are affecting our water resources in many ways, and can result in nutrient enrichment (eutrophication), increased sediment loads and other pollution (e.g., heavy metals, organic pollutants, and other hazardous substances). Hence, it will become increasingly important to monitor responses in water quality of both human pressures and the effects of the mitigation measures we employ. At the same time, water quality, especially in streams, is notorious for its rapid fluctuations over time, which can mean that information is lost when using water grab sampling with monthly, bi-weekly or even weekly intervals. Here, sensor technology can offer a solution, as it can monitor a set of substances frequently and give us data in real-time, at relatively low costs. In this policy brief, mainly aimed at water managers, we give an overview of advantages and challenges with sensor monitoring, related to their multiple uses.

Water monitoring to assess status and trends in water quality is becoming increasingly important as human activities affect our water resources. Deterioration of water quality can affect societies, since we depend on clean water for drinking, irrigation, industrial processing, recreation, and last but not least, for the maintenance of healthy ecosystems.

A water quality monitoring sensor is a device that can be placed in a stream, a lake, in groundwater wells or coastal waters, and monitor a set of parameters frequently and in real-time.

This policy brief is aimed at managers that deal with water quality at local, regional and national levels.

We have gathered information on experiences with sensors from researchers and managers in North-European countries. We have interviewed stakeholders and managers at different levels on their views of sensors, and we also present how sensors can be used in science.

Follow our work on sensors on NORDBALT-ECOSAFE's web-page.

The Nordbalt-Ecosafe project is exploring pros and cons of sensor monitoring as compared to traditional monitoring with water samples and laboratory analyses, with a particular view on the monitoring requirements for implementing the EU Water Framework Directive (WFD). Nordbalt-Ecosafe's partners are from Denmark (lead), Norway, Sweden, Finland, Latvia and Poland.

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Sensors can monitor	Can be a substitute for
Turbidity	Sediment, Phosphorus
Nitrate	Other nitrogen fractions
Temperature	
Conductivity	
Dissolved organic carbon	Total organic carbon
Dissolved oxygen	
CO_2	
Depth/pressure	Water depth/water discharge
pH	
Chlorophyll-*a*	
Phycocyanin	
Dissolved metals	Total metals?

*The left-hand **table** shows parameters that sensors can monitor (left-hand column) or be a substitute for (right -hand column). More parameters are expected as the development of sensors evolve. However, some important parameters when implementing the EU Water Framework Directive (WFD) cannot (at least yet) be monitored by sensors, such as total phosphorus, total nitrogen, orthophosphate, or total organic carbon. There is a possibility, though, to use substitutes, but more research on this is needed on how accurate this will be in different water types.*

Advantages with sensors

Sensors have several advantages over ordinary water grab sampling. As an example, they can

- monitor frequently (e.g., each 10-30 minutes) at relatively low costs,
- give you real-time data for early detection of pollution events,
- detect events with high concentrations that are otherwise missed,
- inform you if a high concentration found in one single water sample lasted for a long or short period,
- detect trends and thereby assess effects of environmental mitigation measures,
- improve the accuracy of load estimates,
- give better estimates of the sources of pollution,
- give early warnings (e.g., by alarm to a mobile phone) on concentrations above given thresholds,
- improve our understanding on impacts of climate change effects (e.g., water temperature, turbidity, nutrient contents and eutrophication levels).

Especially in water bodies with rapid fluctuation of concentrations and fluxes, sensors can give more accurate data on state and trends, and can also improve our understanding of catchment processes.

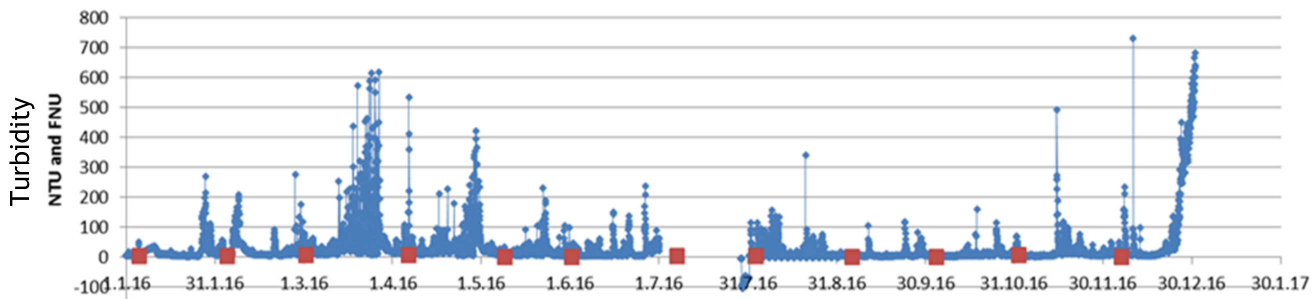
Challenges with sensors

Sensors also has some obstacles. For example, they

- can only monitor a limited number of parameters, and hence, a substitute must sometimes be monitored instead of the actual parameter,
- will need water samples for correlation and calibration, collected at various concentrations to obtain a good correlation curve,
- can have other maintenance costs, such as cleaning (or even changing) the lenses,
- can fail to record high concentrations above the maximum recordable level,
- can be difficult to use in some water types where the correlation between sensor recordings and parameters from water samples are poor,
- can be hard to operate in the winter in Northern countries due to frost and ice drift.

In addition to the above, there is a lack of harmonisation of the methods related to monitoring with sensors (see page 4), and therefore sensor data from different monitoring programmes cannot be readily compared. It should also be mentioned that sensors will result in a high amount of data that needs to be quality controlled and stored in a safe way.

Sensor data can be transferred through a logger and then on to a computer, to give real-time data. This requires a mobile connection and a power source, which can be a sun-cell and battery, or just regular electricity supply. Stakeholders can be given access, and then be able to keep an eye on the water quality in nearby water bodies.



*The **graph** above illustrates that turbidity measured by monthly water grab samples (red squares) can underestimate the turbidity levels as measured by turbidity sensor (blue dots and lines) in a river. Data from River Alna in Oslo. Source: Skarbøvik et al. (2017).*

Sensors in research

Research communities have long embraced sensor technology, due to the many opportunities for improved insight in processes such as mobilisation, transport and deposition of pollutants. Hence, sensor data have been used to

- improve pollutant load calculations in streams;
- improve understanding of catchment processes, such as erosion, leaching, transport and sedimentation;
- support catchment modelling studies;
- monitor threshold values in streams.

Stakeholders’ views on sensors

NORDBALT-ECOSAFE interviewed stakeholders from all six project countries, including managers at different levels (for more information, and detailed results, see Deliverable WP7).

The vast majority of the stakeholders voted that accurate estimates of nutrients concentrations are of high importance for implementing the EU WFD, and that it would be desirable to have more frequent data on this. Almost all stakeholders believed that access to real-time water quality/quantity data would be of interest to the people living in a catchment. Amongst obstacles to actually use sensors, investment costs and the required time to carry out maintenance were rated highest.

Sensors in national monitoring

In Denmark, Finland, Poland and Latvia, sensors are not yet part of national monitoring programmes, although strategies to introduce sensors exist in some of the countries. As an example, Finland has developed such a strategy, and presently 11 rivers in SW Finland are monitored by sensors. Sweden has used sensors at regular monitoring stations since 2017 and currently seven sites are in operation (Fölster et al., 2019). In Norway, sensor monitoring is employed in six (out of 20) rivers in the national River Monitoring Programme (Kaste et al. 2022).

Interviews with national representatives in the six NORDBALT ECOSAFE countries revealed that national managers are to a large extent aware of both the advantages and disadvantages of sensors, but that they would welcome more information on the issue. We therefore aim to ensure that more hands-on experiences and knowledge on sensor monitoring will be available to managers through our web-site.

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Comparison of sensor data

NORDBALT-ECOSAFE's work on sensors is in many ways a follow-up of former co-operation, where researchers from North-European countries compared turbidity data from sensors with water grab samples analysed for suspended sediment concentration. Data were gathered from 31 stations, covering 11 different monitoring programmes. This gave some new insight on sensor monitoring that we have summarized here:

1. Poor harmonisation of methodologies made it difficult to compare sensor data from different monitoring programmes. This included variations both in how different sensor brands recorded turbidity, as well as variations in methods used in the regular water sampling programme and the laboratory analyses.

2. The best correlation between turbidity and suspended sediment concentration (SSC) was found in agricultural streams draining catchments with predominantly clay, silty or sandy soils.

3. Poorer correlations between turbidity and SSC were found in forested and peatland streams, and in catchments with coarser soil types.

4. Correlations were best with a mean and maximum SSC above approximately 30 and 200 mg/l, and a mean and maximum turbidity above approximately 60 and 200 NTU/FNU, respectively. However, there were considerable variations.

The results underpin the recommendation to prepare a separate calibration curve between turbidity and suspended sediment concentration for each individual stream, at least as long as methods differ, and until more knowledge can be gained from monitoring programmes using similar methodologies.

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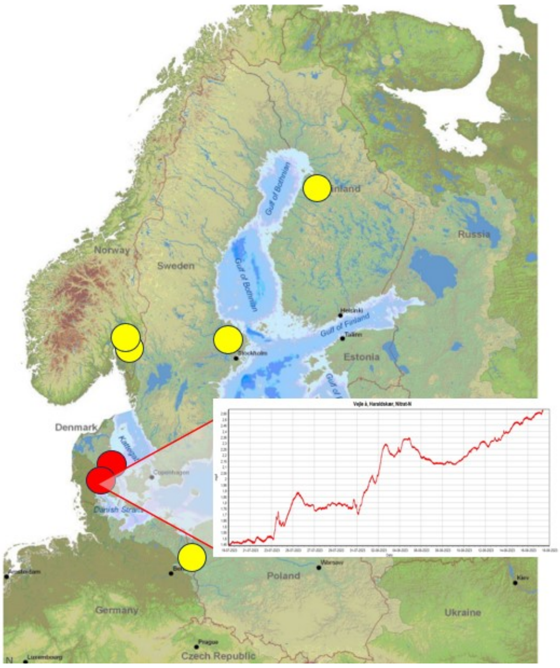
Demonstration sites in Nordbalt-Ecosafe

In each of the six countries, Nordbalt-Ecosafe will have demonstration sites where stakeholders can check the status of the water quality in real time, through our web page. The service will open by February 2024, but two streams in Denmark are already on-line.



Map of stations from which data are (red dots) or soon will be (yellow dots) available on-line and in real-time.

References

Fölster et al. 2019. Sensorer för vattenkvalitet i miljöövervakning av vattendrag - Hur användbara är de i praktiken? SLU, Vatten och miljö: Rapport 2019:10.

Kaste et al. 2022. The Norwegian river monitoring programme 2021 – water quality status and trends. NIVA Report 7760.

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The NORDBALT-ECOSAFE consortium will develop and demonstrate innovative methods and establish best practices to improve current river basin management and governance by reaching the following major aims: i) setting ecologically safe nutrient boundaries in different types of water bodies; ii) improving monitoring of nutrient concentrations by comparing benefits of novel high-frequency online sensors with traditional monitoring; iii) establishing nutrient loading tipping points for carbon sequestration and emissions in water bodies; iv) establishing a harmonised river basin modelling tool for precise estimation of nutrient sources, pathways and transport; v) demonstrating novel Nature Based Solutions (NBSs) and Mitigation Measures (MMs) for reaching the required nutrient load reductions; and vi) developing advanced solutions supporting regional governance structures to implement the most suitable measures to meet the ecological nutrient boundaries. A conceptual diagramme is showing the links between different parts of the project and a ma shows our working platform consisting of six river basins and riverine monitoring points under HELCOM and OSPAR.

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