Project: A system for the sustainable management of Lithuanian marine resources using novel surveillance, modeling tools and ecosystem approach

Technical Report No. 2

Installation and testing of automatic water quality observation system

Project indicators:
1. A set of buoys purchased, installed and tested

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A system for the sustainable management of Lithuanian marine resources using novel surveillance, modeling tools and ecosystem approach. Technical Report 2: „Installation and testing of automatic water quality observation system“.

SUMMARY

The report presents the results of the project based on activities of workpackage “Surveillance of water quality using automatic observation system” during 2008-2012. During the course of the project the automatic observation system (oceanographic buoy) was selected according to defined technical specifications, location for buoy installation selected and oceanographic buoy installed. Communication, data collection and transmission system were fixed and tested. After two months of operation in the sea, connection with the buoy was lost in November, 2010 and system testing activities have been stopped. Oceanographic buoy was not found in the installation place after visiting the place in early December 2010. Insurance company was informed according to the requirements and analysis of the incident was started.

The role of project participants:

Inga Dailidienė - researcher - general administration of the Working Group, an automatic water quality measurement system selection, installation and testing.

Saulius Gulbinskas - researcher - automatic water quality measurement system installation, site selection, system integration in the Lithuanian marine waters monitoring and research of sustainable environmental assessment and planning system.

Loreta Kelpšaitė - researcher, automatic water quality measurement system installation and testing.

Saulius Pauliukaitis - junior researcher, automatic water quality measurement system buoy and data communication systems installation, maintenance services.

Vitalijus Malejevas - student, project technician - automatic water quality measurement system selection and preparation of specifications.

Toma Mingėlaitė - student, technician, data communication system maintenance, data processing, reporting.

Edvardas Valaitis - student, project technician - automatic water quality measurement system instalation, technical maintenance.
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**Introduction**

During the implementation of the project „A system for sustainable management of Lithuanian marine resources using novel surveillance, modelling tools and an ecosystem approach“, automatic water quality observation system was selected, purchased and installed. This activity is directly related to the marine resource management and quality improvement set out in the European Parliament and Council Directive 2000/60/EC. Environmental monitoring data, assessment of status indicators, research and modelling results contribute to the EU “Marine Strategy Framework Directive” (2008/56/EC). Marine environmental monitoring system facilitates the management of Lithuanian marine resources and their holistic assessment as well as facilitates application of water quality improvement measures in the Curonian lagoon and the south-eastern Baltic Sea.

Different institutions such as Lithuanian State Port Authority, business companies, research institutes, Lithuanian Ministry of Environment and international environmental organizations contributed to a different but significant extent during the various stages of automatic water quality monitoring system setup. Main:

1. selection of automatic observation system specifications and purchase.
2. site selection, installation and insurance of automatic observation system.
3. installation of data transfer and storage system.
4. testing of the Automatic water quality observation system and data collection.
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1. **Purchase of automatic water quality observation system**

   Implementation of the project Automatic water quality observation system (Fig. 1) purchase consisted of several stages:
   
   - Oceanographic studies of similar systems in Europe, including the Baltic Sea.
   - The Baltic Sea coastal characterization and oceanographic research buoy installation site selection.
   - Setting the most necessary needs of Lithuania and oceanographic parameters.
   - Providing optimal automatic measuring system specification.

   ![Fig. 1. Scheme of Automatic water quality measurement system.](image)

1.1. **Oceanographic systems in Europe and the Baltic Sea**

   During the first phase of the project implementation the automatic water quality measurement systems in European seas and particularly in the Baltic Sea (Fig. 2, 3) were analyzed, oceanographic parameters adopted according to the Lithuania and Europe requirements were identified, and a study of possible devices according to the producers and users was carried out (1 table).
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Fig. 2. European Marine monitoring (www.EuroBOOS.org).

Fig. 3. The operational marine environment oceanographic measurement stations in the Baltic Sea.

Presently about eight oceanographic buoys are installed in the Baltic Sea (Fig. 3, source http://www.io-warnemuende.de): Laso Ost, Ost Huvudskar, Store Baelt S, Store Baelt N, Drogden, Oderbank, Arkona, Darss Sill. Baltic Research Institute (IOW) of University of Rostock in Germany exploits in the Baltic Sea Darss Sill (Fig. 4.), Arkona Sea (Fig. 5) and Oder bank (Fig. 6) oceanographic buoys. The data via specific software is provided not only for researchers but also to the public (Fig. 7).

Fig. 4. Darss Sill  Fig. 5. Arkona Sea  Fig. 6. Oder Bank
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Fig. 7. Data from automatic measurement station in Oder Bank, Germany (MARNET),
(source http://www.io-warnemuende.de)

Table 1. Parameters of automatic water quality monitoring systems

<table>
<thead>
<tr>
<th>Producer / Country</th>
<th>Aanderaa</th>
<th>Fugro OCEANOR</th>
<th>SEBA Hydrometrie</th>
<th>RBR Europe Ltd</th>
<th>AXYS technologies inc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design of the frame</td>
<td>Firm and small construction with polythene panes; Low power consumption; Buoy has a separate outside storage for equipment.</td>
<td>Vertically standing buoy is cylindrical shape. Around it there are three six-meter-long, water-proof, vertical aluminium supports, which maintains the balance. Sensors are fitted on the upper and lower parts.</td>
<td>The equipment consists of a frame, radar, solar panels, and antennas.</td>
<td>The device is made of polyethylene.</td>
<td>Aluminium. Six water-proof sections, plus central section for electronics, batteries and sensors. Aluminium top-water part and steel underwater part is attached to the frame.</td>
</tr>
<tr>
<td>Svoris</td>
<td>600 kg</td>
<td>1400 kg</td>
<td>-</td>
<td>200, 2000, 7000, 9000 kg</td>
<td>1500 kg</td>
</tr>
<tr>
<td>Navigation lights</td>
<td>Marine lamp: SL 15; Range: 1 nautical mile;</td>
<td>IALA standard lamp</td>
<td>-</td>
<td>The buoy system includes a programmable navigation lights and radar - reflector</td>
<td>IALA standard light bulbs, and multiple automatic changer</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Typical sensors</th>
<th>Air temperature; Air pressure; Wave height and period; Current direction and speed; Water temperature; Dissolved oxygen; Salinity;</th>
<th>Air temperature; Air pressure; Wave height and period; Current direction and speed; Salinity; Dissolved oxygen;</th>
<th>Water level; Temperature; Water electrical conductivity; Salinity; Dissolved oxygen; pH</th>
<th>Wind speed and direction; Temperature; Air pressure; Salinity; Turbidity;</th>
<th>Wind direction and sour cream; Air temperature; Air pressure; Wave height, direction and period;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other sensors</td>
<td>Algae; Nutrients; Radioactivity; Bicarbonate; Chlorophyll A</td>
<td>Nitrate; Ammonia; Chlorides; Ammonium; Sodium; Calcium; Fluoride; Potassium; Chlorophyll A; Cian bacteria; Turbidity;</td>
<td>Other sensors can be adapted</td>
<td>Solar radiation; Current direction and speed; Turbidity; Conductivity; Electromagnetic, acoustic intensity; Fluorescence intensity and wavelength; Nutrients, etc.</td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>Solar batteries</td>
<td>Solar batteries Lead-acid batteries Lithium Batteries</td>
<td>-</td>
<td>-</td>
<td>Galvanic battery. Galvanic batteries supplemented with solar power</td>
</tr>
<tr>
<td>Connection possibilities</td>
<td>VHF/UHF ORBCOMM GSM ARGOS IRIDIUM</td>
<td>INMARSAT C ORBCOMM ARGOS GSM UHV/VHF</td>
<td>-</td>
<td>GSM CDMA RF</td>
<td>GOES INMARSAT C arba D+ ARGOS VHF/UHF CDMA, GSM IRIDIUM</td>
</tr>
<tr>
<td>Positioning</td>
<td>GPS</td>
<td>GPS</td>
<td>GPS</td>
<td>GPS system is included</td>
<td>GPS</td>
</tr>
<tr>
<td>Acquisition of data</td>
<td>Data from the buoy can be transmitted immediately or stored inside</td>
<td>Data from the buoy can be transmitted immediately or stored inside</td>
<td>-</td>
<td>Sensor data and buoy status can be monitored in real time and depicted on a secure Web site, which is accessible from anywhere in the world.</td>
<td>Data from the buoy can be transmitted immediately or stored inside</td>
</tr>
<tr>
<td>Application</td>
<td>Ports, fjords, coastal waters, depending on the depth and wave conditions</td>
<td>Ports. Information can be used in meteorology and climatology studies, water quality monitoring studies, wave and wind energy study</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Transfer capability</th>
<th>The buoy is easy to move and use</th>
<th>The buoy is easy to move and use</th>
<th>-</th>
<th>-</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor selection and replacement</td>
<td>There may be up to seven meteorological sensors, and GPS antenna</td>
<td>Can measure 16 different water quality parameters</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Anchoring</td>
<td>Contact Aanderaa about anchoring</td>
<td>Five main methods of mooring are used. Specific dislocation structures depend on some factors. One of the main is current velocity and depth at which the device is used. In addition, consideration should be given to the ship traffic.</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Appropriateness of the Baltic coasts</td>
<td>Appropriate</td>
<td>Appropriate</td>
<td>Appropriate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appropriateness for the project needs</td>
<td>Appropriate: maximum number of sensors, the possibility of ordering additional sensors, to modify the measurement horizons, lightweight construction.</td>
<td>Appropriate. The problem – not enough sensors and measured parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.2. Specifications of automatic water quality observation system

Automatic water quality observation system consists of:

1. Surface buoy with mast for meteorological sensors
2. Underwater measuring system with oceanographic sensors and equipment
3. Anchoring and solar power system
4. Real time automatic data observation, download, transfer and presentation software
5. Data transmission system (sea-land) with radio and/or GPRS modems.
6. Installation of automatic water quality observation system, data transfer set up, training of personnel.
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The buoy platform should be designed and constructed from robust long-life flotation material with counter weight. Corrosion free in sea water and hard material (preferably titaniuk), should be used for sub surface connectors and metallic structure, stainless steel for surface construction. Construction should provide a faradize like cage mechanism protecting the buoy from electromagnetic impulses and also lightning. Buoy flotation hardware should stay floating even if the polyethylene shell is punctured after collision with sharp objects. Materials used for buoy construction should be applicable for long-term offshore operations, typhoon/hurricane warning and sailing information for the ships captains and coastal administration, reference list should be provided together with Quotation.

Surface Buoy contains several sections: buoy flotation hardware; Buoy hull and mast with sensor ring for meteorological sensors and communication antennas; oceanographic and water quality sensors.

These sections should be individually sealed and water proof to ensure the best operations. The inner waterproof enclosure contains communication devices, data logger, battery regulator, electric compass and all necessary lightning arrestors (for sensor connections, antennas, and power supply). This enclosure should be lockable and its antennas are positioned on top of the buoys meteorological sensor arm/ring. The antenna is also protected with a gas fuse for additional lightening protection.

The buoy should be a cone shaped with low center of gravity in order to make pitch and roll of the buoy minimal. This allow the buoy to move vertically (up and down during wave and storm events), giving better wave measurement accuracy, higher stability and providing more accurate meteorological data and near surface current speed/direction measurements. The buoy should be configured to handle a pressure in water depth of 10 meters, if dragged extraordinary events.

**Blinking light**

Radar reflector (passive) Blinking light (IALA) with an easy service access is installed in watertight compartments. The buoy is also equipped with optional add-ons such as: additional current measurements systems, oceanographic and water quality sensors. Weight of the buoy should not exceed 200 kg, to ensure easy installation and transportation from one location to another, also to provide more precise wave height measurements.

**Additional accessories**
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The meteorological sensors are installed at the top of the buoy on a sensor arm/ring. The motion sensors like wave height sensor are positioned in the centre of the buoy at water level in order to measure the waves at the correct position relative to the buoys floating point.

*Underwater current sensor*

Underwater Doppler current sensor is installed inside a PVC tube in a dark environment in order to minimise the sensor fouling. Other Doppler current sensors can be installed at different depths below the surface with the possibility to change measurement layer. Sensor cable should be protected with a flexible high pressure hydraulic pipe.

Other sensors to be fixed in different layers:

- wind speed and direction,
- air temperature,
- air pressure,
- humidity;
- wave height (significant and maximum), wave period,
- water current speed and direction,
- sea water temperature and salinity,
- oxygen concentration,
- turbidity,
- a-chlorophyll

Different parameters are measured in different layers: meteorological parameters – above the water surface; in the under water in three different layers, that is:

1. First layer – wave height (significant and maximum), wave period, water current speed and direction, sea water temperature and salinity, oxygen concentration, turbidity, a-chlorophyll.
2. Second layer – water current speed and direction, sea water temperature and salinity, oxygen concentration, turbidity, a-chlorophyll.
3. Third layer – water current speed and direction, sea water temperature and salinity, oxygen concentration, turbidity, a-chlorophyll.

*Underwater current sensor*
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The Doppler Current Sensor, installed on buoy, should be calibration free and not affected by marine fouling. However, when the buoy is pulled up of the water it is important that the sensors are cleaned before they are deployed again.

Real time data transmission

Data from the buoy is transmitted to the control centre via cable or radio modem (0.1-1W). Radio frequency has to be selected by buoy operator and according to the radio frequency licence. Data should be received in control centre and connected to computer/server dedicated for this purpose. All the necessary software components should be provided together with the buoy system, as well possibility for future upgrades/replacements of the interface. Solution should allow to combine various sensor technologies and data transfer protocols. The display program of data should be web based program providing numerical values, graphical curves, wind roses for direction and bare indicators for selected parameters.

Installation of the system and personnel training

System installation: anchoring system should be provided by producer. Engineer/specialist qualified from producer should supervise (and consult) the installation and train the personnel during the process. When equipment is delivered on site, suppliers’ engineer(s) should make software installation for data transfer and conduct training on data handling. Supplier provides 2 years maintenance service and consultations after installation if needed for operational exploitation of the automatical water quality observation system.

1.3. Automatic water quality measurement system

Aanderaa Data Instruments (AADI) oceanographic buoy was selected for the purchase. Aanderaa Data Instruments (AADI) develops and sells sensors, instruments and systems for measuring and monitoring in demanding environments. The buoy has fixed stable position, lightweight construction, large amount of measurement parameters, the possibility to adjust measurement parameters according to the needs and use in marine environment. Aanderaa Data Instruments proposed by the appropriate water quality oceanographic research buoy system configuration (Fig. 8).
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Fig. 8. The scheme of automatic water quality and oceanographic research buoy system configuration
2. Installation of automatic water quality observation system

Activity met considerable deviation from the planned progress during Project implementation, when distribution of equipment and installation costs in the first commercial offer differed from the planned budget by more than 15%, and, therefore decision was taken to proceed with a new public procurement. All legal purchase procedures were repeated, contract signed, and automatic observation system equipment delivered to the Klaipeda University at the beginning of September 2010. Different parts of automatic observation system were installed during September – October 2010:

- Oceanographic buoy with data transmission system has been installed (Fig. 9-12) in the coordinates 55° 44’22 N 021° 02’00 E, in depth of 27 m, 3 km from the coastline (Fig. 10).
- The radio system, data receiver and storage system have been installed in Faculty of Natural Sciences and Mathematics of the Klaipeda University.
- Real-Time data collation software was installed and configured; public access web page for online data demonstration was created (Fig. 9).

Fig. 9. Data from automatic observation system freely available via website.

After the assessment of environmental conditions at the Lithuanian coast, the primary oceanographic buoy installation location (55°45’30N, 21°2’00E) at depth of 20 m was selected. However, installation location had to be changed (Fig. 10) after consultations and
request for permission at Maritime Safety Administration and Klaipeda State Sea Port Authority. The location at 27 m depth (coordinates 55°42′930N 021°01′957E) was agreed according to the navigation routes and safety requirements.

Photos of the installation works are shown in Fig. 11. Examples are presented in Fig. 9 and The data from automatic observation system was made available to the public via website (http://buoy.ku.lt/AADI_DisplayProgram/setups/KlaipedaMET/default.aspx) using adopted data acquisition and display charts (Fig. 12):
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3. **Testing of water quality system**

Training and testing of the Data Buoy 4700 was performed by the instructor Einar Hauge Hansen on 21-24 September 2010.
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Automatic water quality observations system testing consisted of (i) oceanography buoy testing, (ii) database development and testing, (iii) establishment and introduction of open access website and its testing, (iv) launch of open database, and (v) testing of the Automatic water quality observation system data quality.

Automatic water quality observation system were calibrated and tested by the producer before delivery to the Klaipeda University. List of the data logger parameters and coefficients was also provided with documentation. Each component and sensor in the system has been thoroughly tested in accordance to ANDERA quality assurance procedure.

Maintenance of the automatic water quality observations system was performed by Klaipeda University CORPI scientists and engineers together with AADI representative persons Einar Hauge Hansen and Tarmo Kouts.

During the buoy maintains the sensors were scanned in a row and the readings, converted into engineering units, were stored in the Datalogger. When database creation, one measuring cycle has completed, the datalogger enters a quiescent state awaiting a new trigger pulse from the clock after which another measurement cycle is carried out. 30 days data could be saved directly in the datalogger.

Data from the Buoy were transmitted to the computer (later to the server) at the Klaipeda University by the radio modem. Data were received to the computer, displayed and saved by the Display Program 3710 (Fig. 12). After Geo View program installation to the data server, radio modem was connected. Hydro meteorological data were successfully collected with 10 min frequency from 24 September 2010 till 18 November 2010 (Fig. 13) and data saved at the Klaipeda University data server as ASCII files.
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Fig. 13. An example of collected air and water temperature at 1 and 16 m depth from October 7 till November 11, 2010.

For testing purposes air parameters measured by buoy were compared with the data obtained from the Lithuanian Hydrometeorological Service Klaipeda station. Comparison of wind speed for the period of October 6 – November 11, 2011 period is presented in Fig. 14. Although Klaipeda Hydrometeorological Station is located in the city and measures lower wind speed and gusts than buoy located in the sea, in general there was good agreement in wind speed dynamics measured by both systems. Wind speed and direction
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measured by buoy were used for wave modelling by SWAN (Simulating WAves Nearshore) wave model (developed at the Delft University of Technology, www.swan.tudelft.nl). As were expected the model did not reproduce the highest waves, but there was good coincidence between measured and modelled wave height in range between 0-2 m height (Fig. 15.).

![Fig. 15. Comparison of wave height measured by buoy (solid line) and modelled by SWAN (points)](image)

In order to test temperature readings, in situ measurements near automatic water quality observations system were carried out on 07 November 2010. The measurement results showed adequate readings of 8.2 C by both systems.

It was foreseen, that real time meteorological (wind speed, wind direction, air temperature, humidity, solar radiation) and hydrological data (current direction and speed\(^1\), wave height and period, water temperature\(^1\), conductivity\(^1\), oxygen\(^1\), turbidity\(^1\) and chlorophyll\(^1\)) will be displayed online along with 24h average and maximum values of all measured parameters (Fig. 9). Example of data collected by automatic water quality observation system on 12 November, 2010 and used for testing of online regime can be browsed from:


4. **Current situation and future development**

Installed automatic observation system provided first high resolution time series on waves and currents incl. those during stormy conditions. Distribution of these data to all

\(^{1}\) in depth of 1 and 15 meters.
relevant institutions (Marine Research Department, Ministry of Environment, Lithuanian Maaritime Safety Administration, Klaipeda State Seaport Authority) were aimed to complement environmental monitoring and minimise environmental risks by increased navigation safety at the harbour entrance. Water quality data were successfully collected by the buoy with 10 min frequency from 24 Sept. till 12 Nov. 2010. Then radio connection was lost, however the system continued measurements in the sea after visiting installation site and proving its condition. The buoy was not found at the installation site on Dec. 27, 2010; insurance company was informed according to the contract conditions and search surveys organised. After the Insurance company refused to cover costs of insured equipment due to unclear accident causes, consultations with the lawyers are being undertaken and the court process will be initiated. Since court process is highly likely, timing of renewed operation of automatic observation system is hardly predictable. However, as soon as process will be finished and positive decision concerning insured costs will be taken, the system will be re-installed and launched in condition described by project proposal.