
WATER QUALITY EARLY WARNING SYSTEM

ON
TRANSBOUNDARY
WATERCOURSES
of the Tisza river basin

Chapter 1-4, 2014

Initial Study



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1. Specifying recommended installation locations of monitoring system and recommended monitoring parameters in the Tisza catchment area.

1.1. Preface

WATER QUALITY EARLY WARNING SYSTEM on transboundary watercourses

Preparation for the implementation of the water quality early warning system through a study on the Tisza water basin.

Background

Water's role – as a strategic resource – has greatly appreciated from social, environmental and economic aspects. Protection and management of water resources are the key elements of sustainable development.

Natural phenomena know no state boundaries, thus their management and adaptation for them need actions in the whole catchment, in our case the Tisza catchment area, occasionally in the wider territory of the water basin, which is outside of the EU. This is in accordance with the principles laid down in the Water Framework Directive.

The establishment of a Water Quality Early Warning System on the Tisza on the water basin level is essential for both the upstream and downstream countries for warning and forecasting of possible catastrophic events, and helping timely reactions. Steps taken in the whole Danube region in order to prevent such incidents, as well as fast and effective treatment is essential.

Early Warning System

The Early Warning System does not replace the monitoring processes required and undertaken by the states, instead it would give help in the analysis and solutions of problems, as it would provide continuous timelines from the whole catchment territory.

- Some elements of the alarm system may already exist in some countries, there is a need for accurate analysis of the situation, so that the elements of the warning system to be installed will conform to the European systems and regulations.
- Instrumentation and full interoperability of information systems and databases used in the Member States and at European level is placed in the foreground.

With the to be established warning system on the Tisza water basin there will be a possibility to replace the missing link in the monitoring system of surface water bodies, because:

- *we currently don't have timelines with sufficient frequency to draw conclusions about the **continuous** development of the state of our watercourses*
- *we currently don't have appropriately detailed and composed unified parameter information.*

Study

The purpose of the study currently written is to lay down the basics of the strategy for the „basic“ Water Quality Early Warning System, and to define the framework of the extendable, configurable and specializeable automatic monitoring system, which includes installation, infrastructural and ICT elements.

The study is based on the existing detailed and circumspect documents and status analyses (WDF, ICPDR, Cross-border cooperation, works of the Tisza group). In addition to these, the warning system would provide for the decision-makers and the groups responsible for sustaining water quality a complimentary information database which would help track tendencies.

There will be a possibility to find correlations between the results of the continuous measurements and the ones published in the reports, thereby supporting bidirectional work and helping countries reach the goals set on the basis of the Water Framework Directive quicker and more effectively.

EWS principles

- Providing a possibility for the precise definition of the concentration and source of harmful substances, this would also be an important added-value from the viewpoint of **prevention** of catastrophes.
- The Water Quality Early Warning System would be made of continuously operating **monitoring stations** and the attached online data transmitter-warning and **remote monitoring systems**. The monitoring stations are focusing mainly, but not exclusively on the water bodies downstream to hazardous objects.
- For this we plan to describe a process model system description, which would be achievable as a „**cookbook**” with various customization possibilities **adaptable to given situations**.
- For the warning system different warning **scenarios** can be worked out for the Tisza catchment.
- There would be a **standardization** of the installation **methods** and sampling techniques for the continuous monitoring warning system, on which we could rely on in the future.
- On the territory of choosing suitable physicochemical and toxicological parameters we determine **indicator parameters** which describe the condition of a water body.
- With the system we give a **framework** to which it is possible to attach **modularly**, information **can be shared** and we also take into consideration the different capabilities of the involved countries.
- Basic expectations are: robustness, operational reliability and **availability**, and remote monitoring with **minimal operating costs**.

EWS structural features

- On the designated installation sites infrastructural connection possibilities for the monitoring stations will be established. This will also provide quick, simple relocation possibility for the mobile measurement units (mobile container/vehicle, buoy).
- Big container monitoring stations are installed with basic devices, with possibility to upgrade them with different additional instruments.
- In the monitoring stations to be installed the uniform connection surfaces are able to operate and get data from different instruments, thus they can be attached to the already established data transmission system.
- Measurement parameters, measurable components don't cover the whole spectrum, but applied methods show the status of the Tisza water basin properly. This can greatly help the work of the specialist teams.
- The established database and evaluation module must be able to share data in a parameterizable way, meaning it can send data to the AEWS of other countries and it is able to accept data from other monitoring systems.

The four parts of the study

1. Proposal of installation sites and measurement parameters for the monitoring system on the Tisza river basin
2. Evaluation of measurement methods applicable on monitoring stations, and introduction and specification of the monitoring devices necessary for implementation.
3. Evaluation of technically applicable sampling systems of EWS, taking into account different riverbed types, sample and data archivation system types and introduction of design options.
4. Calculation of investment and operational costs for monitoring system to be developed

1.2. Introduction

Transboundary river courses and river' catchment areas are not restricted to the geographical territory of a particular country, thus the parameters characterizing water bodies (pollution and conditions resulting from geological attributes) cannot be restricted to the territory of the country, either. During the implementation of monitoring it is to be taken into consideration that the development to be implemented will affect several countries with different cultures, levels and development and different attributes (differences in language, standards and regulations).

In order to achieve trans-boundary scalability of the system the following systems must be unified:

Development of monitoring system: Preliminary selection of locations. Installing monitoring stations. Solving power supply (mains current, battery or solar cell powered system). Defining the number, placing, fixing and protecting sensors.

Ensuring data supply: Communication standards to be used, defining directions (Wi-Fi, GSM, 3G, 4G, Ethernet, satellite, etc.). Declaration of data content. Defining access and information rights. Defining types of display.

Ensuring operation conditions: Recording types of installation. Recording maintenance time. Defining troubleshooting protocols. Defining extension and filtering protocol of data. Defining method of sampling and method of handling samples.

Developing warning system: Defining notification network. Recording critical parameters based on pollution maps. Recording warning levels.

The tasks to be implemented require exploring parameters influencing pollution and conditions of the catchment area and the impact (and size) of pollution on the environment.

The system to be developed would consist of the following system levels:

- **Measurement system/monitoring level:** Autonomous systems. Sensors, processing units, communication devices, power supply management devices (solar cell). Sampling and storing functions.
- **Laboratory level:** Installable mobile laboratory for control measurements. Analytical equipment. IT and info-communication equipment.
- **Data connection level:** modern communication system operating independently from borders, connecting on-site devices scattered in large geographical area or certain elements of the central system.
- **Data storage level:** Modern data storage system with divided structure, equipped with IT protection, which does not mean a central device but redundant units of devices. The system elements have threefold connection: connection to the on-site monitoring devices. Connection to other units of the server park. Connection to the user side.
- **User level:** software and hardware environment developed for displaying, filtering and editing the collected, historical, geographical information system (GIS) and pollution data.

1.3. Characterization of the TISA River Basin

The Tisa River is the longest tributary of the Danube. Its basin is the largest sub-basin of the Danube Basin and home to 14 million people throughout five countries: Ukraine, Romania, Slovakia, Hungary and Serbia. The five Tisa countries successfully worked together on the Tisa river Basin Analysis 2007, and now the same countries have come

together to create the Integrated Tisa River Basin Management Plan [Sources: Tisza River Basin Analysis, 2007].

Size of the Tisa River Basin: 157,186 km².

Length of the Tisa River: 966 km

Percentage of the Tisa River Basin in the Tisa countries:

- Ukraine 8,1%
- Romania 46,2%
- Slovakia 9,7 %
- Hungary 29,4%
- and Serbia 6,6%



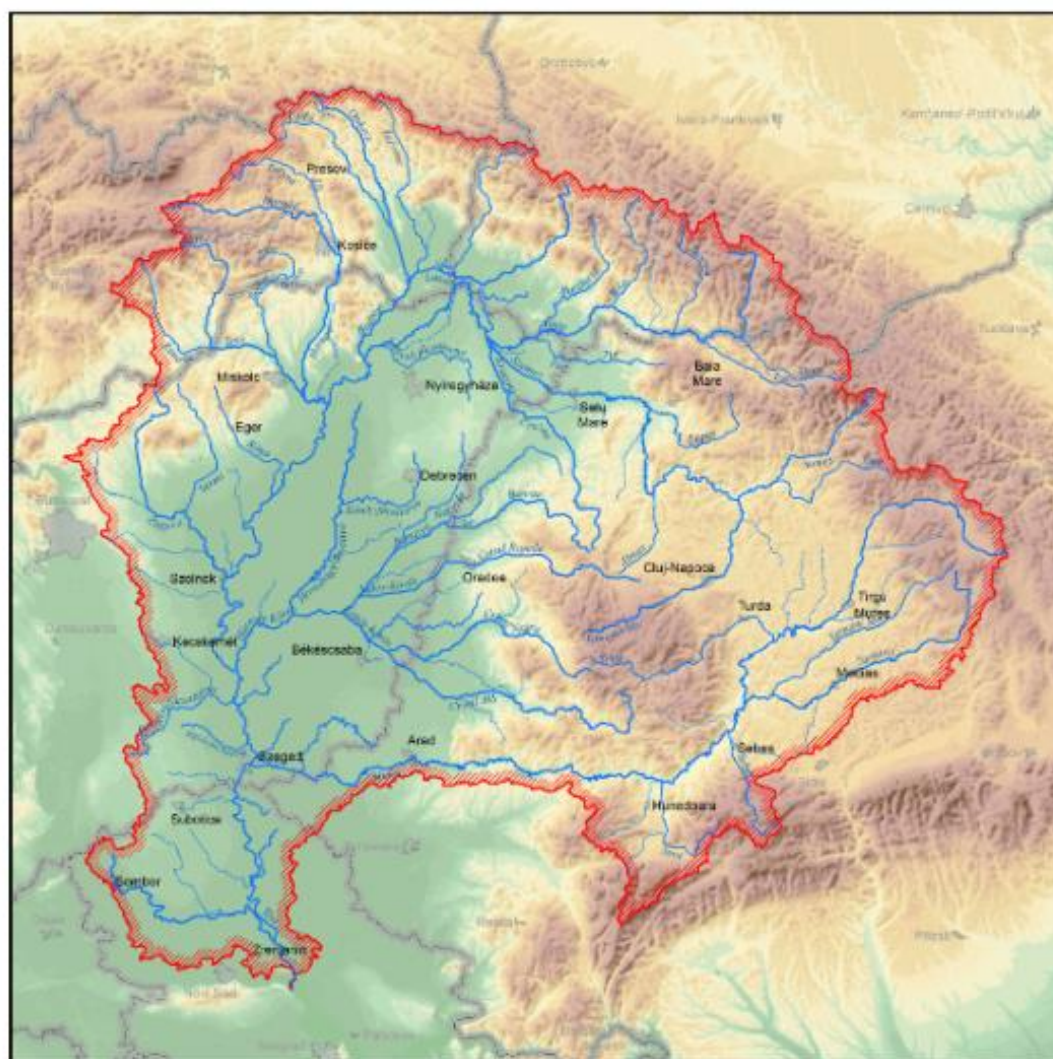
1. Figure: Distribution of the area between the Tisza countries

Percentage of the Tisa Basin in the Danube River Basin: 19,5 %

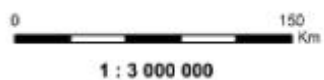
Annual mean discharge: 830 m³/s contributing 5,6 % to the total runoff of the Danube Basin.

The Tisa can be divided into three main sections [Sources: Tisza River Basin Analysis, 2007]:

- the mountainous Upper Tisa in Ukraine, upstream of the Ukrainian-Hungarian border
- the Middle Tisa in Hungary, which is joined by large tributaries including the Bodrog and the Slaná/Sajó (both fed by water from the Carpathian Mountains in Slovakia and Ukraine), as well as the Somes/Szamos, the Crisul/Körös River System and the Mures/Maros from Transylvania
- the Lower Tisa downstream of the Hungarian-Serbian border, fed directly by the Bega/Begej, and indirectly by other tributaries via the Danube – Tisa – Danube Canal System



Tisa Catchment



2. Figure: Tisza catchment

Key tributaries of the Tisa River with catchment areas >1000 km²:

Chorna Tisa, Bila Tisa, Teresva, Rika, Borzhava, Viseu, Iza, Tur/Túr, Somes/Szamos, Sieu, Somesul Mic, Somesul Mare, Lapus, Crasna/Kraszna, Bodrog, Uzh/Uh, Laborec, Latorica, Topla, Ondava, Hornád/Hernád, Torysa, Rimava, Slaná/Sajó, Bodva/Bódva Zagyva, Tarna, Hármaskörös, Crisul Alb/ Fehér-Körös/, Crisul Negru/ Fekete-Körös/, Kettős-Körös, Crisul Repede/ Sebes-Körös/, Barcau/Berettyó, Ier, Kati-ér, Sarkad-Mérgecs Sáros és Hortobágy, Berettyó, Dongérfcs, Kálló-ér Mures/ Maros , Aries, Tarnava, Tarnave Mica, Sebes, Strei , Aranca/Zlatica, Bega/ Plovni, Begej, Bega Veche /Stari Begej, Bajski kanal.

Tisa risk assessment

River classification and categorization

The majority of the countries (Ukraine, Romania, Hungary and Serbia) in the drainage basin of the Tisa use system „B” of the II. annex in the Water Framework Directive for typology catchments, with the exception of the Slovak Republic, who use system „A”.

In every catchment classification on the Tisa all mandatory factors from system „A” have to be used as common factors. These are the following: ecoregion, elevation above sea level, area of the drainage basin and geology. However, the majority of these countries have modified the classification according to their national requirements.

Countries who use system „B” use other, freely chosen factors for classification of rivers types. Romania uses the most (6) of the freely chosen parameters (median fall of the level of the water surface, discharge category, composition of subsoil, average air temperature, precipitation and 95% yearly minimum of specific flow monthly. All other countries only chose to use only one parameter from system „B”, the composition of the subsoil.

The countries through which the Tisa flows have classified the river into eight categories, while type classification system was developed by the states separately. Coordination and harmonisation on the international level has not yet been finished. There were five types identified on the Upper-Tisa, three by Ukraine, one-one by Romania and Slovakia. Hungary has identified two types for the Middle-Tisa, while Serbia one for the Lower-Tisa.

The number of rivers which have a larger drainage basin area than 1000 km² is 40. There are 16 water bodies identified on the Tisa: seven in Hungary, and one-one in Slovakia and Romania. The length of these water bodies are between 5 km (Slovakia) and 159 km (Hungary), with the average of 62 kilometers. There were 203 water bodies identified on the tributaries so far, most in Romania, as the majority of the drainage area lies in there [www.icpdr.org].

General water quality

Measurement points for water quality assessment were Transnational Monitoring Network (TNMN), Romanian Monitoring Network and Tisa section of International Danube Assessment.

On the whole length of the river there are 92 significant pollution point sources. These sources were identified according to the accepted ICPDR criteria. Of the 92 sources 51 were communal, 39 industrial and 2 agricultural.

Of the communal point sources BOD is 21 285 t/a, COD is 48 234 t/a, total N is 8 821 t/a and P is 1 264 t/a on the whole length of the river.

From point and diffuse sources the total amount of nutrients: 98 600 t/a N, and 8 200 t/a P.

Parameters for organic load: dissolved oxygen and BOD₅ was class I in all measurement points. COD_{Mn} was class I and II on the whole length of the river and I and II on the tributaries, except for one measurement, which was class III.

Parameters for nutrients: NH₄⁺-N: class III, NO₂⁻-N: mostly class II with class I, NO₃-N: class I and II, PO₄³⁻-P class I and II, total P class II, with one exception, class III. On the tributaries nutrient concentrations reached class I and II, with one exception which was class IV (NH₄-N) and class III (PO₄³⁻-P).

Heavy metals: Cu: class I and II with one class III exception. Cr: class I. Pb: class IV with class I and II exceptions. Cd: class I and II with one class III exception. Ni: class I with a few class II exceptions. Tributaries were apart of a few exceptions class I and II. These few exceptions were: Zn class III, Pb class III and V, Cd class IV.

Organic toxic compounds (AOX, oil products, lindane, DDT, atrazine, clorophorm, carbon tetrachloride, trichloroethane, tetrachloroethane). Phenole index and AOX were measured. Phenole index measurement: class III with one class II exception. AOX measurement: class I. All tributaries of Tisa were class III for phenol index and class I for AOX.

Risk assessment

Risk assessment data are available for the majority of the length of the Tisa. Exceptions are border crossing sections. This uncertainty will be eliminated with harmonization of risk assessment results. There are three risk categories: not at risk, possibly at risk and at risk. The Tisa is possibly at risk and at risk for organic pollution on 69 %, for nutrient pollution on 65%, for hazardous compounds (heavy metals and organic toxic compounds) on 92% of its length.

For organic pollution the Ukrainian section from the source until the Romanian/Ukrainian border section is not at risk, however from entering this section until leaving Hungary, the river is at risk. The Serbian section is not at risk.

For nutrients the Ukrainian section from the source until the Romanian border is not at risk, the Romanian/Ukrainian section is at risk, then again the Ukrainian section is not at risk, even after entering Hungary. Risk changes to possibly at risk in the second Hungarian section. Both Serbian section is at risk.

For hazardous material (heavy metals and toxic organic compounds) the river is possibly at risk from the source. It is at risk at the Romanian/Ukrainian border section, then again possibly at risk in the second Ukrainian section. From the Ukrainian/Hungarian border section until the second section of Hungary, where it changes to possibly at risk. Both Serbian are at risk.

On the tributaries 144 water bodies were at risk, which is 71% of all tributary water bodies. The majority of these endangered water bodies are in Romania, Slovak Republic, Hungary and Serbia. Except for Serbia, all countries reported water bodies which were potentially at risk, 15% of the total number. Only 14% of tributary water bodies are not at risk [www.icpdr.org.]

1.4. Cross-border cooperation agreements

1.4.1. Legal framework – International conventions

Tisa catchment is the largest sub-catchment of Danube catchment in the territory of five states. Modern, regional, bilateral and multilateral cooperation is of high priority and timely concerning water management policies in the Danube sub-catchment, in Tisa catchment addressed by the European Union and international bodies.

The cooperation within Tisa catchment is coordinated by ICPDR Tisza Working Group, but at the same time within the framework of implementing EUDRS, Hungary undertook a coordination role in the cooperation with Slovakia in the field of water quality protection and is committed to the joint coordination with Romania to manage disasters. During the implementation of EUDRS it is highly important to consolidate cooperation at the level of sub-catchments in the water catchment management of Tisa catchment:

Bilateral transboundary conventions must be updated to ensure better interoperability between water management organizations. Concerning pollution of surface waters early warning monitoring systems and response strategies must be worked out jointly using the available and well-tried devices and improving joint interoperable work processes.

In the following a list of international conventions are provided which serve as an international legal basis for conventions of bilateral transboundary matters or intergovernmental conventions including them. In case the latter ones were established earlier, the international conventions provided legal guidance to regulations and form the basis of bilateral conventions to be renewed in the future.

The international legal bases of transboundary conventions are provided by the following UN/ECE documents:

- Cooperation Agreement on Danube river protection and sustainable use (Sofia, 24 June 1994/ Sofia Convention or International Danube Protection Convention)
- Convention on the protection and use of Transboundary Rivers and international lakes (Helsinki, 17 March 1992. /Helsinki Convention /)
- Code of Conduct in case of water quality disasters of international rivers and lakes (UN/ECE, New York 1990);

Bilateral governmental conventions on issues of Tisa catchment and transboundary rivers are the following.

- **Slovakia:**

55/1978. (XII/10.) MT Decree on the regulation of transboundary water management between the Government of the Hungarian Republic and the Government of the Czechoslovakian Socialist Republic,

1999/17. International Agreement between the Slovakian and Hungarian governments on the cooperation in environmental protections and nature reserve.

- **The Ukraine:**

117/1999. (VIII/6.) Government Decree between the Ukraine and Hungarian Governments on the Convention addressing transboundary water management matters,

1993/11. International Agreement between the Ukraine and Hungarian Governments on regional development cooperation.

- **Romania:**

196/2004. (VI/21.) Government Decree between the Romanian and Hungarian Governments on the Convention on the protection and sustainable utilization of transboundary waters,

2001/9. International Agreement – agreement between the Romanian and Hungarian Governments on the cooperation in environmental protection.

- **Serbia:**

Convention between the Governments of the Hungarian People's Republic and the Federative People's Republic of Yugoslavia on water management matters (1955.).

Recent conventions and policies facilitating transboundary committee work have been established taking the fact into account that the affected states are participants of the Helsinki Convention and Sofia Convention.

In the Danube catchment for all countries concerned (13 countries, including the above five Tisza countries), may they be EU member states or not, the cooperation as an international legal basis in protecting waters and ecological sources and their sustainable use is ensured by the International Danube Protection Convention.

The Convention made with Romania on the protection and sustainable usage of transboundary waters is in accordance with the regulations of the European Parliament and of the Council 2000/60/EC Directive on determining the framework of community actions in water policy (Water Framework Directive, hereinafter as WFD) that came into force 22 December 2000..

Having regard to WFD regulations the Danube Basin Management Plan contained in the ICPDR has been worked out.

1.4.2. The Hungarian-Slovakian Transboundary Commission

The Convention on the regulation of transboundary water management matters concluded on 31 May 1976 by the Governments of the Hungarian People's Republic and the Czechoslovakian Socialist Republic has been effective to this day. The Hungarian-Slovakian Transboundary Committee has a Joint Water Quality Protection and Hydrology Sub-Committee (Joint Sub-Committee) which has a meeting twice a year.

During the latest meeting (October 2013) the Parties, concerning water quality protection, reviewed the water quality actions conducted on transboundary waters in 2012 and laid down the new tasks:

1. Evaluation of results of measurement conducted on the transboundary waters in 2012.
2. Evaluation of extraordinary pollutions of transboundary waters in 2012.
3. Elaborating proposal for state monitoring program of Hungarian-Slovakian transboundary waters in 2014.
4. Drawing up the water quality protection action plan for the joint Sub-Committee in 2014.
5. Mutual coordination of evaluation results of the Hungarian-Slovakian transboundary water courses.

In 2014 the Joint Sub-Committee conducts the water quality monitoring in accordance with the regulation on the water quality monitoring of the Hungarian-Slovakian transboundary

waters and the extended water quality monitoring of the Danube. The sampling schedule of joint water quality monitoring on the Hungarian-Slovakian transboundary waters in 2014 and the water quality monitoring program in 2014 are included in the annexes of the minutes taken of the meetings.

1.4.3. The Hungarian-Ukraine Transboundary Committee

One of the Annexes of the minutes of the meeting of the Ukrainian-Hungarian Water Quality Specialist Group in October 2012 working within the framework of the Transboundary Committee is on the „Regulation on taking samples on the Hungarian-Ukrainian transboundary waters, water quality evaluation and procedures to be followed in case of abnormal pollutions”. The legal basis of the Regulation is formed by the regulations of the Convention on transboundary water management matters concluded and by the Government of the Hungarian Republic and the Ukrainian Government on 11 November 1997 in Budapest which entered into force 16 May 1999.

The Regulation specifies the rules of sampling and measuring on transboundary waters, rules of evaluating water quality state and mentions the events and activities concerning water quality decay which may pose the risk of transboundary pollutions.

Both parties conduct water sampling on a monthly basis in their own area, the Hungarian party in the first week of that month, whereas the Ukrainian party in the third week of that month.

Twice a year Parties conduct sampling and laboratory tests jointly at the places specified in the related Annex, alternately in the Ukrainian and the Hungarian areas at times specified by Parties in advance.

Measures included in the Regulation aiming to prevent and eliminate abnormal pollution of transboundary waters are:

- Parties, in accordance with their legal regulations, shall ensure the application and implementation of actions to eliminate water quality damage for all transboundary rivers, taking the results of risk analysis of potential polluting sources into account.
- Parties shall use their experience with elimination of pollution for prevention and to improve their damage elimination actions, as well as to work out and update agreed and joint action plans to eliminate abnormal pollutions.

1.4.4. The Hungarian-Romanian Water Management Committee

The legal basis of the regulations on the „Regulation on the monitoring of the water quality of rivers forming or crossing the Hungarian-Romanian borders” (Regulation) is formed by the regulations of the Convention on the cooperation for the protection and sustainable utilization of transboundary waters signed by the Government of the Hungarian Republic and the Romanian Government on 15 September 2003, effective on 17 May 2004.

The Water Quality Sub-Committee works within the framework of the Hungarian-Romanian Water Management Committee.

The aim of the Regulation is to determine the evaluation methodology of the state of water quality and chronological changes of water quality for the waters forming or crossing the Hungarian-Romanian borders, listed in the Regulation (Túr, Szamos, Kraszna, Berettyó, Ér-csatorna, Sebes-Körös, Fekete-Körös, Fehér-Körös, Maros).

Taking water samples is conducted in the sections, close to the border and on Parties' own side, as specified in the relevant Annex of the Regulation. Simultaneously with sampling determination of water yield must also be conducted.

Frequency and timing of sampling:

- Both Parties shall conduct sampling on a monthly basis, on their own side. The Hungarian Party shall conduct it in the first week of that month, and the Romanian Party on the third week of that month. Physical, chemical and biological tests are to be conducted by the frequency and timing specified in the relevant Annex of the Regulation.
- For the purpose of inter-calibration, twice a year, Parties shall conduct sampling and water quality analyses jointly, alternately in the Hungarian and the Romanian side at times specified by the Water Quality Sub-Committee.

1.5. TransNational Monitoring at present

Considering the high environmental damage of pollution due to accidents, especially in the mining areas, the relevance of preventive measures is much higher in the Tisa basin than in the Danube basin. Special attention is needed to update facilities with a high accidental risk, including sites, on-going mining activities, solid waste disposal and abandoned tailing deposits. Emergency management procedures related to cross-border accidental pollution, such as mutual assistance and contingency planning have to be developed. Measures to reduce or eliminate hazardous substances need to be based on a variety of approaches addressed to individual pressures and sectors.

Best Available Techniques for industrial sources-including technological changes in the production process and substitution of specific substances- have been proven to bring significant reduction in a short time period.

For agriculture, implementing Best Environmental Practices and an immediate pesticide ban for the most hazardous priority pesticides would also reduce input of hazardous substances in the Tisa River Basin.

For EU Member States, it will also be necessary to implement the Integrated Pollution Prevention Control Directive and the Dangerous Substances Directive.

These measures, along with the Urban Wastewater Treatment Directive needed for organic and nutrient pollution, will serve as comprehensive instruments to integrate and address different aspects of pollution control to further contribute to achieving environmental objectives.

The Tisa basin wide vision for accidental pollution is that land is managed in such a way that the negative impacts of flood and droughts (such as pollution from contaminated sites or agricultural impacts) are minimized.

It is very important to prevent accidents and ensure effective contingency planning in case of an incident. The Danube as well as Tisa countries, in the framework of the ICPDR, have taken important steps to ensure such mechanisms are in place.

An *ACCIDENT EMERGENCY WARNING SYSTEM (AEWS)* has been developed and is being used and continually improved.

The Danube Accident Emergency Warning System - Danube-AEWS and its continuous operation represents the effectuation of the *Helsinki Transboundary Convention* of 1992 and *Sofia International Danube Protection Convention* of 1994. Domestic center with Principal Industrial Alarm Center (PIAC-05). (Source: http://www.fresh-thoughts.eu/userfiles/file/pptmrc/20VITUKI_tnmn&aews.pdf)



3. Figure: Danube River Basin, Accident Emergency Warning System (DAEWS)

The Accident Emergency Warning System is activated whenever a risk of transboundary water pollution exists or dangerous levels of hazardous substances are released. The system sends out international warning messages to countries downstream. This helps national authorities put environmental protection and public safety measures into action. The National Centres of the system established within the program in each of the co-operating countries are called as PIACs (Principal International Alert Centres), being in close contact with the national pollution control structures.

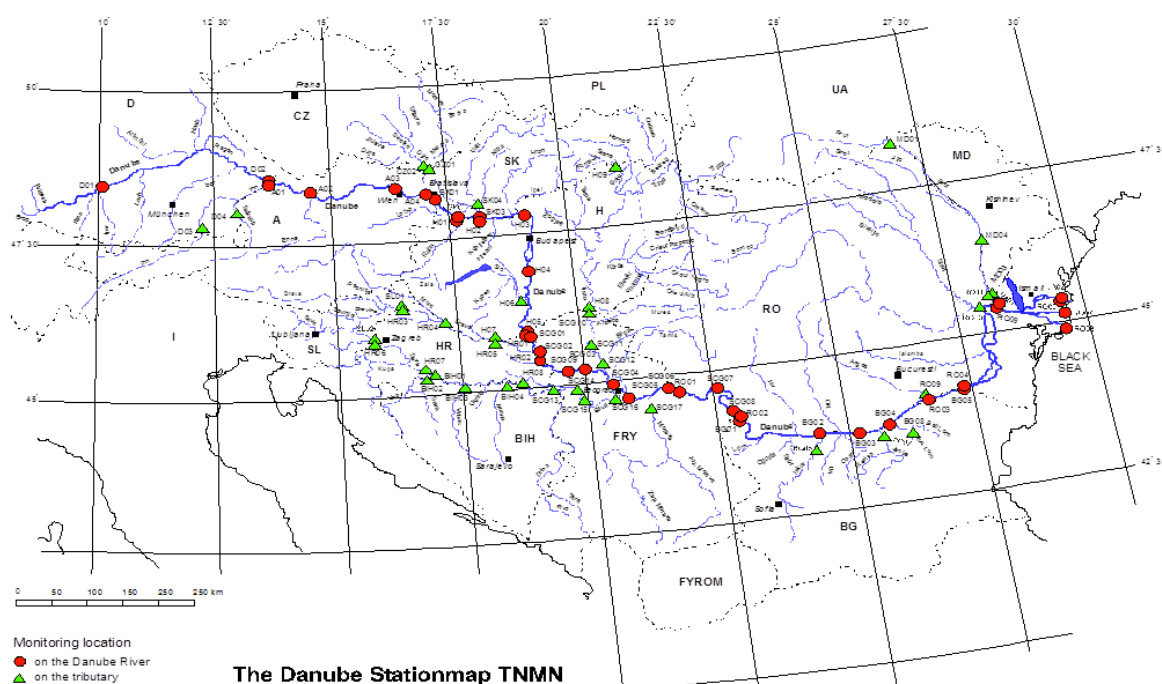
Principal International Alert Centres (PIAC) in each country from the central points of basin-wide cooperation in early warning.

These centres are made up of three basic units:

- Communication Unit (operating 24 hours a day), which sends and receives warning message
- Expert Unit, which evaluates the possible transboundary impact of any accident using the database of dangerous substances and the Danube Basin Alarm Model
- Decision Unit, which decides when international warnings are to be sent.

The parties concerned in the **Protection and Sustainable Use of Danube** signed a Cooperation Agreement on 24 June 1994 which entered into force on 22 October 1998 and the full-time secretariat has been working since 01 October 1999. The **International Commission for the Protection of the Danube River** – ICPDR and the (TransNational Monitoring Network-TNMN) are indicated in the map (Source: http://www.fresh-thoughts.eu/userfiles/file/pptmrc/20VITUKI_tnmn&aews.pdf).

- 79 monitoring stations
- 52 water quality components
- 12 measurements per year
- annual data evaluation and publication (TNMN yearbook).



4. Figure: The Danube Stationmap TNMN

1.6. Water management in the countries of the Tisa catchment area

1.6.1. Ukraine

Country analysis of current situation: Ukraine

The area of the Tisa river basin is 12 732 km² in the Ukraine, which is 8.1% of the whole river basin, 2.1% of the country area.

There are 16 (of which five are bilateral) monitoring stations in the Tisa basin. Sampling is manual, laboratory analysis includes:

conventional water quality parameters (temperature, pH, conductivity, total dissolved solids, suspended solids, dissolved oxygen, Na, K, Ca, Mg, Cl, SO₄, HCO₃, BOD₅, COD, nutrients, NH₄-N, NO₂-N, NO₃-N, PO₄-N);

- heavy metals (Cd, Pb, Cu, Cr, Zn, etc);
- organic micro pollutants (oil components, PAHs, phenols, pesticides);
- radioactivity indicators (Sr-90, Cs-137);
- microbiological indicators;
- biological indicators;
- water quantity parameters (discharge, flow velocity)

1.6.2. Slovakia

The territory of the Slovak Republic belongs to two international river basin districts (RBDs): Danube River basin and Vistula River basin. The Danube River Basin District is shared with 18 countries. The Ministry of Environment is the competent authority for WFD implementation. The other government authorities participating in the WFD implementation process are the Ministry of Agriculture, Ministry of Health, Ministry of Finance and Ministry of

Transport, the Supreme Postal and Telecommunications Office and other unspecified organizations.

The national approach in WFD implementation has been followed on the whole territory of Slovakia, no specific differences can be distinguished between Danube and Vistula RBDs at the national level.

A specific sub-basin-wide cooperation (B-level) is organized under the ICPDR for the international Tisa River Basin shared by Ukraine, Romania, Hungary, Serbia and Slovakia. In addition to the cooperation in river basin districts, the bilateral transboundary RBM issues in all Slovak RBDs are dealt with by the bilateral commissions established in cooperation with the Czech Republic, Hungary, Austria and Ukraine. These Commissions meet regularly to manage RBM issues between two neighboring countries.

Various elements of the RBMP for the Danube River Basin District have been applied in the Slovak plan, such as the concept of significant water management issues, nutrient emission assessment by the MONERIS model, the concept of confidence of the status assessment, measures for phosphate reduction and flood protection measures.

The following protected areas are addressed in the RBMP:

- Drinking Water Protected Areas;
- Bathing water areas (Directive 76/160/EEC);
- Sensitive areas and vulnerable zones;
- NATURA 2000 sites designated under Directive 92/43/EEC (Habitats) and Directive 79/409/EEC (Birds).

WFD compliant monitoring has been established in Slovakia based on a "Monitoring program for Slovak Waters", which is periodically updated. It includes monitoring of surface waters, ground waters and protected areas. In surface waters, all quality elements as required by the WFD were monitored. Both the operational and surveillance monitoring programs had two sub-programs, one for rivers and one for lakes. Operational monitoring is based on the results of the characterization and impact assessment carried out in accordance with Article 5 which identified water bodies at risk. Sampling sites are revised on an annual basis. Sampling sites are located in the lower parts of the catchments or downstream the significant pollution sources. There is no information given in the RBMP as to the relationship between the pressures and the BQEs that indicate the pressure.

The major aims of operational monitoring in Slovakia are in line with WFD:

- establishing the status of those bodies identified as being at risk of failing to meet their environmental objectives,
- assessing any changes in the status of such bodies resulting from the programs of measures,
- monitoring of water quality and quantity in relation to impacts from water uses.

The selection of biological quality elements and physical-chemical quality elements monitored in water bodies at risk took account of the causes of risks and the expected impacts. Water bodies at risk included in the monitoring program for 2007 and 2008 were located mainly on medium and large watercourses, and most of them were candidates for, or had already been designated as heavily modified water bodies.

All substances listed in Annex I of the Directive 2008/105/EC were monitored in surface water bodies – at representative sample points specified for the assessment of the

chemical status. However in most of the water bodies not all priority substances were analysed. Priority substances were monitored 12 times per year, while the other river basin specific substances four times per year. This is in agreement with WFD Annex V 1.3.4. Monitoring of priority substances in sediments or biota was not carried out; therefore no trends in these matrices were assessed.

In Slovakia all EQSs laid down in Part A of Annex I of the Directive 2008/105/EC have been applied for the assessment of the chemical status of surface water bodies, but in most of the water bodies not all priority substances were monitored. All priority substances pursuant to the draft (at that time) EQSD were monitored at representative monitoring points for the assessment of chemical status of surface water bodies. Slovakia did not opt to apply EQSs for biota for mercury and its compounds, hexachlorobenzene, or for hexachlorobutadiene according to Article 3(2a) of the EQSD, nor were EQSs for sediment and/or biota derived for the priority substances.

The chemical status assessment was, in principle, compliant with the WFD, following the provisions of the EQSD, but more clarity is needed as to the description of which priority substances were monitored in which water bodies. In addition, in the event that some substances were not analysed because they were considered as not relevant based on the pressures and impacts analysis, a justification should be added.

Background concentrations for heavy metals have been set using the available data from chemical monitoring activities in 1993-2007 in combination with information on geological characteristics, chemical composition of river sediments and ground waters, and on the surface water typology. Mixing zones were not used for chemical status assessment. There was no explanation found on how the bioavailability factors of metals were considered in the assessment of compliance with EQS.

Total costs of program of measures in the Danube and Vistula RBDs for 2010 - 2027 are €2724 million. There is a breakdown of costs by pressure provided in the plan addressing point sources, diffuse sources, morphological alterations, specific measures in protected areas and monitoring activities [Source: COM(2012)670 final, Slovakia].

Measures implementation time plan is as follows:

- Legislative measures – their implementation is required by 2012 at latest;
- Administrative measures – their implementation will follow the legislation;
- Technical measures
 - In agglomerations – construction of collecting systems and WWTPs – the implementation timetable is based on the needs to fulfil obligations arising from the Treaty on Accession to the EU (in accordance with the requirements of 41 Council Directive 91/271/EEC) published in the EU Official Journal no. 17 of 23. 9. 2003;
 - Industry – sources subject to the IPPC Directive – within the meaning of the accession agreement between Slovakia and the Commission for implementation of that directive;
 - Agriculture – application of the Program of agricultural activities in declared vulnerable zones, which has been implemented since the introduction of the first action program in 2004; completion of storage capacities where required for livestock manure in vulnerable areas depending on the focus of production and number of animals;

- The implementation of hydro-morphological measures (with the exception of measures to improve the hydrological regime) is based on a longer timeframe – to 2027.

There is an inventory of sources of pollution which covers priority substances, non-priority specific pollutants or main pollutants identified by Slovakia at the river basin level, and nutrients. Total N and total P emissions and a list of relevant priority substances and national river basin specific pollutants are provided for key sources and for all sub-basins. The relevant national river basin specific pollutants include aniline, benzothiazole, PCBs, MCPA, 4-methyl-2,6-di-tert-butylphenol, bisphenol-A, dibutylphthalate, diphenylamine, phenanthrene, zinc, arsenic, chromium, copper, cyanides, toluene and xylenes. The RBMP identifies industrial emissions (including wastewater from mining industry), emissions from households through public sewers, atmospheric deposition and emissions of pesticides from agriculture as significant sources of chemical pollution. The inventories are based on reporting to the European Pollutant Release and Transfer Register (EPRTR) according to Regulation EC No. 166/2006.

Revision of permits/authorizations and construction of wastewater treatment plants are among the key measures to be taken to tackle chemical pollution. No information is provided in the RBMP on substance specific measures.

Reduction of pollution by priority substances and the phasing out or cessation of emissions, discharges and losses of priority hazardous substances will be accomplished by issuing permits for waste water discharges into surface waters pursuant to Section 21 (2) (d) of the Slovak Water Act and in accordance with point 3 of Part A of the Annex to Government

Regulation No. 279/2011. In the permit, the state water management authority shall also specify measures and the timeframe of implementation to achieve environmental objectives, taking account of the availability, effectiveness and complexity of the technical solution according to an industry branch. If a detected spill of dangerous substances into water endangers the water body, corrective measures must be taken by the subject responsible for handling these substances, i.e. the polluter.

Following the steps of river basin planning as set out in the WFD should ensure that water management is based on a better understanding of the main risks and pressures in a river basin and as a result, interventions are cost effective and ensure the long term sustainable supply of water for people, business and nature.

Country analysis of current situation: Slovakia

The area of the Tisa catchment is 15 247 km² in the Slovak Republic, which is 9.7% of the whole river basin, 31.1% of the country area.

Monitoring of surface and groundwater in Slovakia in 2008 was based on the proposal for a network of monitoring surface water quality in 2007 in accordance with the Decree No. 221/2005 Coll. 39 water quality monitoring stations exist in the Tisa water basin, of which 7 are bilateral.

Transboundary (Slovakia-Hungary) sampling is annual, but analysis is very thorough:

- general physical and inorganic chemical parameters
- general organic parameters
- inorganic industrial pollutants parameters
- organic industrial pollutants parameters
- biological parameters (including based on WFD:

- phytoplankton, macrophytes and phytobenthos, benthic invertebrate fauna

1.6.3. Romania

97.4% of Romania's surface is part of the international Danube River Basin District (DRBD), representing approximately 29% of its surface. The Romanian part of the DRBD encompasses 11 sub-basins.

The Danube River Basin Management Plan (RBMP) was published on 22/12/2009 and was adopted by a Governmental Decision on 26/01/2011. The RBMP was reported to the Commission on 18/03/2011.

A common strength for Romania's RBMP is that it identifies the major sources of pollution and the monitoring program is continuously adjusted (e.g. the relevant BQEs are monitored). The RBMP was set up based on strong stakeholder involvement and good coordination at international level with EU Member States and third countries under the framework of the International Commission for the Protection of Danube River. The establishment of methodologies extensively uses the CIS guidance documents.

The RBMP was published on 22/12/2009 and submitted to the WISE system on 22/03/2010; further completions were added on 11/03/2011, 21/03/2011, 29/06/2011, 27/02/2012 and 12/03/2012 (in response to the additional request of the EEA).

In addition, the final National Management Plan for the RO part of the international DRBD was published to schedule on 22/12/2009, with national approval provided on 26/2011.

The Ministry of Environment coordinated the elaboration of the National Management Plan by NARW, which supervised further the elaboration of the sub-basin Management Plans by the 11 Water Directorates. The chapters concerning the groundwater were realized by the National Institute for Hydrology and Water Management. The 11 sub-basin Management Plans were further agreed by the Basin Committees; these structures aim to support the public consultations in every Water Directorate by involving the local stakeholders in the decision making process.

The Romanian National Management Plan was elaborated under the guidance of the ICPDR and its provisions were integrated in the international DRDMP. For transboundary catchments (e.g. Tisa River Basin, Danube Delta) the management plans are elaborated under ICPDR coordination based on the contribution of the countries sharing the catchment. For the Tisa River Basin the Management Plan was finalized in 2010, while for the Danube Delta the Article 5 report is under development.

The relevant quality elements are included in the monitoring program including the optional elements, except for QE 2-7 in transitional waters which is not relevant for transitional lake WBs. However, not all the parameters are currently measured at every surveillance site, as the monitoring program is subject to the relevance of monitoring elements to the WB categories, types and associated pressures.

The monitoring program is carried out on an annual basis and all monitoring sites were defined as surveillance points. The networks for surveillance and operational monitoring have overlaps. One monitoring site can belong to more than one surface water program and one monitoring site can include more than one monitoring sub-sites. One WB may have one or more monitoring stations, but the quality elements have been monitored at the representative station.

The list of monitored parameters and general information about the priority substances, specific and non-specific pollutants are provided; the substances included in WFD are monitored if the pollution sources include significant discharges of such substances.

Sediment and biota are monitored in all water categories. For both surveillance and operational monitoring, the sampling frequency is annually for sediment, while biota is sampled only in the operational program (annually).

The WBs lacking monitoring sites were evaluated by considering the monitoring data obtained in a different WB with the same typology and anthropogenic pressure. Grouping was applied especially for rivers, where only 1263 sites are monitored out of the total 3262 WBs assessed. For lakes, transitional and coastal waters, the number of monitoring sites exceeds the number of the evaluated WBs.

The Romanian monitoring program is established according to the CIS guidance No 7 on monitoring and is coordinated with the other countries in the Danube River Basin through ICPDR.

The total number of monitoring stations has changed since the 2007 report, the current monitoring program comprising 1263 sites for rivers, 434 for lakes, 12 for transitional waters and 42 for coastal waters.

The evaluation of chemical status was based on the values included in Annex I of the Directive 2008/105/EC. The relevant QEs are included in the monitoring program; the substances included in WFD Annex X WFD are monitored if the pollution sources include significant discharges of these kinds of substances.

The priority substances in water have been used in the assessment of the chemical status. Background concentrations were considered in the assessment of compliance with the EQS. There is no information provided that bioavailability factors have been used. For the current reporting, mixing zones have not been used. The RBMP provided information on specific substances causing failures to achieve good chemical status.

According to Annex VII of the WFD, the RBMPs should contain a summary of the program of measures (PoM), including the ways in which Member States expect to achieve the objectives of Article 4 WFD. The programs should have been established by 2009, but are required to become operational only by December 2012. The assessment in this section is based on the PoM as summarised by the Member State in its RBMP, and the compliance of this with the requirements of Article 11 and Annex VII of the WFD.

It therefore does not include a comprehensive assessment of compliance with the requirements of Article 11(3)15 on basic measures. It focuses in particular on key sets of measures. Member States will report to the Commission by December 2012 on the full implementation of their PoMs, including the progress on the implementation of basic measures as required by Article 11(3). The Commission will assess what Member States report and will publish its assessment in accordance with Article 18 WFD.

The Joint Program of Measures (JPM) includes measures of basin-wide importance oriented towards the agreed visions and management objectives for 2015. The JPM represents more than a list of national measures, as the effect of national measures on the Danube basin-wide scale is also estimated and presented. Specific measures to restore river continuity, to reduce the pollution loads with nutrients, organic and hazardous substances are included in the JPM.

In Romania the measures at sub-basin or WB levels are addressed in the 11 specific sub-basin management plans.

The RBMP presents the major sources of point and diffuse pollution at basin level, these sources being under continuous monitoring. Other pressures are considered as well, such as: the sources presenting potential of accidental pollution, fishery/aquaculture activities, gravel exploitation directly from the river bed and forestry that may impact also water quality and could represent a source of chemical pollution. The substances envisaged are nutrients, organic and priority/hazardous substances, according to WFD requirements.

The basic measures of the PoM address: reduction of pollution with priority substances and other substances in SWs, prior regulation of point source discharges liable to cause pollution, measures to prevent pollution from diffuse sources (agriculture, industry, households), prohibition of direct discharge of pollutants into groundwater, prevention of significant losses of pollutants from technical installations and prevent/reduce the impact of accidental pollution incidents; besides the basic measures, supplementary and additional measures address point and diffuse pollution, such as: construction of wastewater treatment plants, raising public awareness, habitat restoration to enhance the purification function of natural ecosystems, etc. Coordinated measures for the reduction of organic, nutrient and hazardous substances pollution are presented in the Danube RBMP (ICPDR - Joint Program of Measures).

Substance specific measures are addressed in the sub-basin management plans, such as: prevent/reduce significant losses of contaminants from technical installations, improved sewage connection of human agglomerations, floodplain restoration, creation of buffer strips along rivers etc. For heavy metals, closure of waste deposits, construction of retention basins or modernization of waste water treatment facilities are envisaged; for organic contaminants (chloroform, carbon tetrachloride, pentachlorophenol, hexachlorobutadiene), modernization of waste water treatment, extension of sewage system to connect to the industrial sewage system or stabilization of waste deposits are foreseen.

Following the steps of river basin planning as set out in the WFD should ensure that water management is based on a better understanding of the main risks and pressures in a river basin and as a result, interventions are cost effective and ensure the long term sustainable supply of water for people, business and nature.

To deliver successful water management requires linking these different steps. Information on pressures and risks should feed into the development of monitoring programs, information from the monitoring programs and the economic analysis should lead to the identification of cost effective programs of measures and justifications for exemptions. Transparency on this whole process within a clear governance structure will encourage public participation in both the development and delivery of necessary measures to deliver sustainable water management [Source: COM(2012)670 final, Romania].

Country analysis of current situation: Romania

The area of the Tisa river basin is 72 620 km² in Romania, which is 46.2% of the whole river basin, 30.5% of the country area.

There are 89 (of which 13 are bilateral) monitoring stations in the Tisa basin.

1.6.4. Hungary

On-line monitoring stations on the Tisa catchment area

The Tisa catchment area lies on the territory of 5 countries: Slovakia, the Ukraine, Romania, Hungary and Serbia. A decisive majority of potential polluting sources are located in the territory of the upper water course of the Tisa, that is, in the bordering countries, primarily in the catchment area of Tisa tributaries, and the country affected the hardest by the pollutions coming from these countries is Hungary.

For the above-mentioned reasons, it is in the common interest of these countries to monitor continually the surface waters flowing through borders, detect the pollution as soon as possible and work out action plans for the potential pollutions.

The Automated Water Quality Monitoring and Early Warning System originally consisted of three continually operating monitoring stations (Hernádszurdok/Hernád, Fig.1., Csenger/ Szamos, Pocsaj/ Berettyó). The next step of developing the monitoring system was to build a station in Técső in the Ukraine and integrate it into the system, extending the monitoring system to 4 in 2003, which was built with the contribution of the Hungarian Ministry of Environment and Water and the US Agency for International Development (USAID). The system administrator is the North Hungarian Environmental, Nature Reserve and Water Inspectorate (ÉMI-KTVF) seated in Miskolc and the collaborating inspectorates are: Upper Tisa Region Environmental and Nature Reserve Inspectorate (Nyíregyháza); and Trans-Tisa Environmentaé, Nature Reserve and Water Inspectorate (Debrecen).

The monitoring stations are controlled by the system centre of ÉMI-KTVF: it conducts data poll, display, analysis and archivation, furthermore, it checks the warning signals from the stations and it notifies the competent organizations if needed. The devices and instruments of the monitoring stations conduct scheduled tests by default but the system configuration allows polling control from the centre too.



5. Figure: MS-1 monitoring station and the perforated sampling tube with barrier

The main components of the equipment of the monitoring stations are the measuring instruments, sampling pump, hydraulic system, auxiliary equipment and test control-data collection system. Since 2005 on domestic monitoring stations water level measurement has been conducted and the water yield calculated by this also appears in the database.

Water sample supply for instruments follows an hourly measurement cycle. Before starting a measurement cycle, the pump system maintains a continuous water flow of specified speed and after finishing the measurement it empties the system with compressed air. It helps avoiding stagnant water remaining in the sampling tube. On the section in front of the perforated sampling tube installed in the riverbed a barrier had to be built to protect it from drifting scum (graph above).

The basic equipment of monitoring stations allow the continuous (frequent) measurement of the following parameters: water temperature, pH, dissolved oxygen, conductivity, turbidity, ammonium ion, TOC, surface oil (from the TOC data of surface sample), chlorophyll-A and toxicity (T-index). In addition, at the Csenger station devices measuring potential pollutants like heavy metals (zinc, cadmium, lead and copper) nitrate and cyanide arriving on river Szamos are also installed.

The task of the automated sampling device is to take samples and store them cooled for further laboratory tests, in case of the sudden diminution of water quality.

The photos and the list above also indicate that the installation and operation (building, fixed installation of water sampling pipe system, measurement devices, auxiliary devices, etc.) and the maintenance (frequent servicing, need for chemicals) require considerable investment costs.

1.6.5. Serbia

Geographic information

There are more than 500 water bodies, 25 reservoirs and 6 lakes in Serbia. The main rivers are: Danube, Tisa, Great-Morava, Sava, Drina, and Temes. The two most important of these are the Danube, which has a length of 588 km in the country from the Hungarian to the Romanian border. The Tisa enters from Hungary, and flows 168 kilometers until meeting the Danube. The majority of the country is part of the Danube water basin.

Authorities, stakeholders

According to the Law on Ministries, the environmental policy of the Republic of Serbia is predominantly addressed by the following institutions: the Ministry (MEDEP), the Ministry of Natural Resources, Mining and Spatial Planning, the Ministry of Agriculture, Forestry and Water Management, the Ministry of Health, the Ministry of infrastructure and the Serbian Environmental Protection Agency (SEPA) as an authority within the MEDEP,.

There are seven water districts identified in the Water Law (Official Gazette of the Beneficiary Country No. 30/10 as of 7 May 2010).

1. Sava
2. Beograd (Belgrade)
3. Morava
4. Donji Dunav (Lower Danube)
5. Srem
6. Backa and Banat
7. Kosovo and Metohija

Laws and regulations

Legal framework for the protection of water from pollution in the Republic of Serbia:

Law on Environmental Protection ("Official Gazette of the Republic of Serbia" no. 135/04),

Law on Water ("Official Gazette of the Republic of Serbia" no.54/1996),

Law on Water Regime ("Official Gazette of RS" no.101/2005),

Law on Communal Activities ("Official Gazette of RS" no.16/97 and 42/98).

Bylaws:

Directive/Act on water classification ("Official Gazette SRS" no.5/68);

Directive/Act on watercourses categorization ("Official Gazette RS"no.5/68);

Directive/Act on recompense for water use recompense for water protection and recompense for the material extracted from the water courses for the year 2005. ("Official Gazette RS" no.46/91,53/93,67/93,48/94,54/96 and 29/2008);

Rulebook on hazardous substances in waters ("Official Gazette SRS" no.31/82),

Rulebook on hazardous substances that must not be discharged into waters ("Official Gazette SRS" no.3/66 and 7/66),

Rulebook on procedure and number of wastewater quality analyzes ("Official Gazette SRS" no.47/83 and 13/84).

Republic of Serbia has ratified following international agreements concerning management and protection of water:

Convention on Protection of the River Danube, and adopted the Decree on proclamation of the Law on ratification of Convention on Cooperation for the Protection and Sustainable use of Danube River, in 2003;

SCG became a full member of International Commission for the Protection of the Danube River (ICPDR) on August 9, 2003.

Framework Agreement on River Sava Basin, Protocol on Navigation Regime to the Framework Agreement on River Sava Basin and Agreement on Provisions of Framework Agreement on River Sava Basin and Protocol on Navigation Regime to the Framework Agreement on River Sava Basin, in 2004;

Republic of Serbia became a full member of the Sava Commission from the beginning.

Current monitoring system

Currently the national network of water monitoring stations include 134 points along river courses and canals, 33 springs, 4 lakes, 25 reservoirs and 68 piezometers. Water quality is permanently monitored by the network of surface water-stations that includes 133 measurement profiles using largely manual sampling, precluding the possibility of real-time data or Early Warning System, especially on transboundary Rivers.

Current plans

A project for an early warning system of surface water pollution initiated in 2007 by the Ministry of Science and Environmental Protection recommended four automatic stations to replace manual sampling (three at national inlets: one on the Sava at Jamena, one on the Danube at Bezdan, one on the Tisa at Novi Knezevac and one at the outlet from Serbia at

Radujevac on the Danube). Later, the Novi Knezevac station was taken out of the plans, and the Jamena was given an optional status. These stations would not only provide real-time information, but would also act as an early warning system.

Both basic (flow, water level, pH, temperature, turbidity, etc.) and more sophisticated (Daphnia and algae toximeter, algae monitor, nutrients (ammonia, nitrates, orthophosphates), inorganic anions (sulphates, cyanides), dissolved organic substances (using Spectral Absorption Coefficient SAC 254), heavy metals, chlorinated hydrocarbons, radioactivity, etc.) were envisaged to be installed at the automated monitoring stations. Later, station designs were streamlined to measurements needing water related EU directives (and adding flow measurements). Because of land ownership issues the construction of the monitoring stations was postponed.

The improvement of the Serbian Environmental Protection Agency's National Laboratory is also planned, which will give a background laboratory measurement capacity. This enables a more precise analysis of the samples taken at warning events.

The following equipment are planned to be purchased:

- Gas chromatograph - time-of-flight - mass spectrometer (GCxGC-TOF-MS)
- Ultra High Performance Liquid Chromatograph (UHPLC) with Diode Array UV Detector (DAD UV) and high resolution MS/MS spectrometer with on-line SPE sample preparation system
 - Fully automated device for determination of mercury
 - Stereomicroscope
 - Standards

Also, there are other equipments planned besides these for purchasing in other scenarios.

Country analysis of current situation: Serbia

The area of the Tisa river basin is 10 374 km² in Serbia, which is 6.6% of the whole river basin, covering 11.7% of the country.

Currently there are 10 water quality monitoring stations on the Tisa catchment. Water quality is permanently monitored by the network of surface water-stations in the whole country, that includes 133 measurement profiles using largely manual sampling, precluding the possibility of real-time data or Early Warning System, especially on trans-boundary rivers.

After manual sampling, the following parameters are measured: pH, conductivity, redox potential, dissolved oxygen, nitrates, ammonia.

The present situation regarding the monitoring of surface waters in Serbia is characterized by the following:

Monitoring surface water quality with manual sampling at 129 locations on 66 water streams,

one automatic station (the river Kolubara - Beli Brod) with the system comprising of a pump and with water flow through the reservoir with sensors (in operating condition),

two automatic stations (the river Tisa) with multiparameter probes directly immersed into the river water (operating but not functional),

four automatic stations at the inlet and outlet of Serbia - in the design phase.

1.7. Areas studied for designing EWS monitoring network

Action 2 priority area of the European Union “European Union Danube Region Priority 4” (EUSDR PA4 Water Quality) Consolidation of cooperation at sub-basin catchment level”. The first milestone of this action contains the project “Water quality early warning system on transboundary waters, the implementation of which may ensure development of a long awaited warning system on the Tisa catchment area inevitable for the downstream countries.

The planned elements of the early warning monitoring system are as follows:

a) **Transboundary water sites**

b) Monitoring water course sections under **hazardous objects** choosing the points in a way that pollution getting into the water through point like inputs and spill on the ground are also signaled.

c) Exploring spots characterizing **sub-basins** and **major water courses**. Apart from high-risk objects potentially polluting water courses, there are numerous pollution sources with lower risk on the sub-basins. Among others, they are the objects listed in the E-PRTR (European Pollutant Release and Transfer Register) and UWWTD (Urban Waste Water Treatment Directive) spots. In addition, due to diffuse load/pollution on sub-basins, it is practical to establish a point network ensuring general coverage.

To establish a monitoring system, that is, to determine the locations of stations conducting continuous monitoring and the list of physical-chemical parameters, with the measurement of which we can provide sufficient information about the state of the water body and the Tisa catchment, obtaining extensive international information is needed. In this case, very serious cooperation and exchange of information is necessary so that we can establish an effective early warning monitoring system.

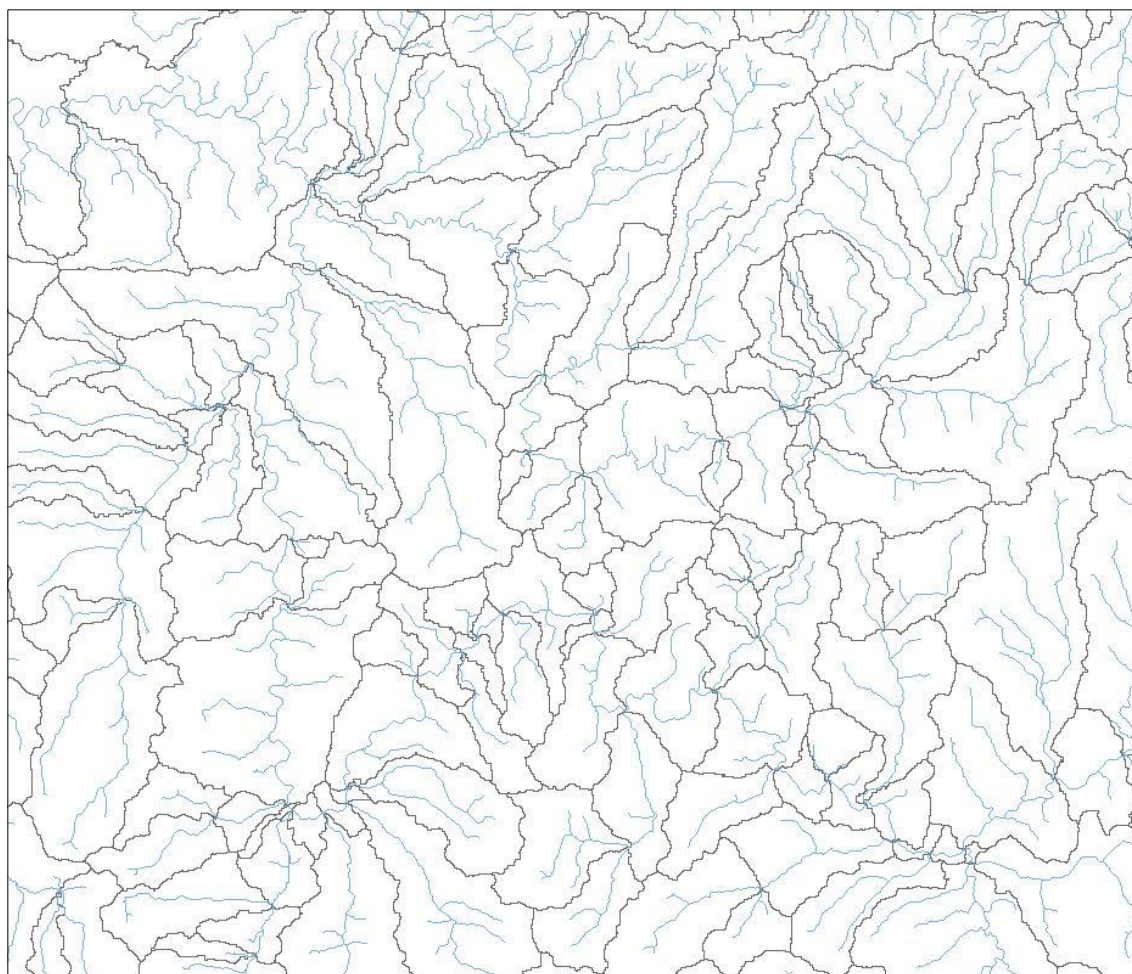
EWS monitoring system can provide additional information with its continuous time series. Correlations may be searched between continuous monitoring and reported results, supporting the bidirectional work and helping countries so that they can achieve the objectives set in the Water Framework Directive as fast/efficiently as possible.

1.8. Background information for designating monitoring locations

1.8.1. *Basic data*

a) **Ecrins water network**

Ecrins (European catchments and Rivers network system) is the model water network developed by the European Environmental Agency. The database breaks down Europe territory into 68 km² functional elementary catchments. Using Ecrins water network was supported by the idea that it is a water catchment and river network which is lifelike and homogenous, consistent and complete for the Tisa water catchment which is the subject of our study. The disadvantages are that it does not always reflect real water networks, especially in plain lands, it cannot follow the artificial channel networks and the current version does not include water flow names. Naming was important so that we could identify, find orientation and can name monitoring points. Thus names had to be collected from other sources.

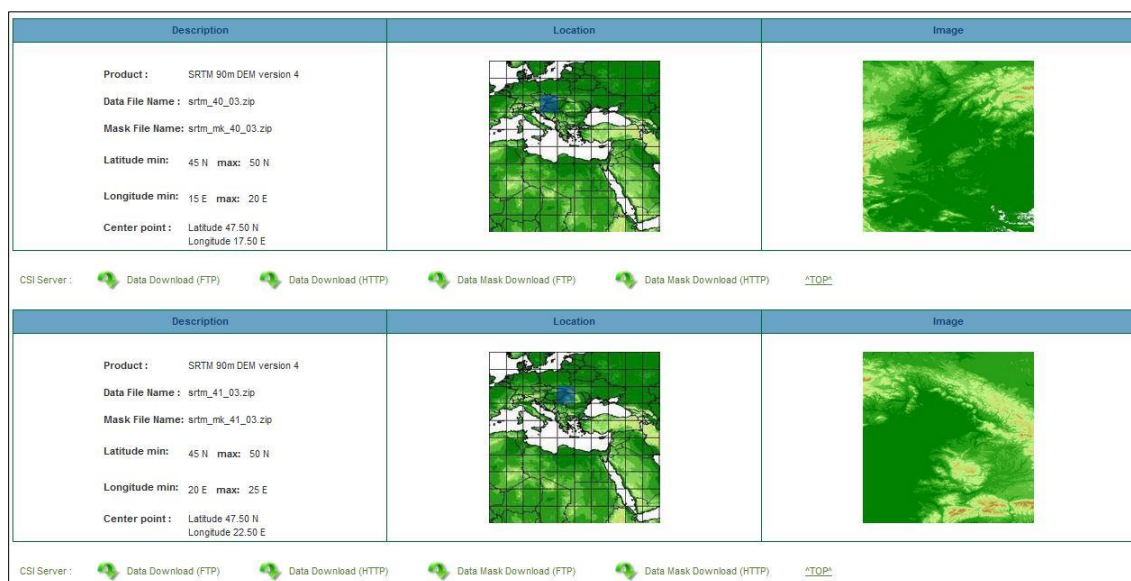


6. Figure: Ecrins River Network

During the study we worked out three versions. Based on the water course database of Ecrins we sorted out water courses with catchments over 500, 1000 and 3000 km² back to their sources and with the help of hierarchical database structure, we combined the elementary catchments for the selected water courses (source: www.eea.europe.eu). The water courses belonging to the catchments of different size (500, 1000, 3000 sheet) are included in the *Rivers.xlsx* Excel sheet with the already collected water course names. On the last, „Summary” tab we hierarchically summarized the water courses included in the study.

b) SRTM terrain model

To study the surface flow of potentially released hazardous substances we needed an appropriate terrain model. We needed a consistent, homogenous and freely available terrain model for the whole Tisa catchment, which has adequate resolution for conducting the above-mentioned studies. These criteria were met by the 90x90m SRTM (Shuttle Radar Topography Mission) (source: www.cgiar-csi.org).



7. Figure: SRTM Digital Elevation Model

1.8.2. Thematic information

a) ICPDR maps and studies

Within ICPDR a separate working group dealt with the Tisa catchment. In 2007 maps of the Tisa catchment were attached to their reports made in the framework of WFD (Water Framework Directive). Map attachments made in 2009 for the total Danube catchment also provide useful information about the state of water bodies and risks by hazardous substances (source: www.icpdr.org).

b) National River Basin Management Plans

Information on the water bodies created in the studied area, their types and state can be obtained from the national water catchment management plans of various countries.

c) ARS studies

The ARS points included in the studies published in 2000 and 2004 were aggregated (*ARS_pontok.xlsx*). Most of them matched each other but changes took place even during 4 years. Altogether there are 54 points like this in the list and we could use this numerical data, but we did not have coordinate data. Accurate designation requires the acquisition of the geographical coordinates of risky objects. Another task is to have the list of risky objects updated by the countries affected in the catchment and to reconcile changes in technological processes. A comprehensive data collection, involving the Tisa catchment countries could not be included in the framework of this study, but we needed to find a method which is fast and effective, and does not reduce the quality of designation. As a solution for the two available studies we used the map attachments in image format with georeferencing and marked ARS points manually in a "shape" file (source: www.zinke.at; www.grida.no).

d) Other pollution sources in the catchment

We also collected data about high number but low-risk pollution sources.

- *Urban Waste Water Treatment Directive (UWWTD)*, because it means additional load on water bodies. Water treatment plants use different technologies on the Tisa catchment, so different loads can be expected (source: www.eea.europa.eu).
- *European Pollutant Release and Transfer Register (E-PRTR)*. European level records about crucial environmental protection data of industrial installations (source: www.eea.europa.eu).

GIS files were prepared and sorted out for the Tisa catchment based on geographical coordinates available in both databases. (The Pollution Inventory made this way is included in the **UWWTP** and **EPRT** Excel file.)

1.8.3. Technical preparation

Before starting the analysis of the GIS data, the above-mentioned source data had to be converted into unified ESRI shape and grid format and transformed into identical projection, which is the Lambert Azimuthal Equal Area on ETRS 1989 surface adopted by the European Union.

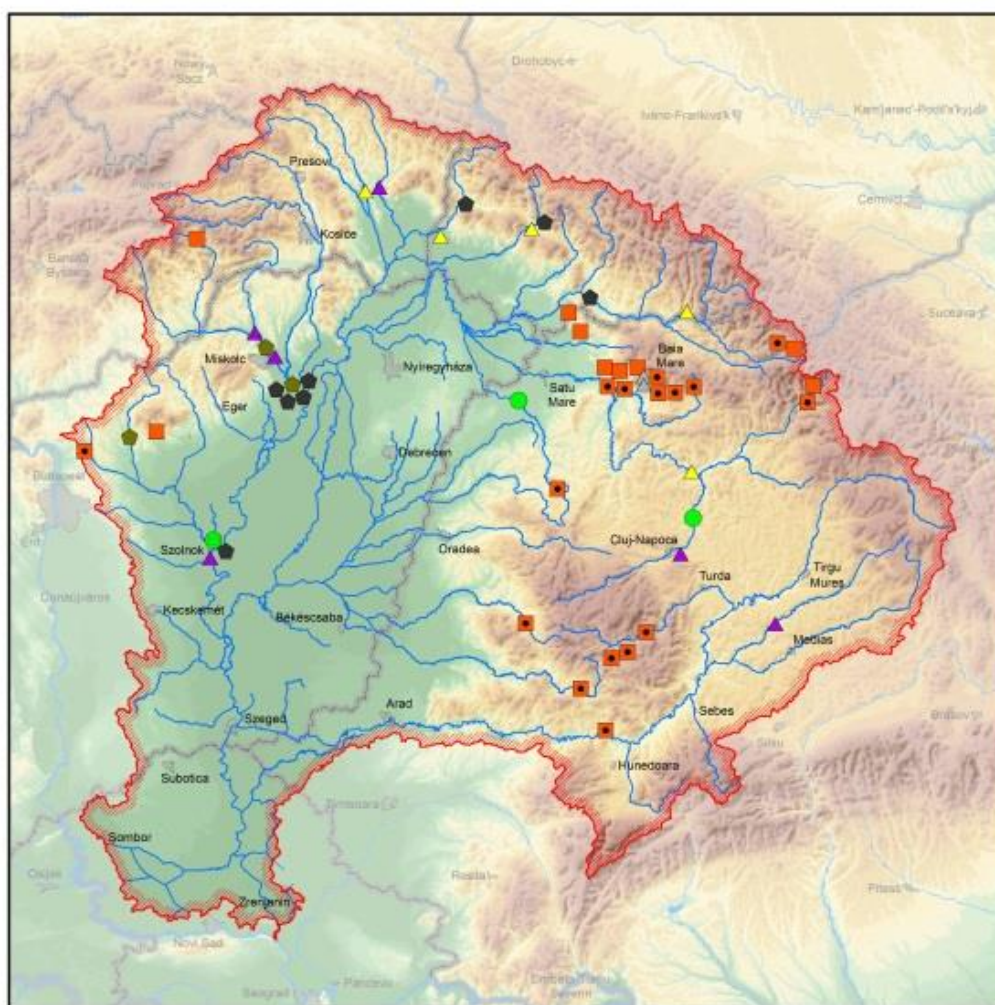
1.9. Methodology of designating monitoring locations

1.9.1. Designating ARS spots in the Tisza catchment

Depicting hazardous release places on map: based on data from 2000 and 2004.

Monitoring rivers downwards the hazardous objects: spots must be selected in a way that they can signal pollutants getting into the water both through point inputs and after spills getting on the ground.

The image indicates well on which area hazardous objects are concentrated.



Accidental Risk Spots in the Tisa Catchment

0 150 Km
1 : 3 000 000

Legend

Accidental Risk Spots

- Mining industry
- Mining with tailing ponds
- Oil industry, pipeline
- Energy production and deposit
- Metallurgical industry
- Chemical industry
- Cellulose and paper industry
- Stock-raising
- Food, sugar factory

Country border

Tisa catchment

8. Figure: Accidental Risk Spots in the Tisza Catchment

Numerical distribution of hazardous emission spots:

- In Romania: number of high-risk spots: 28
By release of pollutants: cyanides; heavy metals (Cu, Zn, Pb, Mn); sulphuric acid; organic substances, lignine, tannin, ammonium, Cr6+; acid solution;

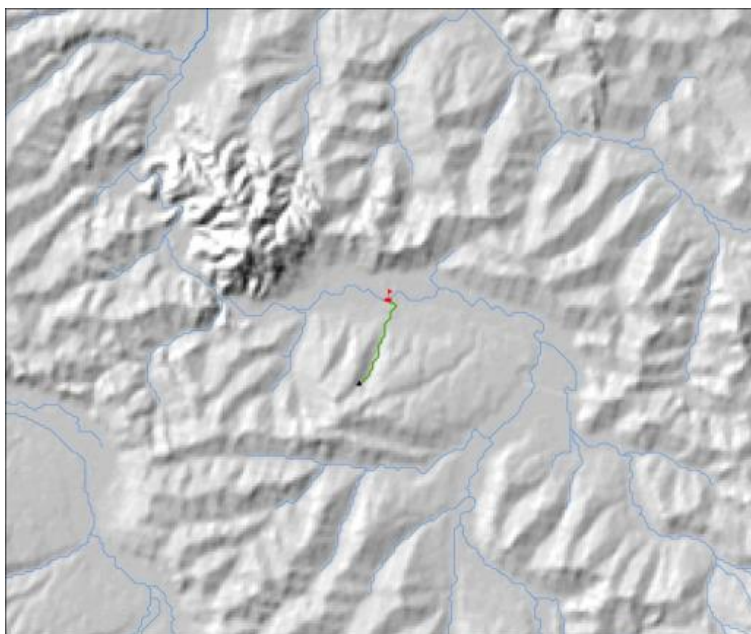
- In the Ukraine: number of high-risk spots: 6
By pollutants: phenols, oil products
- Slovakia: number of high-risk places: 3
By pollutant: As, Pb, Zn in sludge
- Hungary: number of high-risk spots: 15
By release of pollutant: Disposal of radioactive wastes, organic nitrogen content, gasoline, metal sludge (Mn, Zn, Cd, As, Pb), reservoir for slag and slurry with metal content (Cu, Cd, Cr, Pb, V and As)

Regional Inventory of Potential Accidental Risk Spots in the Tisa catchment area of Romania, Hungary, Ukraine & Slovakia (2000)					Rapid Environmental Assessment of the Tisa River Basin (2004)				
Country	ARS Map no.	National number and sub-region	Industry Sector		ARS Map no.	Industrial Hot Spots			Industry Sector
RO	1	1. SC TERAPIA SA	Chemical (pharm)	cyanides					
RO	2	2. SC AURUL SA (pond)	Mining	cyanide, heavy metals (Pb, Zn, Cu, Pb)	8	Transilvania Baia Mare-Boranta Aurul pond			Mining with tailing ponds
RO	3	3. SM BORSA - Colbu Pond	Mining	heavy metal	16	EM Baia Borsa-Colbu pond			Mining industry
RO	4	4. SM BORSA - Novat Pond	Mining	heavy metal	15	EM Baia Borsa-Novat pond			Mining with tailing ponds
RO	5	5. SM BAIA MARE UP Central Flotation Unit, UP Sasar (pond)	Mining	cyanides, heavy metals (Pb, Zn, Cu, Mn)					
RO	6	6. SC ALLIED DEALS PHOENIX SA	Metallurgy	heavy metals, sulphuric acid	9	EM Aurum Baia Mare-sector Sasar			Mining with tailing ponds
RO	7	7. SM BAIA MARE - EM Baia Sprie (pond)	Mining	heavy metals	12	EM Baia Sprie-Tauti de Sus pond			Mining with tailing ponds
RO	8	8. SM BAIA MARE - EM Cavinic (pond)	Mining	heavy metals	13	EM Cavinic-Plapris Rachtetele pond			Mining with tailing ponds
RO	9	9. EM AURUM - Iba Sector	Mining	heavy metals from mine waters	4	IMI Baia Mare-sector Iba			Mining industry
RO	10	10. SM BAIA MARE - EM Herja	Mining	heavy metals	6	EM Baia Sprie-sector Herja			Mining industry
RO	11	11. CMNP REVIN BAIA MARE - EM Turt (pond)	Mining	heavy metals (Cu, Pb, Zn)					
RO	12	12. EM AURUM - Nistru Section	Mining	heavy metals from mine waters	3	EM Turt			Mining industry
RO	13	13. C.N.P.N. REVIN SA BAIA MARE Mining Subsidiary Rodna (pond)	Mining	heavy metals (Pb, Zn)	5	IMI Baia Mare-sector Nistru			Mining industry
RO	14	14. SM BAIA MARE - EM Baita (pond)	Mining	heavy metals	18	EM Rodna-Valea Glodului pond			Mining with tailing ponds
RO	15	15. SC SOMES SA, Dej	Pulp & Paper	organic substances, lignine, tarsins	14	EM Baita-Bitoaja pond			Mining with tailing ponds
RO	16	16. SC COMINEX NEMETALIFERE SA - Mining Subsidiary Agheles (ponds)	Mining	organics	19	SC Somes SA Dej			Cellulose and paper industry
RO	17	17. SC AGROCOMSUI - SA BONTIDA (biological ponds)	Agric./Pig Farm	organic substances, ammonium, suspensions					
RO	18	18. CNCAF Minvest, SC Devamin SA, Branch Mine Brad - U P Garabaza, Răbăta Pond	Mining	cyanide, heavy metals (Pb, Zn, Cu, Mn)	20	SC Agroflor SA Bontida			Pig farm
RO	19	19. CNCAF Minvest, SC Devamin SA, Branch Mine Bita - U P Bita, Fânate Pond	Mining	cyanide, heavy metals (Pb, Zn, Cu)	22	SC Devamin SA Mine Brad (Răbăta)			Mining with tailing ponds
RO	20	20. SC BICAPA SA (pond)	Chemical	cyanide, Cr6+	21	SC Devamin SA Mine Bita (Fânate)			Mining with tailing ponds
RO	21	21. E.M. ABUD (pond)	Mining	heavy metals, suspensions, acid solutions	27	SC Bicapa SA Tarnavei			Chemical industry
RO	22	22. EM Rosia Montana (pond)	Mining	heavy metals, acid solutions, suspensions	24	EM Abud			Mining with tailing ponds
RO	23	23. EM Baia de Aries (pond)	Mining	heavy metals, cyanides, suspensions	25	EM Rosia Montana			Mining with tailing ponds
RO	24	24. EM Coranda Certej (pond)	Mining	heavy metals, suspensions	26	EM Baia de Aries			Mining with tailing ponds
RO					23	EM Coranda Certej			Mining with tailing ponds
RO					1	Nutisan Mofin			Pig farm
RO					2	West Construction Company			Mining industry
RO					7	Romplumb Baia Mare			Metallurgical industry
RO					10	Captim Bucuresti-nord Baia Mare			Metallurgical industry
RO					11	UP Ploiesti Centrala Baia Mare			Mining with tailing ponds
RO					17	Comma Bucovina Frasin-Valea Balilor			Mining industry
UA	1	1. Opened joint-stock company "Perechynsky chemical timber industrial complex", State	Pulp & Paper	phenols	1	Perechynsky industrial complex			Cellulose and paper industry
UA	2	2. Opened joint-stock company "Svalyava chemical timber industrial complex", State	Pulp & Paper	phenols	3	Svalyava industrial complex			Cellulose and paper industry
UA	3	3. Opened joint-stock company "Velykobychnytsky chemical timber industrial complex", State	Pulp & Paper	phenols	6	Velykobychnytsky industrial complex			Cellulose and paper industry
UA	4	4. "Prykarpattans oilproduct", Russian Federation	Oil	oil products	2	Prykarpattans oilproduct			Oil industry, pipeline
UA	5	5. "Donbass", State	Oil	oil products	4	Donbass			Oil industry, pipeline
UA	6	6. Platform 2/1 village Rososh, "Prykarpattans raftproduct", Russian Federation	Oil	oil products	5	Prykarpattans raftproduct			Oil industry, pipeline
SK	1	1. Zebra s.p. 02 Siderit, Rožava	Mining	As, Pb, Zn in sludge	1	Zebra s.p. Siderit Niwa Stara/Rozava			Mining industry
SK					2	Budocel Hencovce a.s. Vranov nad Topľou			Cellulose and paper industry
SK					3	Chemko Strážske a.s.			Chemical industry
HU	1	1. Landfill for radioactive wastes Pálpókollány	Waste	Disposal of radioactive wastes	1	Radioactive landfill at Pálpókollány			Mining with tailing ponds
HU	2	2. HUNVIRON Kft. Pile from flying ashes, Lőrinci	Energy	In the area of the flying ash pile of the Lorinci Power Plant besides the waste from the plant there are different waste of III hazard category		HUNVIRON deposit Lőrinci			Energy production and deposit
HU	3	3. Sugar factory Rt. Begin-Say (French)	Food	Waste water from sugar production with organic nitrogen content	2				
HU	4	4. MOL Rt., Sajó József	Oil	gasoline, petrol, motor oils	12	Begin-say, Szolnok			Food, sugar factory
HU	5	5. HIDROTECH Bányászati és Környezetvédelmi Kft., ÁPV Rt., Gyöngyösiország	Mining	metal sludge (Fe, Mn, Zn, Cd, As, Pb)	14	MOL base depot, Sajó			Oil industry, pipeline
HU	6	6. AES Borsodi Energetikai Kft. Power Plant, AES Summit Generation Ltd., Kazincbarcika	Energy	Reservoir for slag and slurry with metal content (Cu, Cd, Cr, Pb, V and As)	3	AES Borsod Power Plant and AES Summit Generation, Kazincbarcika			Mining industry
HU	7	7. Kőolajáró Rt., Tiszajáráros MOL Rt. Tiszai Finomító	Oil	Crude oil, Petrol, Gasoline	5				Energy production and deposit
HU	8	8. Terméktároló Rt., Tiszajáráros MOL Rt. Tiszai Finomító	Oil	turbine oil, transformer oil, heavy metals	9	MOL oil refinery, Tiszajáráros			Oil industry, pipeline
HU	9	9. Columbian Tiszai Koromgyártó Kft., Columbian Chemical Company USA, Tiszajáráros	Oil	organic material, oil	7	Columbian Chemical Company and Columbian Tisa Soot Plant, Tiszajáráros			Oil industry, pipeline
HU	10	10. AES Tisa ereme Kft., AES SUMMIT Generation Ltd., Tiszajáráros	Oil	heating oil, heavy metals	10	AES Tisa II oil power plant AES Summit Generation			Oil industry, pipeline
HU	11	11. AES Borsodi Energetikai Kft Tiszapalkonyai Hőerőmű, AES Áramtermelő Holding, Tiszajáráros	Energy	organic material, slurry water, slag, flying ash	8	AES Tisa I coal power plant, Tiszapalkonya			Energy production and deposit
HU					4	Borsodchem Rt., Kazincbarcika			Chemical industry
HU					6	EMV Kft (North Hungarian Chemical Works Ltd.), Sajóbalony			Chemical industry
HU					11	Tivk Chemik Kombinát, Tiszajáráros			Oil industry, pipeline
HU					13	TVM chemical works, Szolnok			Chemical industry
HU					14	MOL base depot, Sajó			Oil industry, pipeline

1. Table: Grouping of ARS releasers by countries in 2000 and 2004

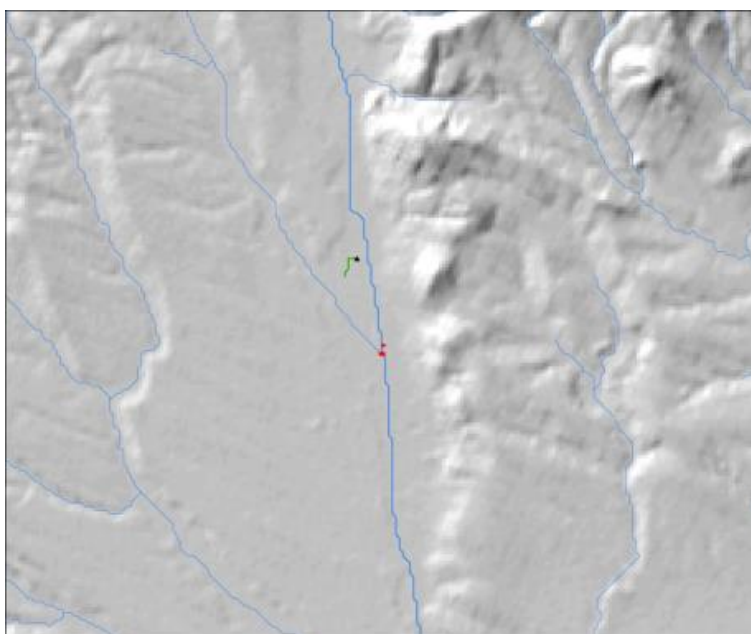
Monitoring locations assigned to ARS spots

We looked at the elements of spot data obtained as described above to see, what path a potential pollution would follow from a specified point by the terrain model. (We conducted Flow path trace.) In the event if a flow path reached a segment of Ecrins water network, the monitoring location belonging to the particular ARS points was marked by the „flow path trace” and the intersection of the water flow segment.



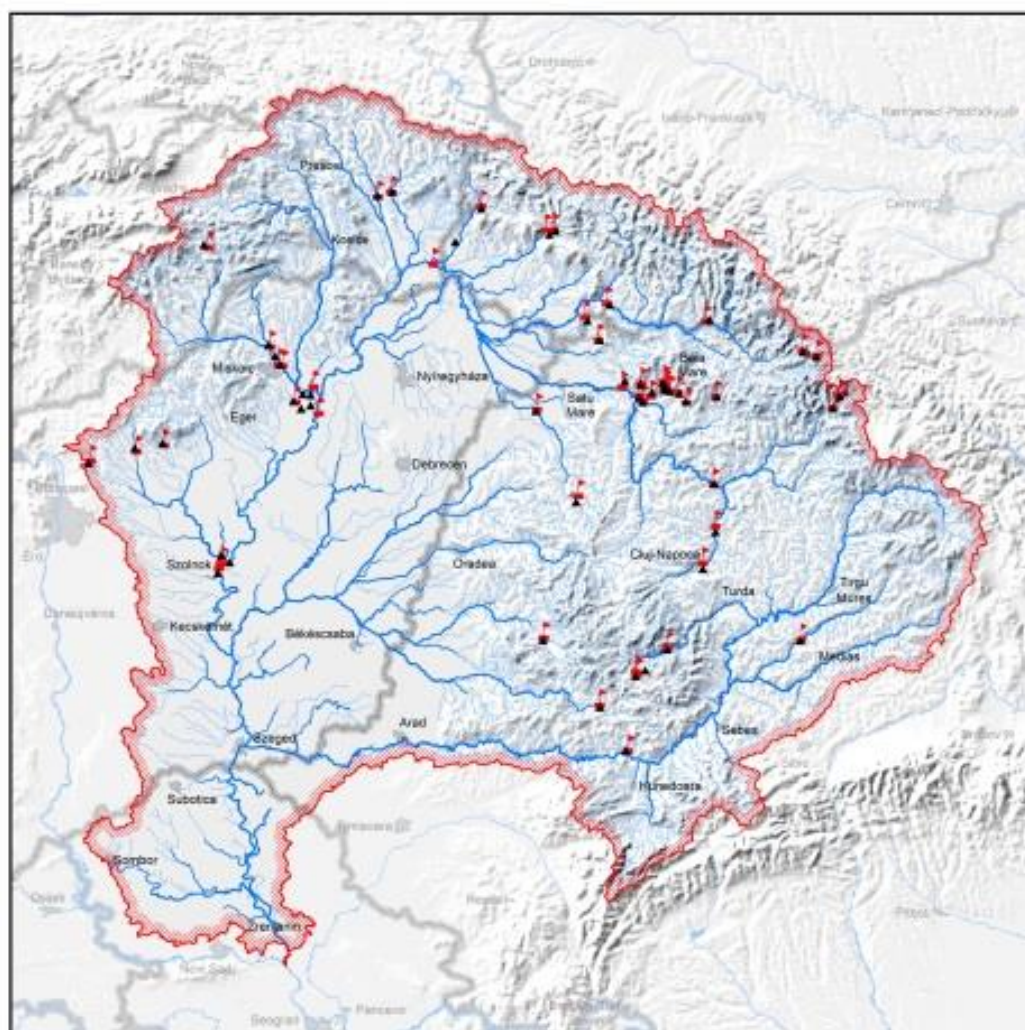
9. Figure: Flow path trace

The other case was when as a result of tracing no path running to a particular segment was found on the terrain model. In this event we looked for the closest water flow segment disregarding the terrain and placed the spot on the endpoint of the flow.

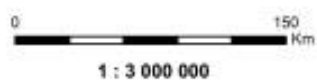
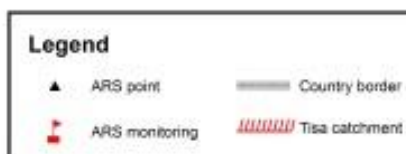


10. Figure: No path running

It may be so, that using this designation the same monitoring location belongs to more ARS spots close to each other. There were 50 monitoring locations for the 54 spots included in the study. If an updated ARS list with more accurate geographical coordinates will be available the designation must be revised.



Accidental Risk Spots Monitoring



11. Figure: Accidental Risk Spots Monitoring sites (50)

1.9.2. Designating transboundary monitoring sites

Spots of transboundary water flows at the borders of RO-UA, RO-HU, UA-HU, UA-SK, SK-HU, HU-SRB

Three versions were made during the study. Based on the Ecrins water flow database we sorted out water flows over 500, 1000 and 3000 km² catchment area to their sources, and using a hierarchical database structure we aggregated the basic catchments for these selected water flows. In the Tisa catchment we differentiated between sub-basins also, in order to make designation of monitoring stations easier.

We cross-checked the three-level 500, 1000, 3000 km² water catchment Ecrins water networks with the country boundaries. A national boundary and a particular water flow can have two types of meeting. They may intersect each other or they may be common sections of Transboundary Rivers. These two topological cases had to be handled by working out an appropriate method. We placed the boundary monitoring spots to places where the particular water flow from the source running downstream first meets the boundary. It may be the intersection of a boundary and the water flow or the starting point of a common boundary river.

1.9.3. Designating monitoring spots by catchment

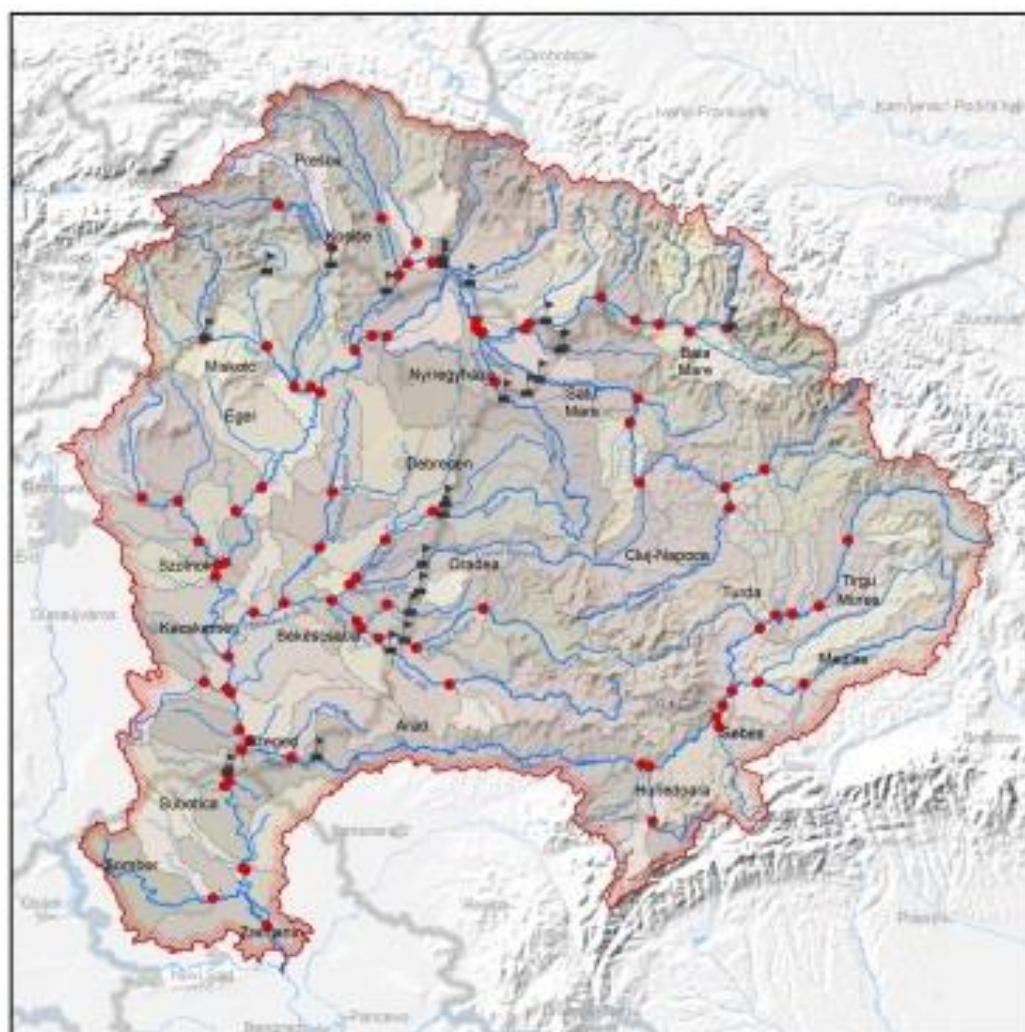
The basis of designation was the three-level 500, 1000 and 3000 km² water catchments of the Ecrins water network and the aggregated catchments belonging to them. Choosing one from the three versions will be decided by feasibility and financeability.

In the first step after sorting out catchments with 500, 1000 and 3000 km² area, we marked a point at the endpoint of each water flow which is also the outlet of the catchment belonging to a particular water flow.

In these cases we need to calculate with the following number of monitoring sites:

Catchment area (km ²)	Monitoring sites on country border	Monitoring sites at the outfall point of the catchment	Summary Number of monitoring sites
500	23	86	109
1000	21	49	70
3000	14	16	30

2. Table: Calculated number of monitoring sites



Catchment Monitoring (500 km²)

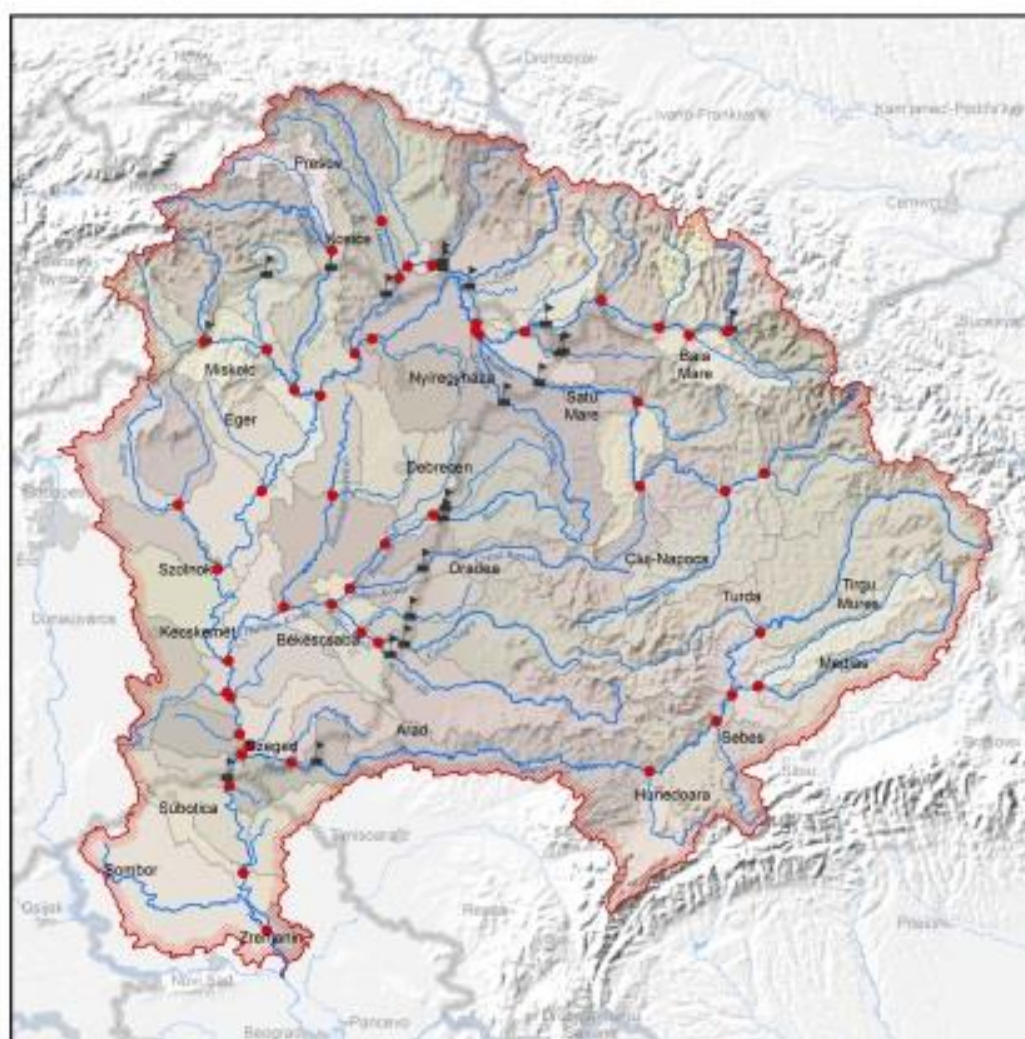
Legend

- Monitoring site on country border
- Monitoring site at the outfall point of the catchment
- Catchment of rivers over 500 km²
- Country border
- Tisa catchment

0 150 Km
1 : 3 000 000

12. Figure: Catchment Monitoring (500 km²)

Sorting out catchments with 500 km² area indicating country border and catchment level monitoring sites.



Catchment Monitoring (1000 km²)

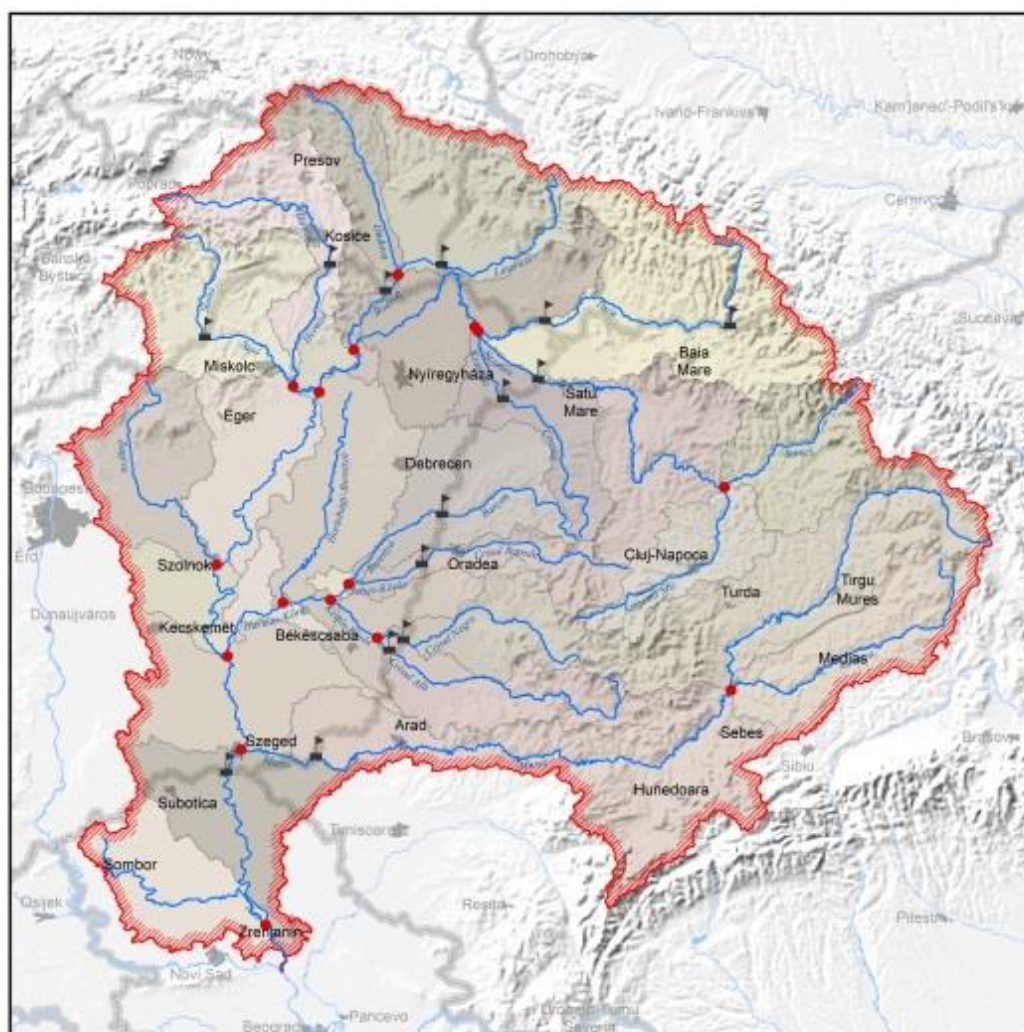
Legend

- Monitoring site on country border
- Monitoring site at the outfall point of the catchment
- Catchment of rivers over 1000 km²
- Country border
- Tisa catchment

0 150 Km
1 : 3 000 000

13. Figure: Catchment Monitoring (1000 km²)

Sorting out catchments with 1000 km² area indicating country border and catchment level monitoring sites.



Catchment Monitoring (3000 km²)

Legend

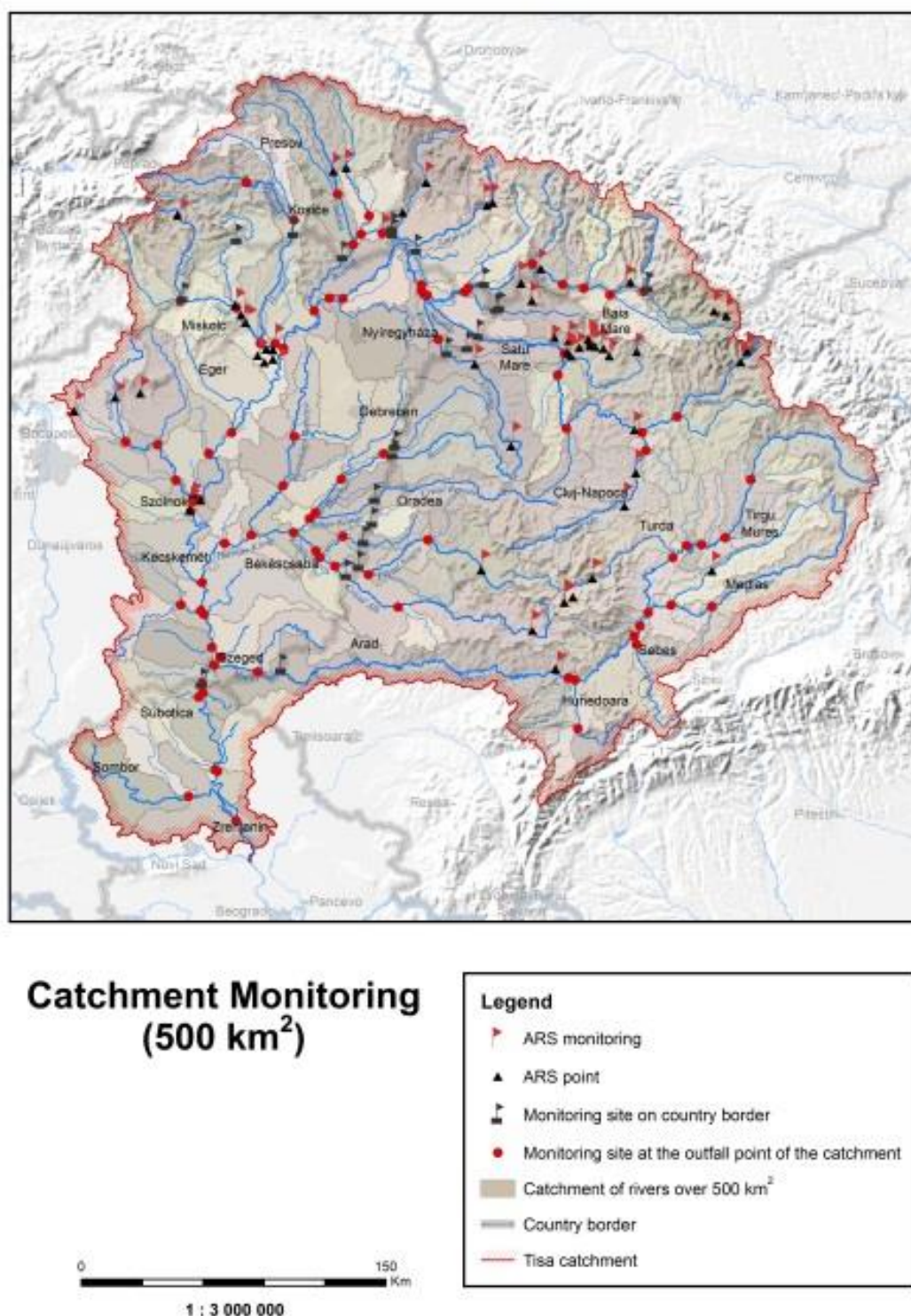
- Monitoring site on country border
- Monitoring site at the outfall point of the catchment
- Catchment of rivers over 3000 km²
- Country border
- Tisa catchment

0 150 Km
1 : 3 000 000

14. Figure: Catchment Monitoring (3000 km²)

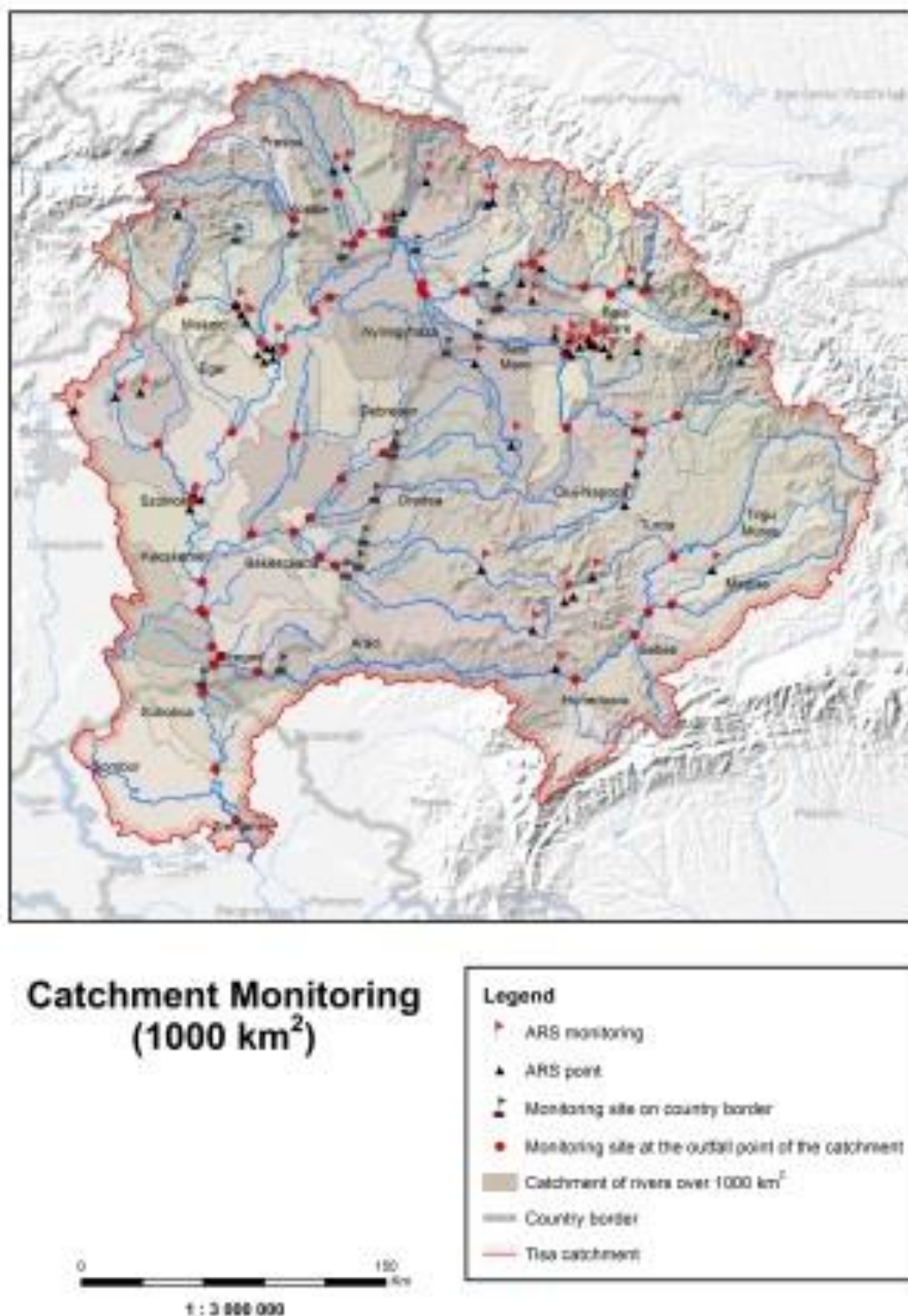
Sorting out catchments with 3000 km² area indicating country border and catchment level monitoring sites.

The aggregate map has been prepared where ARS spots, country border monitoring sites and catchment level monitoring sites are indicated.



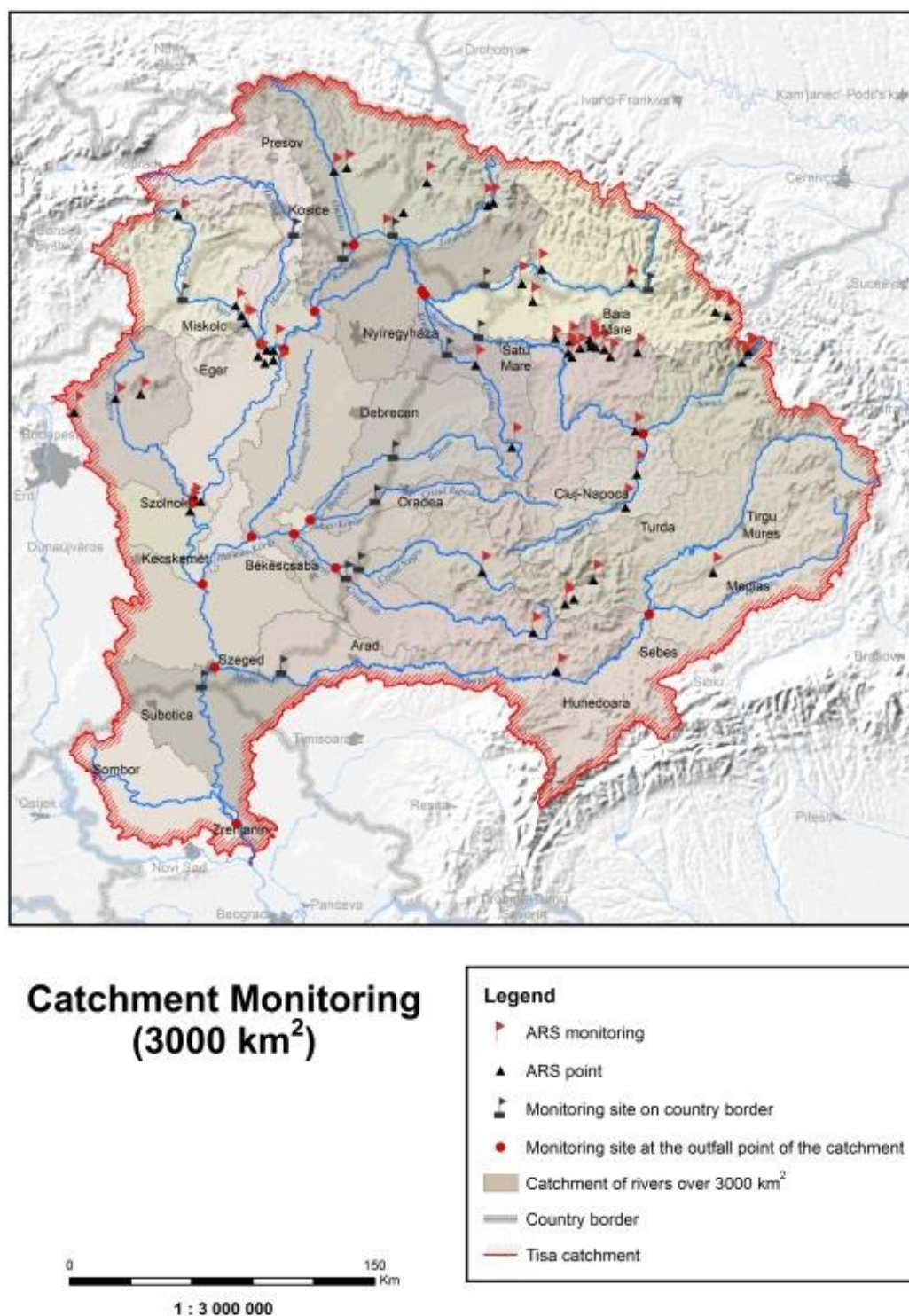
15. Figure: Catchment Monitoring (ARS, 500 km²)

Based on the sorting out of catchments with 500 km², locations of ARS monitoring and country border monitoring sites.



16. Figure: Catchment Monitoring (ARS, 1000 km²)

Based on the sorting out of catchments with 1000 km², locations of ARS monitoring and country border monitoring sites.



17. Figure: Catchment Monitoring (ARS, 3000 km²)

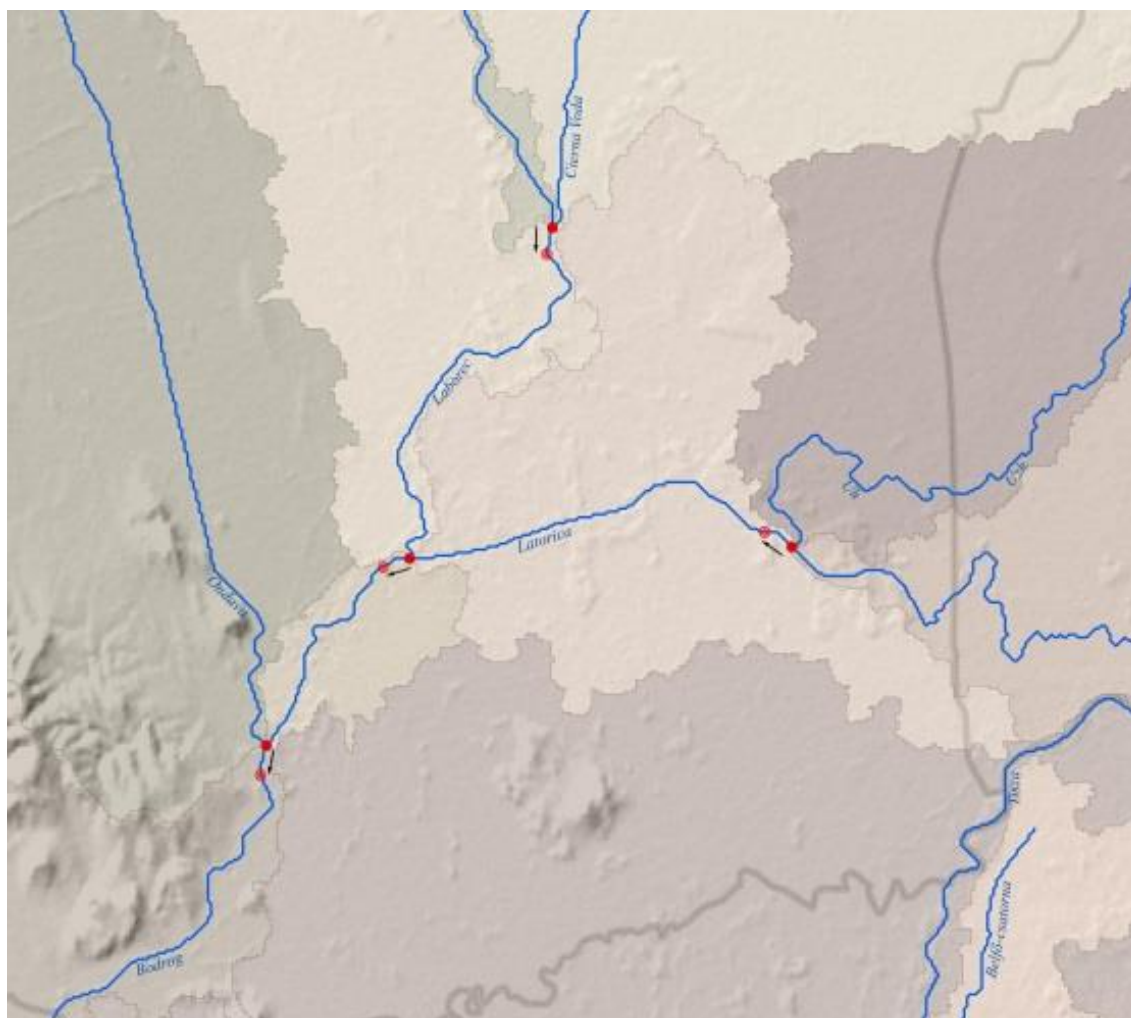
Based on the sorting out of catchments with 3000 km², locations of ARS monitoring and country border monitoring sites.

In this case we need to calculate with the following number of monitoring sites:

Catchment area (km ²)	ARS monitoring sites	Monitoring sites on country border	Monitoring sites at the outfall point of the catchment	Summary Number of Monitoring sites
500	50	23	86	159
1000	50	21	49	120
3000	50	14	16	80

3. Table: Calculated number of monitoring sites

In this form, however, the direct catchments of receiving major rivers would be excluded, or we could get information about the particular water flow only from the monitoring site located at the endpoint of the major river. Therefore the estuary spots have been modified in a way that we located them 1 km downwards the estuary. Locating the site this way allows monitoring the upward section of the receiving river, the direct catchment running to the next branch.



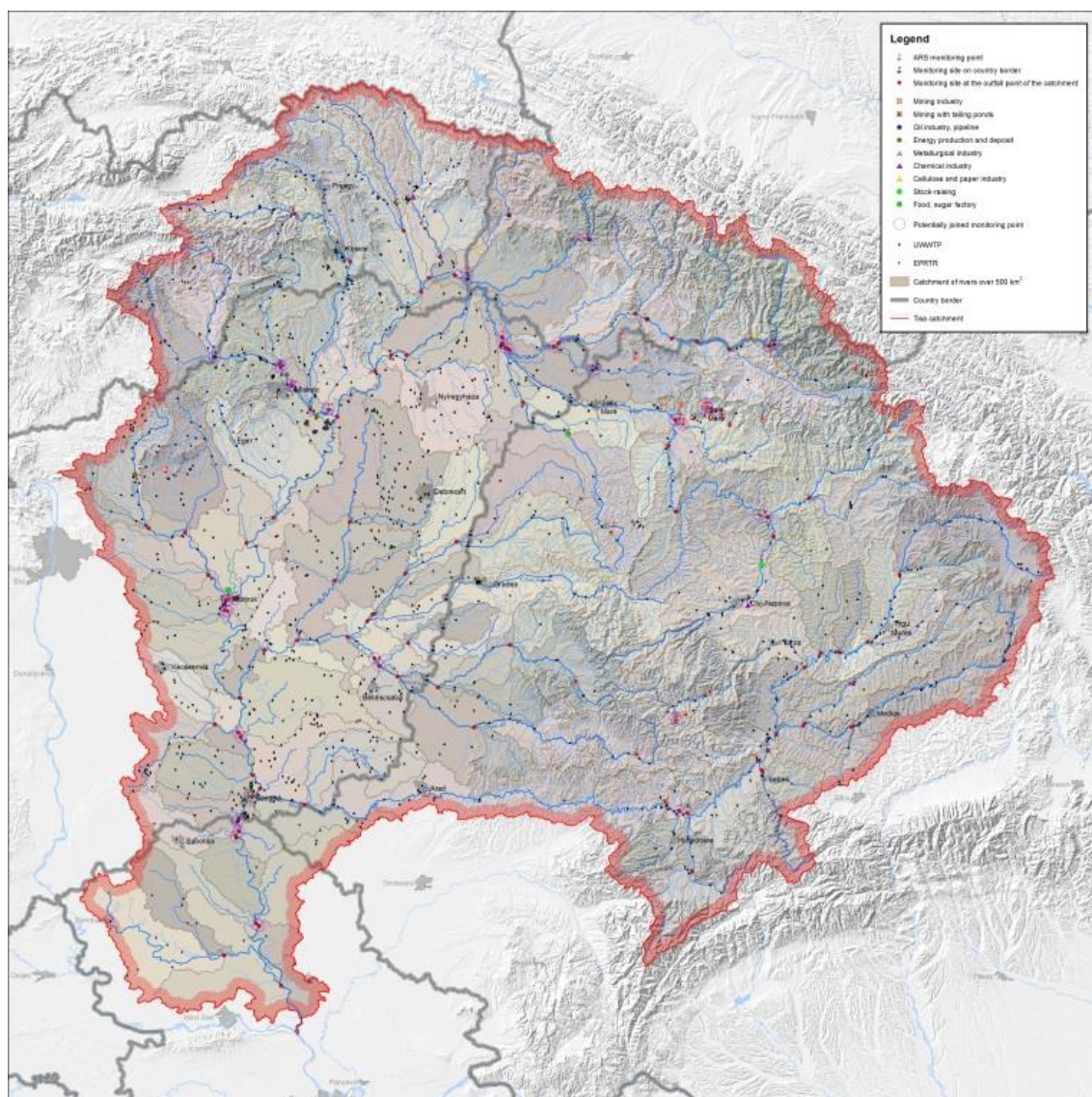
18. Figure: Modifying the catchment level monitoring sites for receiving water flows

Thus we prepared the maps where both ARS spots and the related monitoring sites, transboundary monitoring sites were indicated and based on the size of catchment we located the monitoring sites 1 kilometer downwards from the estuary on the receiving flow.

To designate EWS monitoring sites it is necessary to know, apart from potentially high risk polluting objects, the spot pollution sources posing lower risk on the sub-basins.

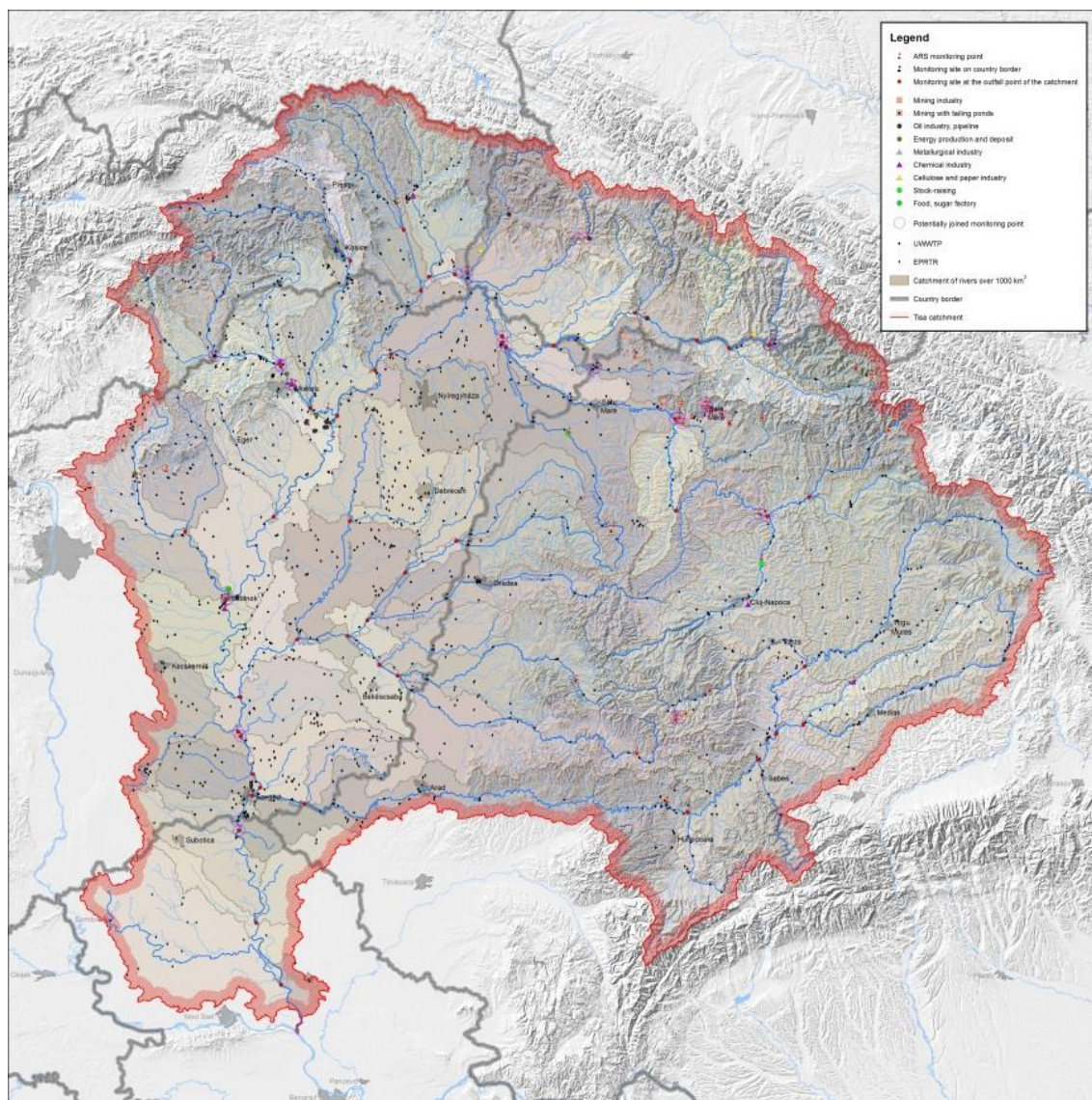
Objects like this are the ones indicated in the E-PRTR list and spots based on the reports of UWWTD water treatment plants. In the case of wastewater treatment plants, the available database is made only for EU member states, so we could not indicate spot sources for the Ukraine and Serbia in the map.

In addition, due to diffuse pollution/loads affecting catchments, it is practical to establish a spot network with general coverage, which was not worked out in detail in this study because this study aims to illustrate the structure and logic of the EWS network.



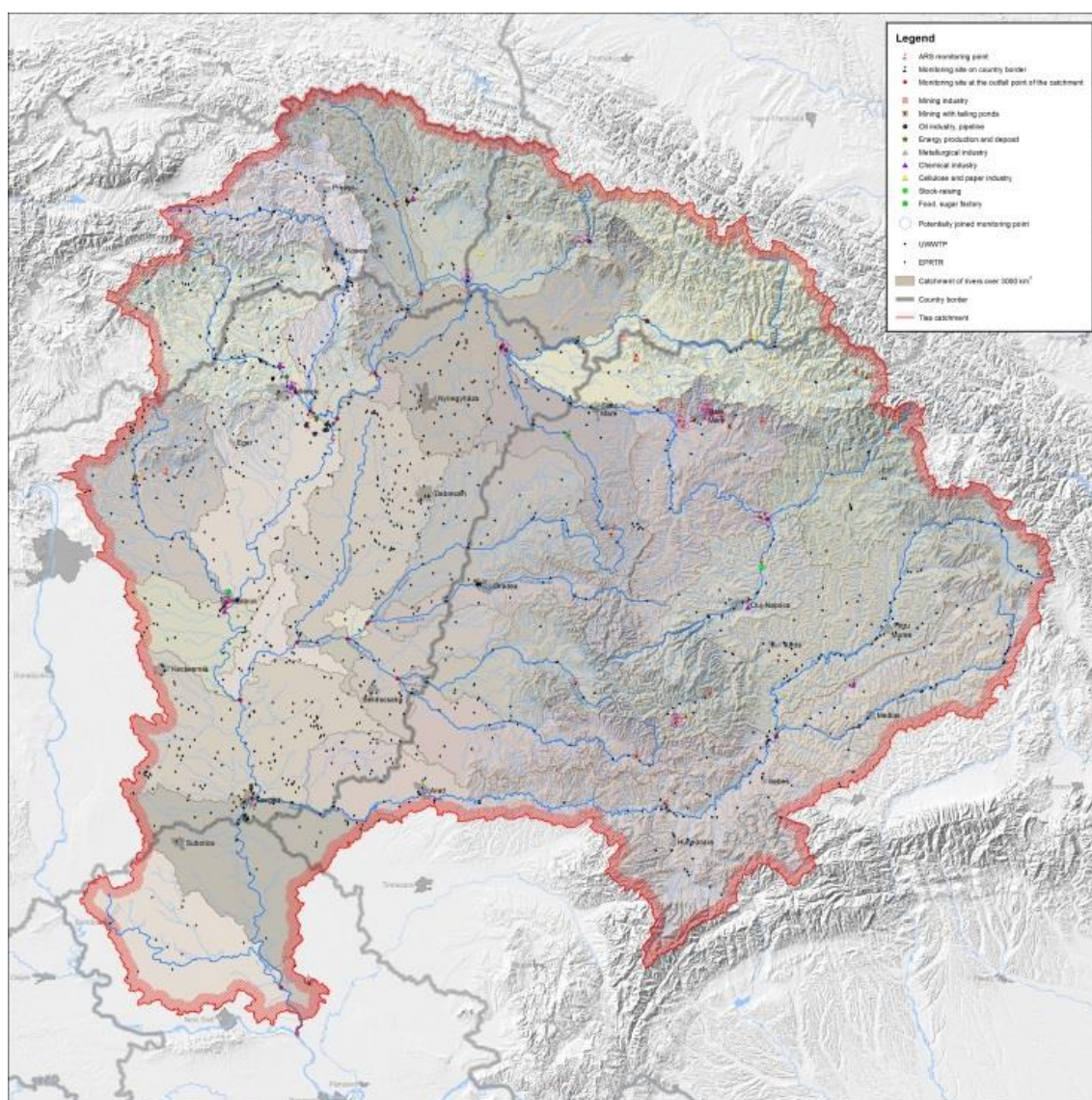
19. Figure: Pollution sources and monitoring sites (500 km²)

Map for catchments with 500 km² area indicating ARS/ UWWTP/E-PRTR plants and recommended ARS monitoring sites/country border monitoring sites/catchment level monitoring sites



20. Figure: Pollution sources and monitoring sites (1000 km²)

The catchments plant with 1000 km² area indicating ARS/ UWWTP/E-PRTR plants and recommended ARS monitoring sites /country border monitoring sites /catchment level monitoring sites



21. Figure: Pollution sources and monitoring sites (3000 km²)

Map with 3000 km² catchment area indicating ARS/ UWWTP/E-PRTR plants and recommended ARS monitoring sites/country border monitoring sites /catchment level monitoring sites

Based on the principle indicated above we specified the maximum number of installation sites for continuous monitoring stations. It is shown below:

Catchment area (km ²)	ARS monitoring sites	Monitoring sites on country border	Monitoring sites at the outfall point of the catchment (1 km)	Summary Number of Monitoring sites
500	50	23	86	159
1000	50	21	49	120
3000	50	14	16	80

4. Table: Maximum number of installation sites for continuous monitoring stations

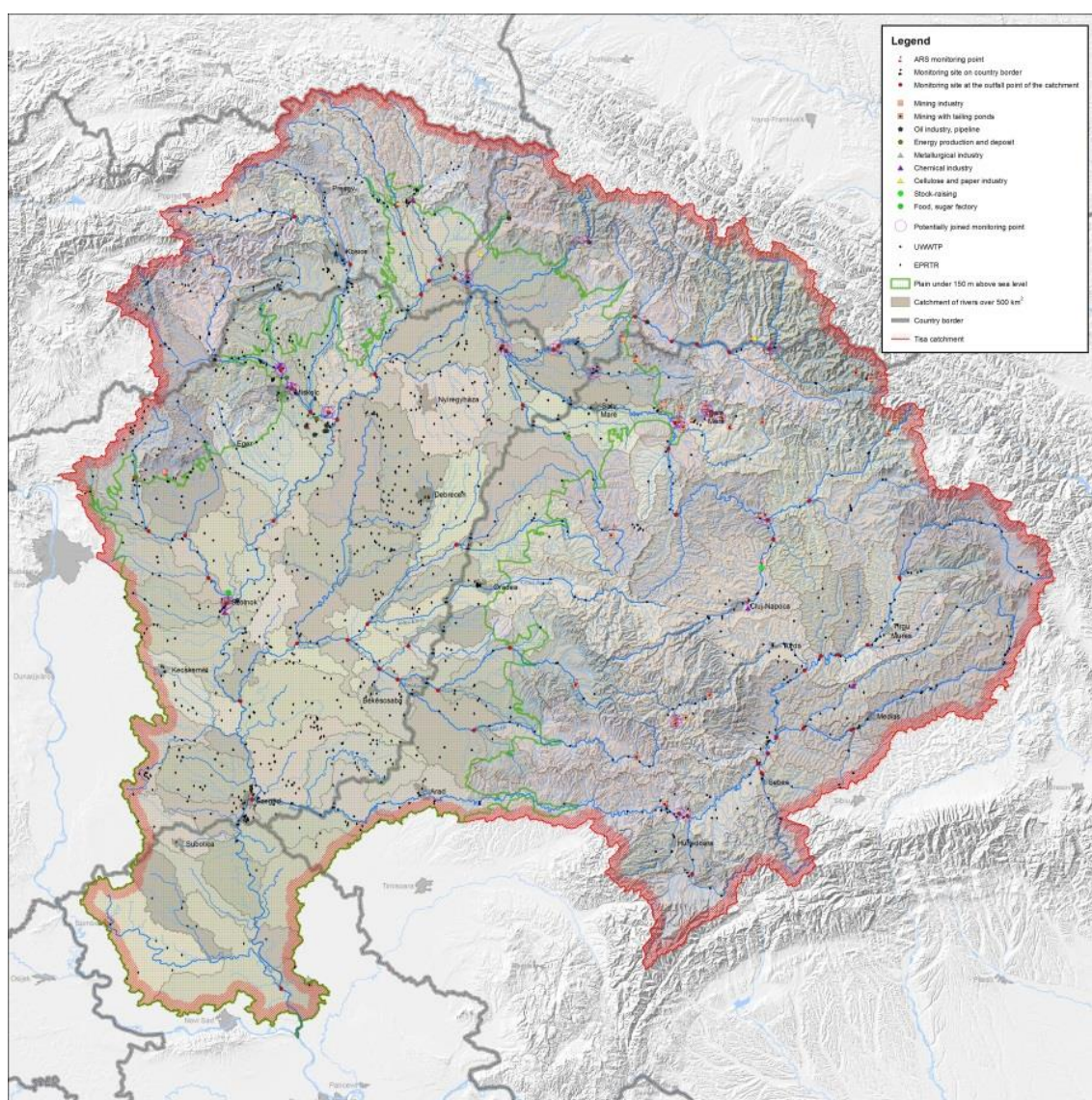
1.9.4. Aggregation and recommendation for designating monitoring stations

Aim: reducing the number of monitoring stations to a sustainable number which can still ensure achieving the aim of EWS monitoring network.

In **plain areas** it is practical to thin the spot network. It is because the Hungarian Plain without man-made drainage system would be an area without discharge so natural catchments could not be developed. The Ecrins model water network needs to cope with this problem too. It can't simulate reality in these areas so accurately, in contrast with highlands.

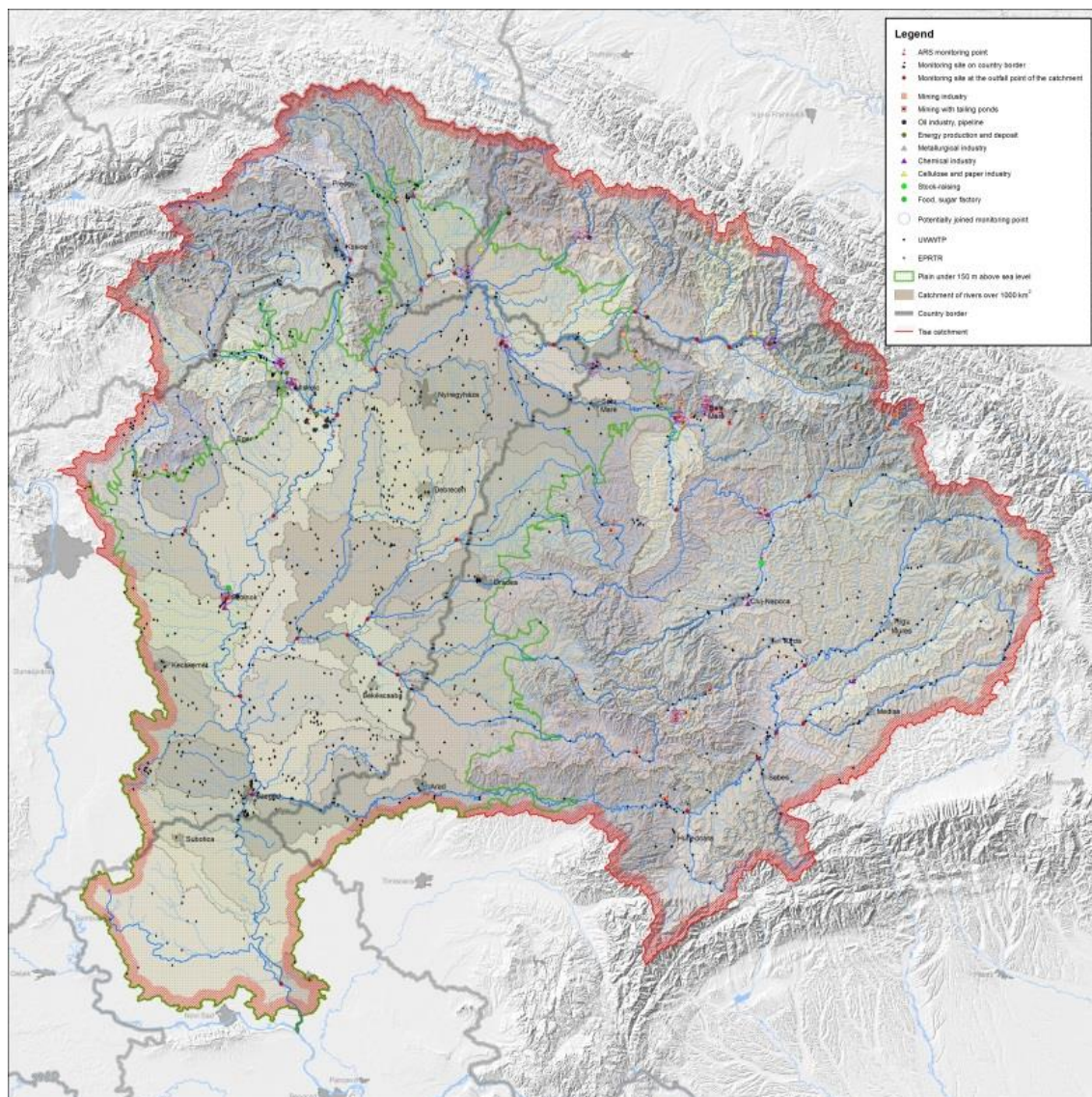
It is recommended that in all three scenarios out of plain rivers running below 150 meters of sea-level in their full length, only the ones with over 3000 km² catchment are included in the study.

In the next maps the results of reducing the number of plain rivers are indicated for 500 km²; 1000 km²; 3000 km² catchments.



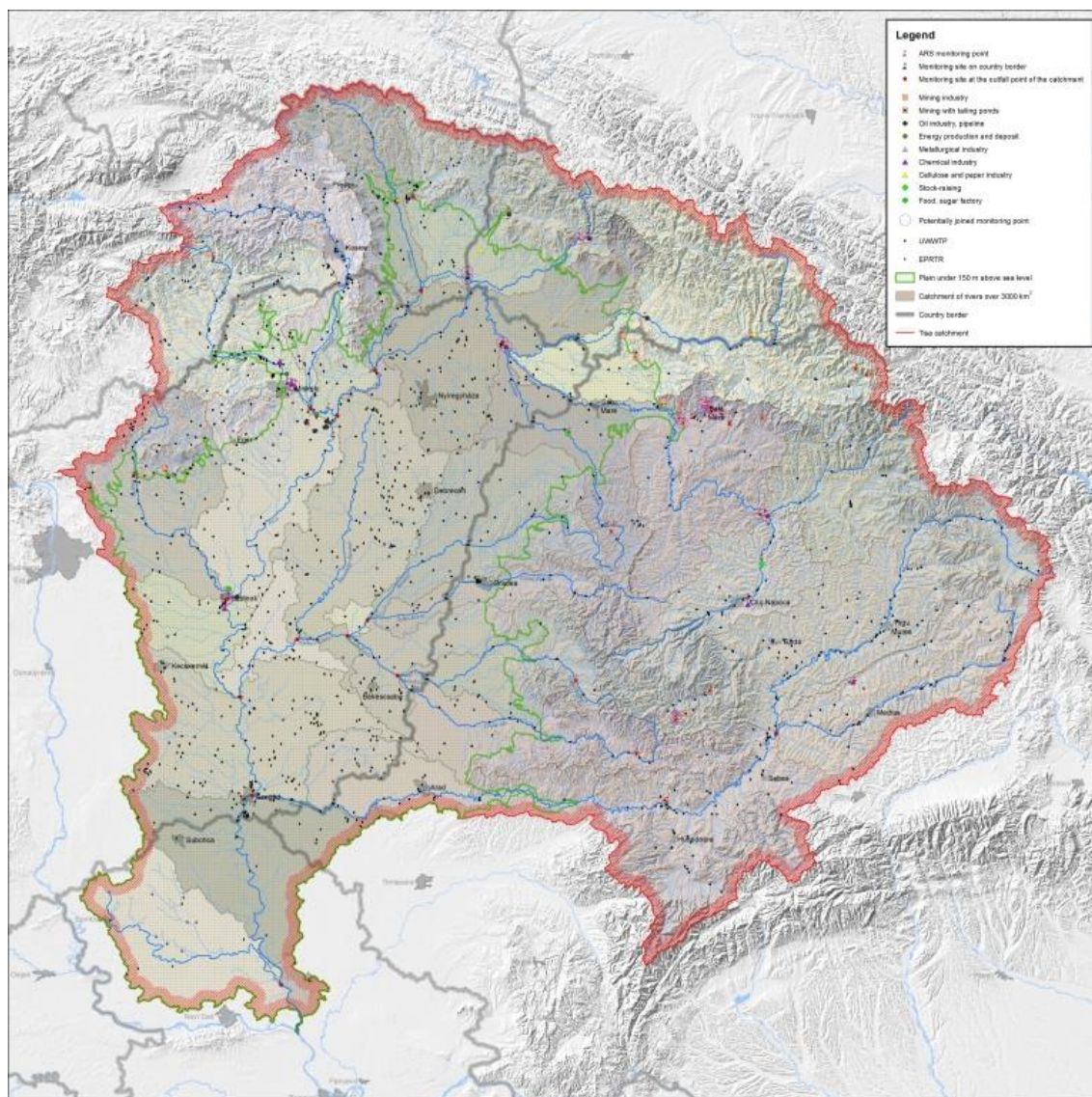
22. Figure: Result of aggregation used for plain areas (500 km² catchment map)

ARS/ UWWTP/E-PRTR plants and the recommended ARS monitoring sites/country border monitoring sites /catchment level monitoring sites.



23. Figure: Result of aggregation used for plain areas (1000 km² catchment map)

ARS/ UWWTP/E-PRTR plants and the recommended ARS monitoring sites/country border monitoring sites /catchment level monitoring sites



24. Figure: Result of aggregation used for plain areas (3000 km² catchment map)

ARS/ UWWTP/E-PRTR plants and the recommended ARS monitoring sites/country border monitoring sites /catchment level monitoring sites

Based on the results of aggregations, the number of monitoring stations is as follows:

Version by catchment area (km ²)		Monitoring points			
		ARS	Border	Catchment	Total
500	With all rivers	50	23	86	159
	Without plain rivers	50	23	61	134
1000	With all rivers	50	21	49	120
	Without plain rivers	50	21	38	109
3000	With all rivers	50	14	16	80

5. Table: Number of monitoring stations

Potentially joined monitoring points

We found it necessary to study whether there are any monitoring points within the 5 km proximity of other monitoring points, designated by using another applied methodology. These places with monitoring points within 5 km proximity, where an individual study is required, are circled in the map (legend: purple circle – Potentially joined monitoring point). In each case, an individual study is needed whether two points may should be joined and where the joined points should be.

The following chart shows the number of potentially joined points:

Version by catchment area (km ²)		Monitoring points				
		ARS	Border	Catchment	Total	Potentially joined point
500	With all rivers	50	23	86	159	52
	Without plain rivers	50	23	61	134	37
1000	With all rivers	50	21	49	120	36
	Without plain rivers	50	21	38	109	34
3000	With all rivers	50	14	16	80	21

6. Table: Number of potentially joined points

Let us take 500 km² catchments as an example. If we do not exclude the plain rivers and do not join points within 5 kilometer proximity, Tisa catchment would be covered by designated 159 stations. Out of 159 points, in 52 points another point is within 5 kilometer. It means that 52 points must be studied individually to decide whether monitoring points can be joined or not. If yes, 26 points out of 159 points are excluded and the number of final monitoring points would be modified to 133.

In the plain area version out of 134 total points, there are 37 points where 2 or 3 points are in 5 km proximity. Looking at this, about 18-19 would be dropped out, what means there would be 115-116 monitoring points left.

Aspects to be considered with individual judgment:

- type of pollution sources (point/diffuse/ARS spot)
- type of expected load (identifying physical-chemical parameters)
- after identifying these parameters it is possible to identify indicator parameters and choosing monitoring locations
- if monitoring points within 5 km proximity are not on the same water flow but on different branches, individual studies are needed to determine whether the two points can be replaced by a monitoring station located at the confluence of branches.

We accepted as a guiding principle that points on the border and ARS points are kept, and if points are along a water flow, the lower points downstream get priority.

When designating the installation site of EWS system it is recommended taking the location of hydrographic remote monitoring stations (water level, water yield) operated in the countries concerned and the necessity of communication between the stations into account.

1.10. Summary

Apart from providing the number of EWS monitoring stations estimated/recommended on Tisza catchment, additional analyses are also necessary so that providing parameters monitored at the station and alert limit values can be configured:

- coordinating water body typology because based on the typology, type specific water quality classes were designating
- reviewing water quality rating systems/international legal regulations applicable on the water catchment, and comparison of related physical-chemical-toxicological limit value and specifying alert limit values
- reviewing background analyses of database operated by countries and measures taken in order to achieve good quality surface waters.

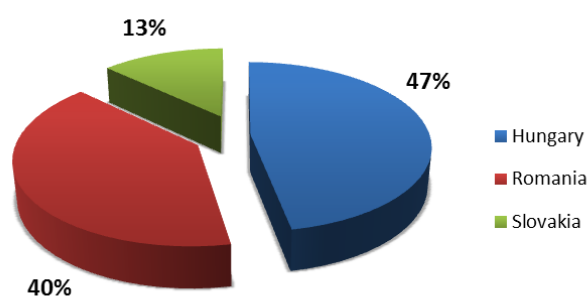
The presence of strongly diversified pollution sources in the catchment makes it difficult to establish the list of continuous early warning monitoring system. The variety of pollution sources can be traced back partly to natural conditions and the related use of area and economic orientation.

It is to be noted that from the point of view of surface water pollution of the catchment, strong exposure to flood is a significant characteristic. In the rivers in Tisza catchment water yield, water mass and flow speed are highly important from the point of view of the spread of pollution, because these flow features determine the time of run-off, dispersion of pollutants in the water body or sedimentation in the bed. Accidental pollution simultaneously with the flood may result in damaging the flora and fauna of the flood area.

Based on the range of pollution sources taken into consideration, we recommend a list of physical-chemical parameters which allows choosing area specific indicators.

Methods	Parameters
Standard parameters	temperature, pH-level, conductivity, dissolved oxygen, turbidity, chlorophyll-a, blue algae, COD _{Mn} , TOC, PO ₄ ³⁻ -P, NH ₄ ⁺ -N, NO ₂ ⁻ -N, TN, TP, Kjeldahl-N
Extended parameters	PAH, SO ₄ ²⁻ ; Na ⁺ , K ⁺ , Ca ²⁺ , Mg ²⁺ , Zn, Cd, Co, Fe, Pb, Al, Hg, toxicology measurement,
Pollution Sources	Measurement parameters
Accidental Risk Spots (ARS)	cyanides; heavy metals (Cu, Zn, Pb, Mn); sulphuric acid; organic substances, lignine, tannin, ammonium, Cr6+; acid solution; phenols, oil products, organic nitrogen content, gasoline, metal sludge (Mn, Zn, Cd, As, Pb), reservoir for slag and slurry with metal content (Cu, Cd, Cr, Pb, V and As)
UWWTP	COD _{Cr} , BOD ₅ , TSS, TN, TP, Ammonium-N,
Agriculture area	Nitrate-N, Ammonium-N, pH-level
Industries (E-PRTR)	chloride, toxicity, conductivity, Sulphate, total hardness, AOX, phenol index, lindane, antrazine, PAH, PCB selected pesticides

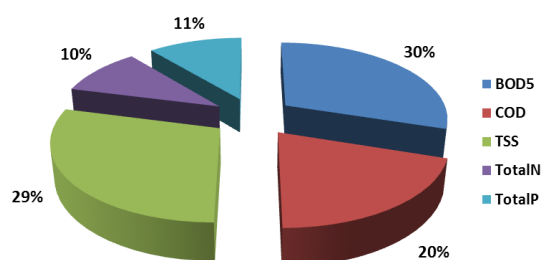
7. Table: List of physical-chemical parameters



27. Figure: Percentage distribution of total UWWTP in the Tisza catchment

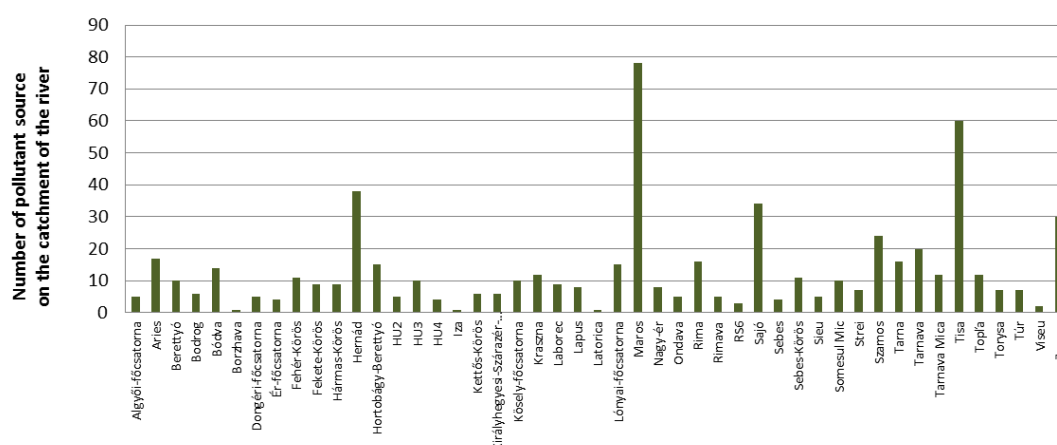
From the UWWTP chart we collected the inappropriate treatment performance for different chemical parameters. The diagram indicates the percentage of inappropriate treatment of parameters for the total number of waste water treatment plants.

The pie chart below shows the percentage of inappropriate treatment performance of various chemical parameters



28. Figure: Percentage of inappropriate treatment performance

In the diagram below the number of pollutant sources (Urban Waste Water Treatment plants) in the 1,000 km² catchment of water courses is indicated.



29. Figure: Number of Urban WWT plants on the river basin

2. Evaluation of measurement methods usable at monitoring stations and describing and specifying monitoring systems required for their implementation

2.1. Analyzing the current method and equipment

2.1.1. Monitoring of surface waters

Monitoring of surface waters include identifying biological elements indicative of ecological and chemical state and special hazardous materials, as well as physical, chemical parameters and hydro-morphological attributes that influence the ecological state of the particular water body.

Adapting the Water Framework Directive to domestic practice, the nature of monitoring surface waters has changed, in particular, the former, traditional method based on chemical and hydrological observations has been expanded by biological and morphological tests.

Biological tests include the constitution, loading, volume and age composition of the following groups of living creatures:

- free-floating algae (phytoplankton),
- macroscopic, water herbaceous plants (macrophyta),
- algae building coatings on the bottom or other solid surface (phyto-benton),
- benthic macroscopic water invertebrates (macro-invertebrates),
- fish.

Hydromorphological tests – pursuant to Water Framework Directive – aim to explore hydrological and morphological elements influencing biological elements. Based on the domestic methodology, state assessment requires defining the following parameters. Thus in Hungary:

Hydro-morphological attribute	Tested parameter
<i>Hydrological conditions</i>	
Strength and dynamics of water flow (water course)	Water flow. Is there a banked up stretch considerably influencing water depth and speed?
Quantity and dynamics of streaming water (stagnant water)	Water rate. Does any water level control influence water depth?
residence time (stagnant water)	Does any human activity influence natural water movement?
Connection with underground water bodies (water course and stagnant water)	Changes of medium water level due to deepening of bed or banking up Bed colmatation
River continuity (water course)	Longitudinal penetrability. Transversal penetrability (water supply of branch backwaters and stagnant waters on floodplain).
<i>Morphological conditions</i>	
Changeability of river depth and width (water course), changeability of lake depth (stagnant water)	In case of large rivers regulation of river ways In case of small or medium-sized water courses meandering of medium water and small water beds, and the longitudinal changeability of bed. In case of lakes territorial changeability of depth.
Size, structure and material of bed (water course and stagnant water)	Coverage and overgrowth (vegetation on and under the water surface). Bed material. Extent of colmatation/siltation. Extent of deepening of bed without dredging (only water flow). In small- and medium-sized water courses, the sizes of medium water and small water beds, and the steepness of the side of medium water bed. In case of lakes the nature of deepening of bed. Sizes of lake (area and perimeter, length and width)
Structure of riverside/lakeside (water course and stagnant water)	Flood-area/flood-plain/width and state of buffer, in case of small and medium-sized water courses and lakes, the presence of vegetation zones characteristic of the type

8. Table: Hydro-morphological attributes

The elements tested by *physical-chemical parameters*, influencing biological elements can be divided into two groups:

- general attributes – temperature, oxygen supply (dissolved oxygen, BOD, COD), salinity (conductivity, TDS), level of acidification level (pH, alkalinity), nutrient conditions (orto-phosphate ion, total phosphorous, ammonium-ion, nitrate-ion, organic nitrogen, total nitrogen, chlorophyll-A), transparency (only in case of lakes), quantity of organic matter (TOC, DOC);
- particularly hazardous for aquatic environment or represents high risk through aquatic environment including water bodies used for producing drink water. The list of particularly hazardous materials listed in Annex X of the Water Framework Directive contains 33 substances or group of substances (the so-called list of 33). The list of hazardous materials can be extended and as a result, 4 metal substances have been added to the list of elements tested in domestic monitoring: copper, zinc, chrome and arsenic. The first three metals, thinking of their physiological effects are known as trace elements but due to industrial activities they may reach harmful and poisonous concentration, and that is why they are included in the hazardous substance list

Due to the nature of monitoring, that is, the explorative and operative nature, *the number and frequency of tested parameters are different*:

- Explorative monitoring includes a wide range of tests but at a relatively few sampling locations. For example, in the Hungarian territory of the Tisa catchment there are explorative sampling points on 9 stagnant water and 65 water flow locations (by figures of 2010). The tests include five biological elements, basic chemistry essential from biological aspect, hydro-morphological observations and hazardous substances.
- The active monitoring programs have been developed by rating of hazard classification of water bodies. In Hungary for example, operative measurement takes places at 28 lakes because of nutrient content and at 16 places because of hydro-morphological risks (2010). Concerning water courses operative measurements take place at 49 places because of water quality problems (hazardous substances) and at 161 places because of organic matters. Because of the risks resulting from hydro-morphological reasons (through-flow reservoir with dam, damming up, water abstraction, water distribution, etc.) there are 118 monitoring points at the water catchment
- Testing monitoring cannot be planned ahead it must be ready for use in cases when a parameter exceeds the limit value and the reason is unknown, or it is necessary to investigate the impact and consequences of some extraordinary events, or the operative monitoring is not in operation, yet, and its temporary replacement is necessary (period of gathering information).

The current monitoring system is characterized by continuous re-assessments and developments. One of the reasons for this is the attempt to better meet the regulations of the Water Framework Directive (biological elements, measuring hazardous substances). The other reason is that more cost-effective operation can be achieved if other directives of the EU (e.g. Nitrate, NATURA 2000), or some elements of planned EWS can be integrated into the Water Framework Directive monitoring. It is to be examined and analyzed how often on-the-spot samplings must be carried out in various catchment areas.

2.1.2. Methods and devices

The methods used during monitoring must be in accordance with international standards (CEN/ISO) or national or international regulations that ensure that provision of data is of scientific quality and comparable. The effective regulations and standards of water testing methods and devices are summarized in Annex 4.4 (Annex X) of the Water Catchment Management Plan for the Hungarian territory of the Danube catchment area.

In the currently operating system the standardization of methods and unification within the EU include all monitoring elements, among others:

- sampling,
- sample storage,
- biological tests,
- physical, chemical tests,
- hydro-morphological tests,
- analyzing data, identify ecological state,
- state assessment, documents of classification, and formal requirements of communicating data to the EU, etc.

Only a small fraction of tests are conducted on the sampling location (e.g. temperature, pH, electric conductivity, dissolved oxygen, transparency). Parameters, however, are largely defined after the samples are sent to the laboratory, keeping all rules of sample storage and preserving. In this case, the analyses conducted in the same environment, laboratory using the same devices ensure the comparability of data of samples from different places.

The laboratory tests of physical-chemical parameters can be divided into several groups.

Testing *general attributes* depends on the particular attribute, the most frequently used methods being potentiometric, titrimetric, UV-VIS photometry and gravimetry.

Anion content is usually measured by UV-VIS spectrophotometry or potentiometric (ISE).

Metal content of major components is measured by complexometry, flame photometry or AAS method. The quantity of toxic metal in small concentration is usually measured by atomic absorption spectrometry (GF-AAS), or with inductive optical emission spectrometry (ICP-OES).

Out of *hazardous substances* volatile (e.g. industrial solvents) and less volatile compounds (e.g. insecticides or certain carcinogenic compounds) are measured by gas chromatography after proper preparation. The measurement of the most toxic compounds (e.g. PCDDs) is conducted by high-resolution gas chromatography-mass spectrometer equipment.

2.2. Trends in technology, standards, breakthrough points

The preparation of the detailed specification requires looking at the effective and widespread technological trends, development directions and possibilities and they must be drawn up at requirement level.

2.2.1. Technical trends of measurement devices and sensors

The range of devices suitable for measuring basic physical and chemical parameters of surface waters is gradually extending, robust sensors and sensor families with little

servicing need, with digital communication that are quick to connect and replace appear day by day.

The following considerations must be kept in mind in connection with sensors and measurement devices used at automated measurement stations:

- they meet the effective CEN/ISO standards,
- is with appropriate sensitivity – according to the measurement limit value of the water parameter (devices suitable only for sewage water must be excluded),
- is robust, suitable for on-site measurement,
- require minimal servicing,
- have longer life cycle (e.g. pH meter ≥ 2 years);
- have little power consumption (it is especially important with solar cell power supply),
- have digital communication, in contrast with the former analogue communication,
- at last, taking into consideration all above-listed aspects it should have good price over value ratio.

In the further part of this section, including but not limited to, a few emerging methods or devices will be described. It is to be noted that some elements are not suitable for automated operation at the moment but technology is dramatically developing, so they must be taken into consideration.

Concerning other specific pollutants, the appearance and permanent development of equipment suitable for measuring heavy metals and compounds by UV-Vis photometry, fluorimetry in-situ.

Identifying metals in small concentration used to be a test that could be done in laboratory only. However, meeting market demands, portable devices are marketed today that can measure on-site metals, especially the ones belonging to the group of micro-pollutants (copper, zinc, chrome and arsenic) (e.g. figure 2.2). The majority of robust devices suitable for on-site measuring work by electrochemical principle (voltammetry, stripping voltammetry). Advantages are: appropriate sensitivity (~ 5 -500 ppb), operation in wide temperature range (as wide as $-20 - +50^{\circ}\text{C}$), or the relatively short measurement time (5 minutes). A disadvantage is that at the moment they are not suitable for on-site automated measurement. (The method is sensitive to cleanness of electrodes, so the working electrode must be cleaned before use.)



30. Figure: Metalyser HM1000 (Trace2O) on-site metal analyzer and its electrodes

Biological water rating is not a simple task but it is time-consuming and demanding and requires the collaboration of several experts. In contrast with this, chemical methods are suitable for identifying water pollutants quickly and simply. Whereas the current form of chemical rating provides information about the momentary state of waters, biological rating provides information about the historical changes of living conditions and sources (food, oxygen content, etc.) and traces of unidentified pollutions can be detected.

The appearance of equipment suitable for automated measurement of these parameters is typical of the period when biological parameters gained higher relevance.

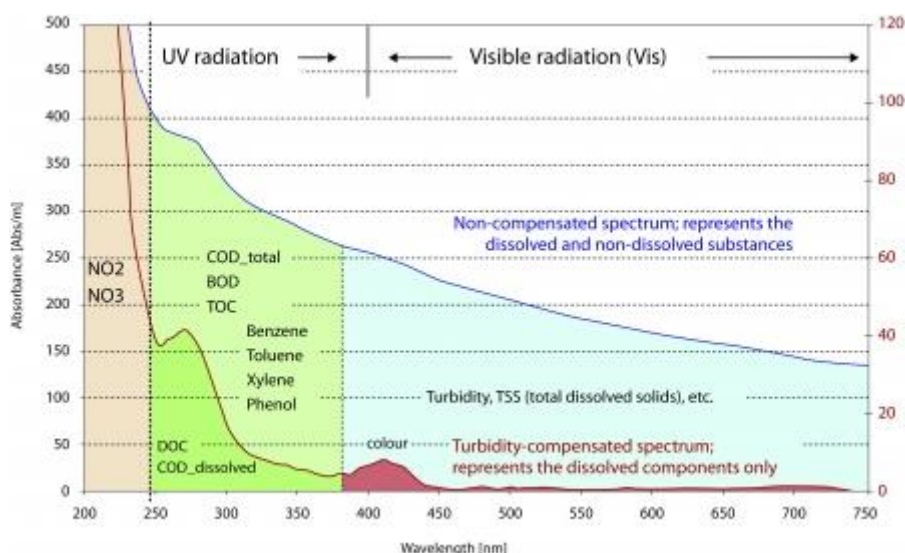
The advantages of devices using UV-Vis absorption and fluorescent method: they are suitable for simultaneous measurement of several parameters (as many as 4 - 8 water parameters), measurement time is very short (mostly seconds) and they do not require any reagents.

The measurement principles of analyzers have been known for a long time and they are based on standard methods often used in laboratories. Their robust, on-site design allows continuous in-situ measurement. The most important currently measurable parameters include but are not limited to:

with UV-absorption: COD, TOC (BOD), nitrate, ammonia, suspended solid concentration, etc.;

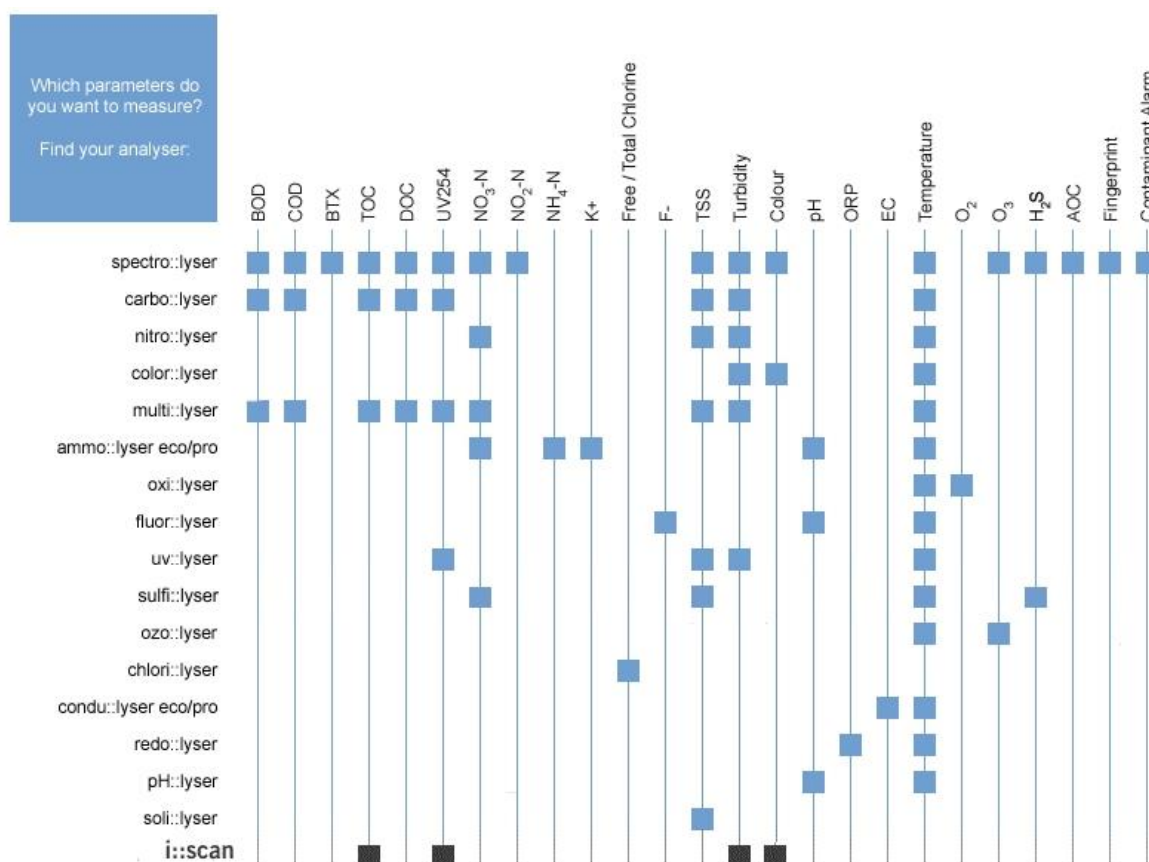
with UV-fluorescence: Oil pollution, aromatic carbohydrates, PAH, BTEX, chlorophyll-A, and other pollutants emitting UV-fluorescence.

The diagram below shows the parameters measurable with UV-Vis absorption method depending on wavelength (Source: <http://www.s-can.at>)



31. Figure: Parameters measurable with UV-Vis absorption method

The diagram below shows the devices based on UV-Vis absorption and fluorescence method and measurable parameters (Source: <http://www.s-can.at>)



32. Figure: Devices based on UV-Vis absorption and fluorescence method

The automated toxicity meter measures the continuous oxygen consumption of the immobilized strains (biomass) cultivated in permanent circumstances in its bioreactor, with known sensitivity. Reduction in oxygen consumption indicates the presence of toxic material. Toxicity meters are often used for the continuous monitoring of outflow of sewage plants.

The small-sized design of toxicity meter is suitable for BOD-measurement. The two devices are different only in the working point of the bioreactor: in this case the oxygen consumption of the controlled biomass in the bioreactor is kept at a permanent level (3 mg/l) which can be achieved by diluting, when needed, the incoming water sample. Thus the oxygen consumption will be proportional to the nutrient concentration.

Another method of measuring toxicity is provided by the devices detecting sensitivity of fish against toxic materials. A device like this is the one (HALARM) developed in the Toxicology Research Centre in Veszprém, which monitors the deterioration of fish's rheotaxis ability. Exposed to toxic materials the rheotaxis ability of fish placed in the observation area deteriorates and they are unable to keep their position in stronger stream. The lost position is detected and transformed into electric signal by the detector. It generates an alarm signal in the computer and simultaneously it can regulate the flood-gate through the programmable channels of the digital card.

In order to ensure continuous operation and enhance the sensitivity of the system, periods of stress ensured by internal circulation and periods of rest alternate each other in the rhythm specified by the control software.

2.2.2. Optional, auxiliary devices

Other optional elements of the monitoring system are for example the automatic water samplers, passive samplers and auxiliary devices that can provide additional useful information about the current state of the particular water body or its environment.

○ *Automatic water samplers*

Integrating the modern samplers controlled by microprocessors into the system allows taking scheduled (by time intervals or taking average sample by combining several sample parts) or even-triggered (post warning) sampling.

Concerning the source of power supply, devices using mains and batteries are available.

Pumps integrated into the equipment (usually peristaltic ones ensuring slower flow), ensure as high as 7-8 m height.

Sampler equipped with active cooling keep the samples at about 4°C. As biological activity at this temperature considerably slows down, the stored samples represent the original state even after a day.

○ *Passive samplers*

The passive samplers are samplers that conduct sampling by selective separation of the material to be analyzed and by pre-concentrating them. They have several advantages: simple design, no need for power supply therefore their installation is cost effective, take concentrated average sample from a big quantity of samples so the analysis of collected samples can be conducted in the usual way. Passive samplers that can be used in environmental monitoring program are the following:

- *For testing organic matter:* Semi-permeable membrane devices, SPMDs; Polyethylene diffusion bags; Ceramic dosimeter; Solid-phase microextraction, SPME); stb.
- *For testing inorganic matter:* Dialysis in situ; Dialysis with receiving resins; Supported liquid membranes, SLMs); etc.

○ *Other auxiliary devices*

Precipitation sensor installed at the monitoring station, or in case of water courses, devices providing information about water yield (flow meter, water level meter) may provide useful information. Rising water and flow speed caused by sudden precipitation on the catchment area change the measured parameters (dissolved oxygen, turbidity, etc.). Knowing the additional information, the changes of parameters can be interpreted remotely.

If the monitoring stations or a part of them monitored other atmospheric parameters (temperature, air pressure, humidity, etc.), forwarding the information to meteorological services would increase the reliability of local forecasts.

2.2.3. EWS with surface water monitoring

The fast spread of remote monitoring systems allow using and adapting Early Warning Systems for monitoring surface and subsurface waters that have been used in other fields of science for a long time. The most important objective is that it can provide early warning about the changes.

Early Warning System basic elements

According to the basic principle of early warning systems, the sooner and the more accurate we are in giving warning about the short-term or long-term potential risks of dangers resulting from the nature or human activity, the highest the probability is that we can manage and alleviate the impact of disasters on the society, economy and environment.

Early warning systems consist of four basic elements that must be considered equally important because failure or deficiency of any element of the system will result in the failure of the whole system:

1. **Risk assessment:** Risk assessment provides essential information for identifying strategy priorities for reducing and preventing disasters and designing the early warning system.
2. **Monitoring and forecast:** Systems integrating devices of monitoring and forecast are needed that can provide forecasts about the potential risks affecting the community, economy and the environment.
3. **Forwarding information:** Communication systems capable of forwarding warning messages to potentially affected places and alarming the local and regional government organizations are needed. The requirements for messages include reliability, simplicity and that the system is available for everyone (authorities and in certain cases citizens).
4. **Response:** Key points of effective forecast: coordination, responsible governance, appropriate action plans. Similarly, crucial aspects of reducing impact of disasters: social awareness and education.

The outlined warning system is used in several fields of everyday life: corporate governance systems (economic crisis), health care (appearance and spreading of epidemics, psychoactive substances), politics (conflicts, war situations) and at last but not least environmental management. The scope of this latter includes: air quality, forest fires, nuclear and chemical accidents, sources of geological dangers (earthquake, tsunami, volcano eruption, landslide), sources of meteorological dangers (desertification, drought, flood, impacts of climate change, extreme weather conditions, storms and tropical cyclones), etc.

During the design and building of warning systems for surface waters the above-mentioned principles must be followed, that is, potential sources of risk and related risk factors must be taken into consideration:

- (1) the causes and indicator parameters of the danger and the dynamism (suddenly or slowly developing) must be identified
- (2) following this, the monitoring program (monitoring points, type and location of monitoring station, sampling frequency) based on the indicator parameters must be identified
- (3) specifications (design, power supply, equipment, communication, etc.)
- (4) programs (systematic classification, analysis, forecast, warning, etc. functions) analyzing the data of tested indicator parameters must be created
- (5) finally the hierarchical levels of warning system must be specified, and
- (6) procedures must be worked out (procedure, documentation policy, models).

Risk analysis, risk model

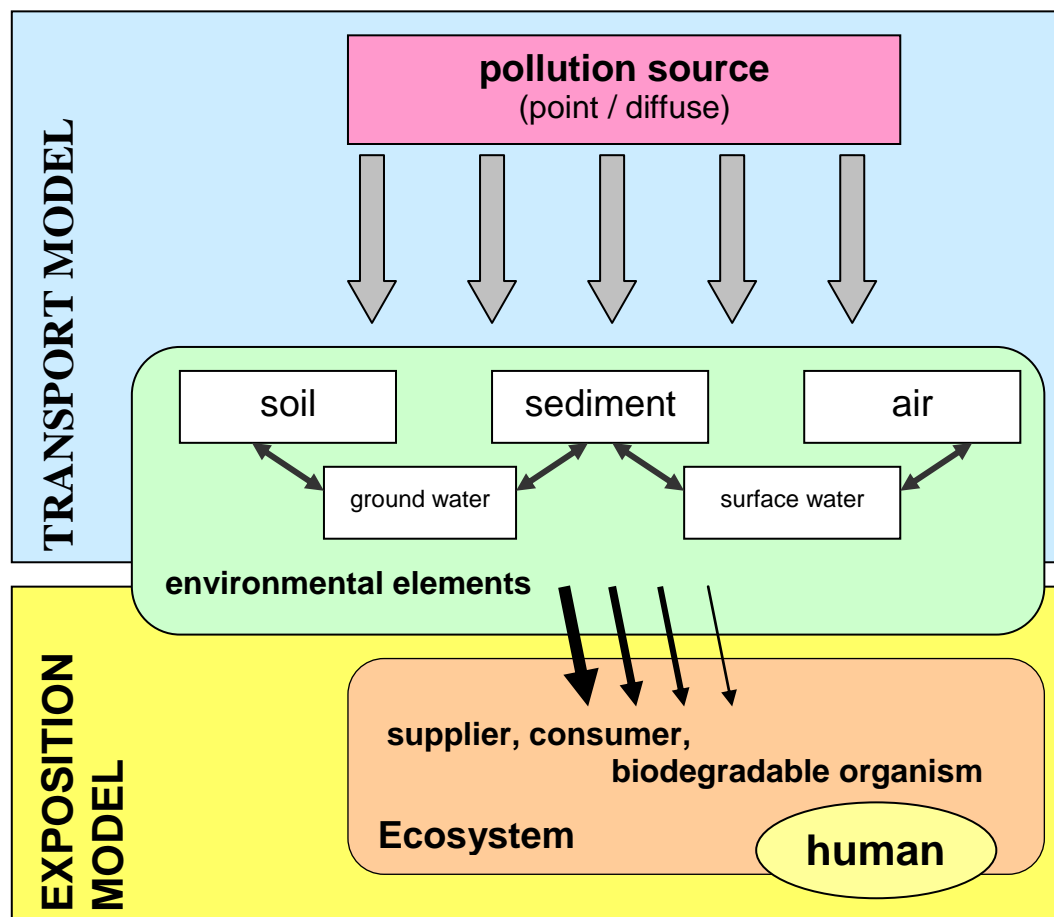
Important parts of early warning systems are the integrated risk models that can be applied for local, regional and global risks. They have two important parts: the model describing the transport processes followed by the pollution entering into the environment and the model describing the impact of pollution on the ecosystem (exposure) (see the figure below).

1. Transport model

The transport model outlines, after the pollution appears, the potential routes of spreading, the affected environmental elements and the connection between the elements.

2. Exposure model

The exposure model describes how the ecosystem or people using the polluted environmental element are exposed to the polluted element or the harmful agent in it (inhaling, swallowing or skin contact).



33. Figure: The structure of the integrated risk model

Indicator parameters

The concept of early warning system is basically defined by the size of the affected area, quality and location of pollution sources and the spread of pollutions (transport processes, routes), etc.

Accordingly, different indicators and methods are used at global, regional and local levels:

1. *Local level indicators:* usually materials and physical attributes (temperature) coming from well-known point sources that are easy to localize. To monitor them, selective physical-chemical methods are used most often. The monitoring point or station is practically located near the point source.
2. *Regional level indicators:* typically indicators providing information at the level of catchment area, part catchment area. Apart from local level indicator, indicator parameters of pollution emitted by diffuse pollution sources, that is, both selective physico-chemical parameters and harmful indicator parameters affecting the ecosystem or a part of it (including humans). It is practical to install monitoring stations and points beyond the emission places of known sources, at the meeting points of transport routes (confluences, points before and after inflows).
3. *Global level indicators:* indicators suitable for monitoring processes and environmental and ecological trends in the Earth system. Remote sensor methods and satellite recordings suitable for monitoring the full area are used.

Time scale of forecasts

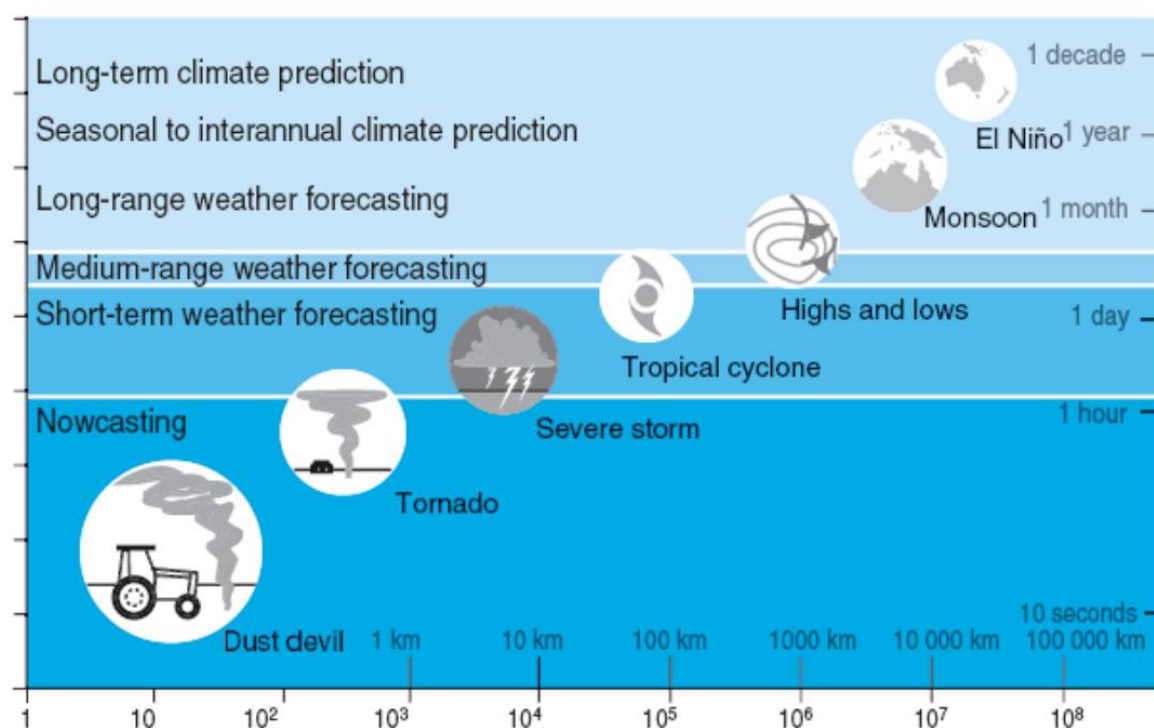
Creating and applying early warning systems is useful if it includes early detection and action. Therefore the expected time scale of forecast must be taken into consideration when designing the system.

Based on the time scale of emergency situations, environmental dangers can be divided into two groups:

1. *Quick-onset*: oil spill caused by accidents; breakdown of nuclear plants, accidents in chemical plant and most hydro-meteorological dangers (flood), etc.
2. *Slow-onset dangers (Slow-onset or "creeping")*: incremental (increasing gradually) but long-term, cumulative environmental changes, to which little attention is paid at the early stages but later they may cause severe crisis. It includes for example: long-term changes of water quality, changes caused by nitrogen overload, reduction of biodiversity or living space, etc.

The time scale of forecast is basically determined by how fast the danger to be forecasted develops and how big area is at risk. Predictability of quickly developing dangers putting small areas at risk is just a few hours, whereas events related to seasonal changes can be predicted about a year earlier and global changes about decades earlier.

An example for the above-mentioned events: the figure below shows the time and space predictability of events warning for meteorological dangers.



34. Figure: How early is the early forecast? (Golnaraghi M., 2005)

2.3. General requirements

After assessing the monitoring methods that can be used at monitoring stations and the monitoring equipment necessary for their implementation, the general system of requirements serving to establish the specification of the system has been set up.

We have drawn up the requirements keeping current technological trends and breakthrough points in view.

2.3.1. Modernity

In the environment management sector connecting information systems initiated recently allows building up and connecting more modern database management systems storing environmental data and monitoring networks. The connectible environmental protection, nature reserve and water management information systems allow the future connection of water management systems to the National Telecommunication Network.

Accordingly, the remotely accessible systems to be installed are designed in a way that they are compatible with the available high-level networks and the database created in them.

Concerning connection, the most important aim is to establish a modern IT system, the elements of which are connected, it is easily accessible and can be operated (remotely) and controlled effectively and cost-effectively.

The mass-produced, cheap and intelligent sensors in usable quality can be integrated easily into the mobile developments including up-to-date technologies.

Modernity includes all requirements made for systems containing electronic and IT elements, where such systems

- must be open source ones, can be developed independently from manufacturers (Open Standards), and they should support future development and extension activities (e.g. connection to other systems, 3G, 4G connection).

2.3.2. Unification

The transboundary application development and operation affecting several countries clearly indicate that only those systems and elements can be used and integrated that meet strictly specified standards. Avoiding to use up-to-date but non standard or not EU conform or CE conform individual devices we aim to establish a system in the European Union development environment that meets European standards and are maximally compatible with elements available in the European Union. Keeping unification in view, we find the following manufacturer- and country-independent categories important:

- development and operation language,
- hardware elements,
- software,
- uniform user interfaces (HMI – Human-Machine Interface), displays,
- standard, uniform database,
- uniform programming interface,
- using uniform, widespread operating systems.

2.3.3. Reliability

Concerning system elements and the full system to be installed outdoors, we make high-level safety requirements to ensure fail-safe operation. To do this we choose the system elements taking into consideration the following:

- they have long-term reliability, the “Mean Time Between Failures” (MTBF), that is, the value of mean time between failures is high,
- if the level of security requires, redundant (multifunctional) elements and solutions are used,
- good service availability,
- robust elements are used.

Concerning equipment, data collection, data storage, data transmission, display and warning functions, we establish a robust system resisting environmental and weather effects which is suitable for field installation.

2.3.4. Manageability

The applicability and manageability of the system operated in international cooperation largely depends on how the user interfaces, documents, help manuals, standards and instruction manuals are created. Based on this and to ensure competitiveness we prefer English language interfaces and contents when implementing the specified categories.

The user interfaces are developed in a form which meets today's requirements and is seen in everyday applications (e.g. mobile screen, icon structure).

2.3.5. Connection

The primary process variables and other parameters provided by the on-site monitoring system are transmitted by wireless system to pre-specified databases. The connection system is divided into two categories:

- local connection providing access to development and supervision systems and databases operated by local water management authorities,
- global connection providing data transmission to higher levels (government, international)

2.3.6. Safety

The safe operation of monitoring stations installed on riversides, exposed to environmental and weather conditions is a basic requirement. The relevant safety requirements are established in the following categories.

Safety of technical solutions

The safety of technical solutions must be ensured during both the implementation and the operation according to the following:

- hardware elements must be chosen in a way that they can stand environmental exposure,
- hardware elements must be built into the system that a stable and robust system is built,
- power supply must be designed taking peak loads into consideration,
- the communication system must be designed on the safest possible and high availability platform,
- data collection and puffer must be ensured during lost communication periods,
- stations must be equipped with self-diagnostic elements that can check basic parameters needed for operation (e.g. voltage supply, charge level and charging process of solar cell),
- the operating elements must be created in a clear and safe form.

Object safety, property protection

Parallel to technical safety the property protection system of remote units must be created where the system transmits an immediate signal about any external intervention to the upper level. The priority of property protection must be higher than the monitoring task and the scheduled communication.

2.3.7. Upgradability

Due to the structure of the water quality monitoring system, the whole system and its individual stations, both at hardware and software level, must be built in modular design. The data collection units built in industrial design and available in ordinary trade are available in specified number of channels but they can be extended.

A higher upgrade which allows connection to other systems can be conducted by standard OPC (Object Linking and Enabling for Process Control) connection which allows connection to office applications, too.

2.3.8. Following technology trends

During specification and selection of certain system elements, we act keeping in view technological sources, development trends and technological trends. We intend to follow this during the specification of certain units and building the whole system.

Sensors

Sensors and transducers are available in measurement technique applications that are cost-effective but have high capacity. These are the basic building elements of the system, so special attention is needed when we choose them because:

- traditional output (0-20mA, 4-20mA, 0-5V, etc.) sensors are cheap, they are easy to use, they are easy to integrate into any other system, their operation is easy to check, but they do not provide any additional information apart from the process variables (e.g. self-diagnosis, configuration settings, etc.)
- connection of the intelligent digital sensors must be done by software or to connect them to their own manufacturer data collection which occasionally

restricts modularity, interchangeability and usability, and operating and especially troubleshooting requires qualified professionals.

Processing/control system

The planned functions of the integrated controller connected to measurement units:

- controlling sensors (e.g. turning on, heating, changing mode of operation, turning off, cleaning),
- reading data measured by sensors (by queries from the Centre),
- warning date, transmitting extreme values, storing sample in case of warning, which will be an important element,
- regular repetition of reading,
- temporary storage of data that have already been read in case of any operational failure,
- transmitting data read or stored to the Centre,
- scheduling mobile communication integrated into the system

Data transmission system

Data are transmitted through wireless, mobile communication system to the pre-specified receivers. The shared intelligence in the system (processor and user software capacity of various stations and the communication ability) allows design similar to expert systems that can make decisions on their own by test values, change mode of operation, and inform nearby stations about it and initiate their switch-over.

The need for this has to be evaluated, and the form of the design and the depth of decision competence must be specified!

Upper-level systems

In the equipment hierarchy the servers receiving from the on-site stations the current data or aggregate data due to breakdown or communication failure are placed at a higher level.

Additional stations necessary for operating the system are placed in the same network as servers:

- engineering station for developments (Engineering Station),
- maintenance station (Maintenance Station may be the same as Engineering station),
- Operatory Station for displaying and analyzing data (Operatory Station).

Through network gateways the above stations may be in connection with other networks (office management), where WEB-based display may be used.

Laboratory support

An integral part of structures observed in foreign practice is the laboratory support which makes the instrumental, IT and communication system complete with specialist personnel sources and laboratory equipment. The laboratory staff carries out occasional maintenance of instruments of the system (on-site inspection, servicing, cleaning sensors,

calibration, replacement, etc.). Cheap operation must be kept in view when this part of the system is established, which is closely related to choosing quality hardware parts and expenditure (CAPEX, investment costs).

2.4. Operation, services

The services related to the operation of the system are based on the implementation of the water quality monitoring stations to be designed in the project and the related data transmission, display and objective documentation modules.

2.4.1. Ensuring early warning signal - Early Warning

The primary aim of establishing the system is to implement a service which allows early warning in case changes take place in the state of living waters. The detection, transmission, and processing of additional signals (warning, emergency, etc.) generated in addition to the primary objective and intervention mechanism are not different from early warning mechanism.

2.4.2. Scheduled measurement program

According to the tasks set forth in the objectives of building a monitoring system, the primary task of various stations is the cyclical measurement of pre-defined process variables by scheduled measurement and continuous transmission of the measurement results to a specified place. Using the intelligence of field equipment the results obtained during the above measurement process are completed by showing the secondary variables in the devices available in ordinary trade, for example, state (ST – state), and the sensor temperature (Sensor Temp), which provides first-hand information about the hardware and the validity and accuracy of the measurement result.

Concerning measurement accuracy and reproducible operation, the aim is not the absolute analytical accuracy but ensuring continuous, informative information indicating the safety level of water pollutants reliably.

2.4.3. Accomplishment of non-scheduled, event-driven tasks

The system must be capable of safely recording and storing information generated during ordinary and extraordinary operation, and transmitting them to a specified place. These require non-schedulable communication connection that must be taken into consideration when designing the system. As a first approach, the accomplishment of the following, non-scheduled tasks must be included:

- managing events and warning signals,
- polling data access,
- conducting simple maintenance tasks during the operation.

2.4.4. Management of events and warning signals

The focus of Abnormal Situation Management, ASM is the alert and alarm signals, that is, the signals generated during ordinary or extraordinary operation. The installed system

must be able to manage the signals generated during operation (event-driven signals). To make it easier, priority levels must be defined according to the arising problems, severity of dangerous situations and type of management of the event and the importance of intervention to be done.

Generally used priority levels:

- critical error (Critical) which requires immediate intervention and troubleshooting,
- warning (Warning) which does not require immediate intervention but it must be displayed on the operator's screen,
- signal to be logged (Log) which is archived until being processed later.

Afterwards, the appropriate priority levels must be assigned to the various events to be displayed. The priority of signals to be displayed and archived must be defined in a way that the number of signals on the operator's screen can be handled and the operators are not overloaded. During the definition the following considerations must be taken into account:

- all signals reach their destination,
- each signal reaches only its specified destination,
- information is not lost or does not stay unnoticed,
- critical signals requiring immediate intervention are displayed by high priority,
- practical selection of the number of signals of secondary importance, not requiring immediate intervention,
- the events are logged.

2.4.5. Polling data access

The system must be suitable for initiating the polling of primary process variables (e.g. starting of pollution) in unscheduled communication periods, at any time, as well as polling information, typically diagnostic ones, that are important for operating the system.

2.4.6. Maintenance – maintenance system based on reliability

Maintenance services must be developed in a way that they are in accordance with the currently approved and required development trends that are characterized by high-level and functional integration, homogenous system development, high-level scheduling and effectiveness, that is, improving the quality of maintenance services. Maintenance must be conducted along with equipment management and modern, integrated applications, strategy developed together with the user must be used as services to support the implementation.

During the development of reliability-based maintenance the following features must be developed:

- scheduled implementation of maintenance according to maintenance work plans,
- more and functional integration,
- longer time focus: high conformity to scheduling,
- customer satisfaction and total cost in focus,
- online, integrated system, monitoring diagnostic parameters.

2.4.7. Maintenance work during operation

Intelligent field equipment and devices should be selected in a way that the system can ensure conducting remote maintenance work through the communication system connected to or integrated into the measurement device. (e.g. cleaning the sampling probe by blowing compressed air into it.)

2.4.8. Objective documentation, historical data storage

All information arriving from the field marked with time stamp for intervention and later data analysis is sent to a historic database (Microsoft SQL Server, Microsoft Access, Oracle, Sybase, Informix, IBM DB2, etc.). Most data can be found on database servers.

Clients can read the required information from this database with the help of the service application.

Special attention must be paid to storing, confirming and managing alert and alarm signals, and permitting or forbidding them individually, by group or category.

The fast and high-level operation and user-friendly nature of database programs allow fast information for the operator and preventing abnormal events thereby.

2.4.9. Data display

Monitoring processes of changes and checking completion of intervention cannot be done without clear, graphic data display assisting fast decision making. Up-to-date displays (HMI) are software systems capable of independent problem solving. Apart from graphic display of process variables and parameters derived from them, trends and displaying graphs, charts and log files also belong to this field.

Trends data are available for operators. Features of display include optionally changeable zooming, specifying time interval, exporting curve, event-driven data collection and pop-up mini-diagram. Real-time curves and curves from the data storage are unified for the operator.

Sampling frequency and storage interval can be modified and precise values belonging to a specified time can be read from trend curves.

For creating log files all momentary values, stored data or data from other data sources or databases can be used. The print preview of the created log can be seen on the screen, and the log can be created for printer, disc or can be stored in the database. Logging may be conducted in a particular time, triggered by an event or by schedule (periodically).

2.5. Aspects of implementation

Taking into consideration the possibilities of implementing the system, building the sub-system, its connection and the auxiliary elements, the following options are available.

2.5.1. Traditional monitoring stations

Both in domestic and foreign practice operating simple monitoring stations in a fixed, protected place (dike-reeve's house, goal oriented buildings) visited relatively often by laboratory fellow-worker is quite usual. These stations are automated monitoring stations

with no external online connection. In our project we aim to go beyond this structure, and we do not intend to implement this type.

2.5.2. Standalone monitoring stations, online connection

The standalone system works on its own, and continuous remote control can be implemented through the integrated communication interface. With the help of the relatively few but good-quality hardware and the purpose-designed software the system provides several additional services.

2.5.3. Sampling

Several options are available for sampling. Depending on the features of the water courses the following systems can be installed using few resources:

- immersion sensor sampler,
- pump sampler,
- equipment installed on spillover dam.

Immersion sensor sampler may be the solution for consolidated water courses where fixing is safe and the risk of washing it away is low in normal operation or flood.

In case of pump samplers, peristaltic pumps installed in protected places can be used, ones that can take samples using atmospheric pressure, but experience shows that frequent part replacement is necessary.

Spillover dams can be built in places where water yield is insufficient or stable water flow is not ensured for sampling.

2.5.4. Implementation of monitoring station

Depending on the design of monitoring stations, we think the following designs can be implemented in this project:

- buoy with fixed or temporary installation in the water body, protected from scums or being swept away
- remote-controlled small boat transported to the venue by operators on a suitable vehicle (van, estate car) and is launched there. Using small boats can primarily be used in stagnant waters.
- container installed at a fixed place temporarily or for a longer period, the size of which may be a mini container (IP protected instrument cabinet) or regular industrial (trailer) container.

2.5.5. Data collection and provisioning system

The active unit of the monitoring system located in the field includes the following:

- sensors,
- interface cards, (AI cards and input channels joining the digital sensors),

- central unit (controller) that collects, stores and transmits data provided by sensors,
- communication unit, modem that can be standalone or integrated into the system (controller) and the connected aerial,
- power supply that means standard (24V DC) efficient supply using solar cells completed with batteries
- object protection sensors.

2.5.6. Documentation system

The system conducting the documentation provides up-to-date, standard, electronic, objective and timestamp information, including historic data that can be used by specified users with access rights. A system like this may be developed in any related development environment

2.6. Instrumental equipment

In the following we provide a summary of the instrumental equipment related to the implementation of water quality monitoring and early warning stations.

2.6.1. Field monitoring and communication system

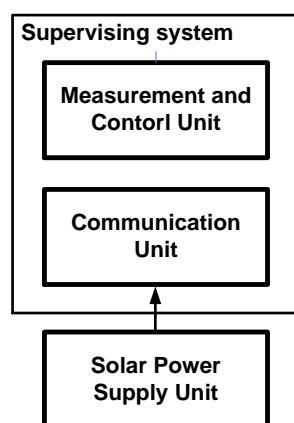
The task of the monitoring system located at the immediate proximity of the water body is to connect the sensors, receive their signals and transmit the received data on wireless connection to the operator stations. The auxiliary blocks ensuring continuous operation are connected to the primary units conducting monitoring tasks:

solar cell power supply system,
wireless communication system

The above-mentioned structure, in any size and design (buoy, small container, large container) can be considered valid.

In the chart below the data collection units and the units of the complete field control system of a monitoring station can be seen.

Sensors
Sensor receiving electronics
Control unit (controller)
Communication unit
Solar cell energy power supply (solar cells, charger, batteries), DC power supply unit.



35. Figure: Block diagram of field control system

The most important modules and functions of the monitoring station are described below.

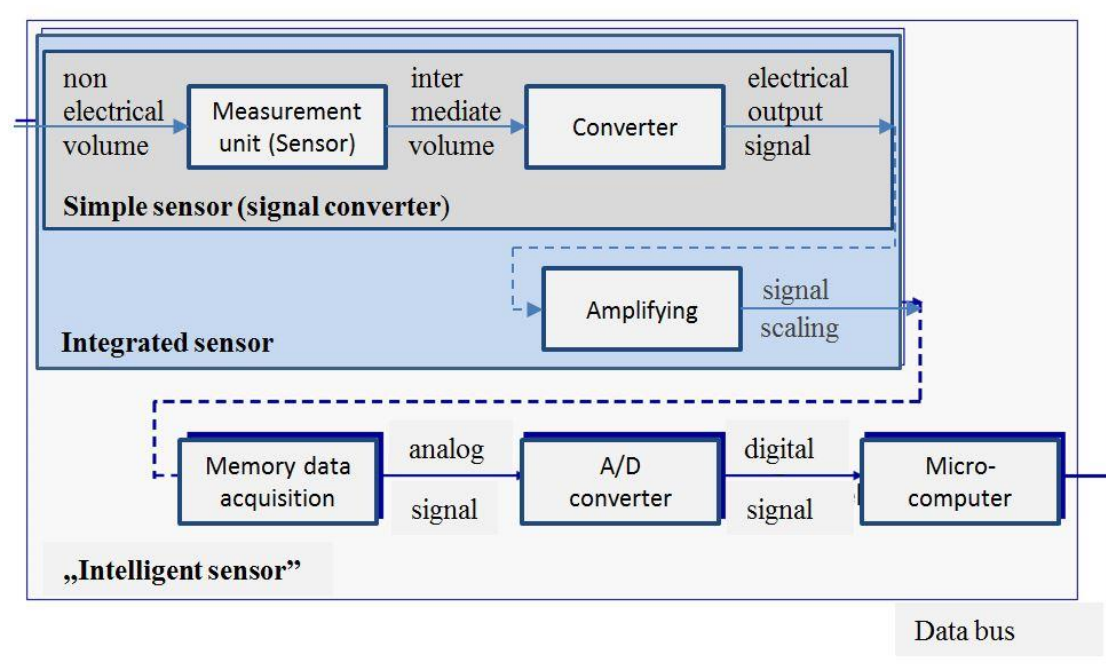
2.6.2. Sensor

The task of the sensors integrated into the system is to detect and measure changes in the state of pre-specified process variables. Based on this, we can differentiate between and connect to the system to indicate the state:

discreet output,

and analogue output sensors suitable for continuous monitoring.

The sensors to be used do not transform electric quantity into electric quantity. In the case of analogue output sensors the analogue output value may be indicated in digital form, taking the appropriate resolution into consideration, if it meets the specification. After amplifying the signals of the sensors they must be transformed and the measured signals must be filtered and scaled. In the case of integrated or intelligent sensors it takes place automatically, whereas in the case of traditional transmitters with two-wire current or voltage output, the analogue interface card will perform these transformation operations.



36. Figure: Design of a simple, integrated and intelligent sensor

Concerning the measurements to be conducted in the monitoring stations, the following process variables and sensor types may be taken into consideration:

Water quality parameter	Unit of measurement	Measurement range	Principle of operation
Water temperature	C°	0-50	Digital, analogue
pH	-	0-14	Potentiometric
Dissolved oxygen	mg/l	0-20	Voltammetry
Conductivity	µS/cm	0-2000	Conductometry
Turbidity	NTU	0-500	Optical
Ammonium ion	mg/l	0-10	Photometry
TOC	mg/l	0-20	UV accelerated oxidation, optical
Surface oil	-	-	optical
Chlorophyll-A	µg/l	0,1-től	Fluorometry
Heavy metal analyzer (cinc, cadmium, lead, copper)	µg/l	0-5000	Polarography
Nitrate	mg/l	0-10	Photometry
Cyanide	mg/l	0-2	Polarography

9. Table: Water quality parameters and sensor monitoring principles

When designing monitoring stations it is an important aspect that we use monitoring principles and devices that require minimal maintenance and zero drift of sensors is small or can automatically be corrected.

Newly developed sensors are available in ordinary trade equipped, for example, with inductive coupling connector and they are suitable for two-direction data and energy transmission. It eliminates the typical problems of coupling systems: waterproofness, corrosion, contact problems, formation of salt-bridge, ground loop currents, etc.

Contact-free sensors eliminate these problems by using inductive, metal contact-free coupling where mechanical fixing is ensured by bayonet-lock. Another advantage of contact-free coupling is that ground loop current will not form in the measurement circuit. Thus the problem of high-impedance symmetric and asymmetric coupling is also solved.

Due to their integrated intelligence, modern sensors can continuously store measured values and sensor attributes, e.g.: manufacturing data, calibration values, number of calibrations, total operation time, time of deployment, measured extreme values, etc., and the stored data can be read through the transmitter.

Instead of the traditional millivolt or microampere (milliampere) output signals, which require good-quality cable, digital transmission takes place. To connect intelligent transmitters four-wire cables can be used. The calibration value of the sensor is not stored in

the transmitter but in the sensor memory, so calibration can be conducted far from the monitoring point, even in laboratory environment. The pre-calibrated sensor just needs to be connected and the transmitter automatically reads and uses the necessary data.



- pH / redox
- conductivity
- turbidity
- dissolved oxygen
- chlorine
- ammonia
- phosphate
- chromate
- copper
- hydrazine
- iron
- manganese
- SAC, nitrate (optical)
- TOC, BOD, KOD
- Nutrients (optical)

37. Figure: Up-to-date digital sensors with inductive coupling (Memosens)

SAC (SAC - Spectral Absorption Coefficient), the so-called spectral absorption coefficient at 254 nm wavelength is used for defining total organic load. ***In the currently available product range there are, at reasonable prices, several sensors and sensor families that can monitor most water quality parameters optically (colorimetry) without using additional chemicals. Efforts must be made to use these products!***

In laboratory conditions using pre-calibration sensors provides several advantages in the implementation of the project

- simple sensor replacement with pre-calibrated devices,
- no field calibration is needed,
- simple installation procedure,
- robust design,
- increased availability due to integrated prognostic diagnostic functions (prognostic maintenance),
- data stored in sensor memory.

In the case of traditional sensors or in former practice sensor replacement, cleaning, regeneration and calibration required outdoor activities. In the current practice only the replacement of sensor is done on-site, whereas the other tasks can be conducted in laboratory. By using replacement sensors significantly lower maintenance costs and considerably longer availability can be achieved.

2.6.3. Sensor interface electronics

Considering that we want to design the stations to be up-to-date, modular and extensible which requires using intelligent sensors and integration of sensor interface electronics. In addition interfaces for traditional (0-5V, 4-20 mA) output transmitters may also be necessary.

Using sensor interface electronics is recommended and may even be inevitable in cases when all sensors are delivered by the same manufacturer or supplier and the product family has receiving electronics. In this case the receiving electronics transforms the factory digital communication into a generally used format (RS-232, RS-485 MODBUS, etc.)

Depending on the attributes of the controlling electronics (PLC) to be integrated or the sensors to be connected, the sensor interface may be omitted in certain cases:

- PLC knows the intelligent sensor communication protocol (e.g. both can communicate through the widely used MODBUS RTU, or other industrial bus – Profibus, FF, HART, etc.),
- intelligent sensors are not used and in this case the 4-20 mA sensor outputs can be connected directly to the PLC AI input.

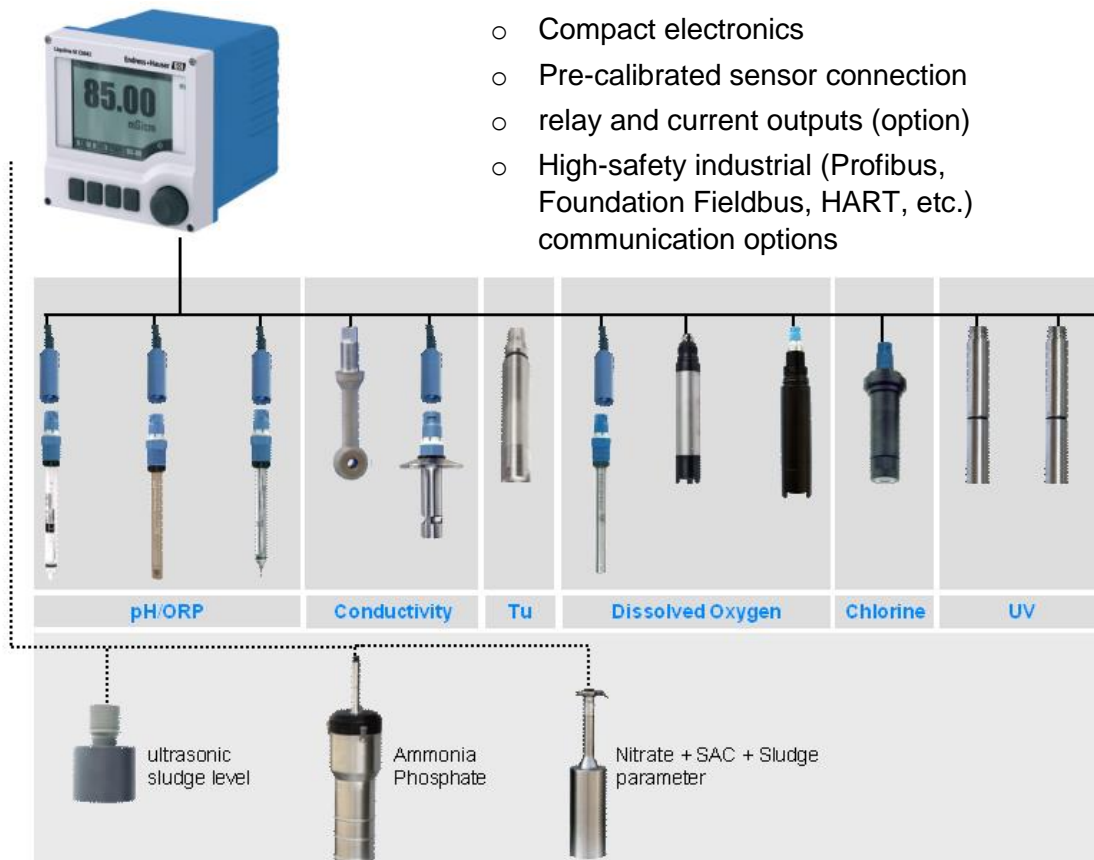
If purchasing and use of sensor interface electronics are needed, it is recommended choosing electronics so that the related sensor family can cover the whole range of process variables to be monitored, that is, at module level a homogenous system consisting of elements provided by the same manufacturer must be built.

In the case of interface electronics sensors from other manufacturers monitoring similar parameters, the connection of sensors may pose a problem.

In practice various manufacturers offer complete and compact solutions, the technical reason of which is to protect their own system and to ensure own developments.

Due to this, it is almost impossible or difficult to solve and is not practical to connect other manufacturer's product to the system concerning physical (connectors, process connection), electric attributes (different supply voltage) or communication protocol (open standard, as opposed to the unknown factory standard) attributes.

A system built from elements of the same product family has several advantages. A few of them:



38. Figure: Intelligent sensor connection to receiving electronics (Liquiline)

2.6.4. Controller

The function of the unit is to connect and control the units conducting measurements and the additional subsystems (power supply) connected to the monitoring system: Main tasks of controller:

- read raw or pre-processed results from monitoring unit (sensors or sensor interface electronics).
- additional operations on measured results (assigning timestamp, scaling, filtering, primary validation, limit value assignment, etc.)
- temporary storage of measured results (buffer),
- event monitoring, alert (handling non-scheduled events):
- generating process alarms: signaling when limit values of process variables are reached,
- generating device alarms: failure, intrusion, property protection. As the equipment is located in the field far from human supervision, alarming in case of third party intervention must be ensured.

- inspection of service units: electronics, temperature, state of solar cell charger, battery voltage, etc.
- ensuring upper level connection, communication, data transmission.
- receiving remotely sent parameters, switching mode of operation.

Taking the nature of task and environmental parameters into consideration, we recommend using PLC as controller (Programmable Logic Controller). Out of the requirements for PLC, ensuring temperature range and lasting, safe operation are outstandingly important because this device will operate in a device cabinet exposed to environmental temperature. Due to the nature of the task (relatively minor task), other attributes, such as I/O channel numbers, communication interface, programmability, etc., cannot be determined in this case, or in the knowledge of the available systems, the functions can be extended by appropriate interface cards.

With the help of the industrial monitoring system equipped with wireless communication monitoring, sensor and control systems can be installed for monitoring live waters specified in the project on objects not equipped with wired electric power supply, in the immediate proximity of water bodies. In the case of these applications using devices suitable for performing functions connected to small number of complex (some analogue and bi-state inputs) signal channels is an optimal solution.

The control system must have the following major attributes:

- the unit must have appropriate number AI and DI channel number,
- must be able to operate in event-driven operation mode as well,
- it should be suitable for handling GSM/GPRS data traffic (through integrated or external modem),
- in order to save energy, the device should be able to operate in sleep mode,
- the device must be able to operate using battery or cell,
- the device must be able to operate without errors in the domestic temperature range,
- manufacturer must give appropriate software support for the device,
- the device must have appropriate application reference.

For performing the task we recommend taking the application of the system specified below into consideration:

- A system which is well-tried in industrial practice having good references,

Currently marketed systems

Out of the systems available in the affected countries, there are few devices that meet the temperature requirements drawn up in the project.

Industrial system with good references

SCADAPack industrial PLC which is available in the domestic market with good references seems to be the practical solution for the specified task.

SCADAPack 350 controller is based on 5209-type controller. The small power-consumption RTU unit contains the following major parts:

- integrated power unit,
- analogue I/O communication channels,
- 10/100 Mbps Ethernet interface,
- 12 Mbps USB A and USB B ports,
- input suitable for receiving the signal of turbine flow meter.

The device can be programmed by:

- ladder network program,
- IEC 61131-3 program,
- C++ programming.

The device has been specially designed for field application purposes and therefore, a separate unit ensures efficient voltage supply utilization. Due to this, the device can work in sleep mode, and this mode of operation affects the Ethernet port and the communication ports including the USB ports too. The device with basic design can be extended with a high number of AI, AO, DI and DO channels using auxiliary units.



39. Figure: SCADAPack 350 industrial PLC

General data

Processor:	32 bit ARM7-TDMI microcontroller
Memory:	16 MB flash, 4 MB CMOS RAM, 4 KB EEPROM

Power supply, consumption

Voltage:	11-30 Vdc
Current consumption, typical:	100 mA
Current consumption, total:	140 mA

Input attributes

Digital signals:	8 pcs. universal input or output
Input signal level:	24Vdc or contact

Output signal level:	24Vdc or contact
Counter input:	3 pcs.
Analogue signals:	6 pcs optionally 0-10 Vdc, or 0-40 mA,
Resolution:	15 bit
Battery voltage measurement:	1 pcs voltage, up to 0..32,768 V
Analogue (option to extend):	2 pcs 0-5 or 0-10 Vdc
Load capacity of output:	250 mA

Communication channels

COM1 port:	RS-485
COM2 port:	RS-232 or RS-485
COM3 port:	RS-232
Ethernet:	10/100 Mbps speed
USB port:	2 pcs, USB A és USB B

Physical attributes

Dimension:	213x127x45 mm
Operating temperature range:	-40 ..+70 °C
Protection:	IP20

2.6.5. Communication unit – data transmission

A crucial part of the water quality monitoring system is the communication module because today's technology allows a wide range of usage from microwave communication, through mobile systems to satellite connection so that we can use wireless communication system with the field-installed systems.

Wireless system is a summary name for technologies designed for replacing wired data transmission. Replacement can be done by microwave and optical methods. Radio-based systems are more widespread because no optical vision is required for connecting these devices.

Wireless systems can be installed using mobile service providers who provide their communication network for data transmission for a subscription fee. The sensory devices of industrial systems can be installed on one side of the network, and to the other side, getting through the network of the service provider, the polling intelligence polling the transmitters are placed.

Concerning this project, installation of traditional (UHF) local radio network is only possible in a defined area and distance with good terrain conditions.

Subscription (GPRS) service using a mobile service provider can be used almost without limitations, due to good coverage, with little cost because the necessary transmitters are provided by the service providers. Industrial monitoring systems use GSM/GPRS-based packet-switched data transmission which has fast response time and bigger data volume can be transmitted cost-effectively. With GSM/GPRS connection there is no need for dialing procedure for all data transmission operations. Apart from coverage, there are no other limitations to this type of data transmission. Concerning the project, we think this is the appropriate solution as the basis of communication.

Concerning the elements of the grid system, the ones capable of providing solutions in short distance may have a communication system usable in simple industrial environment (e.g. ZigBee).

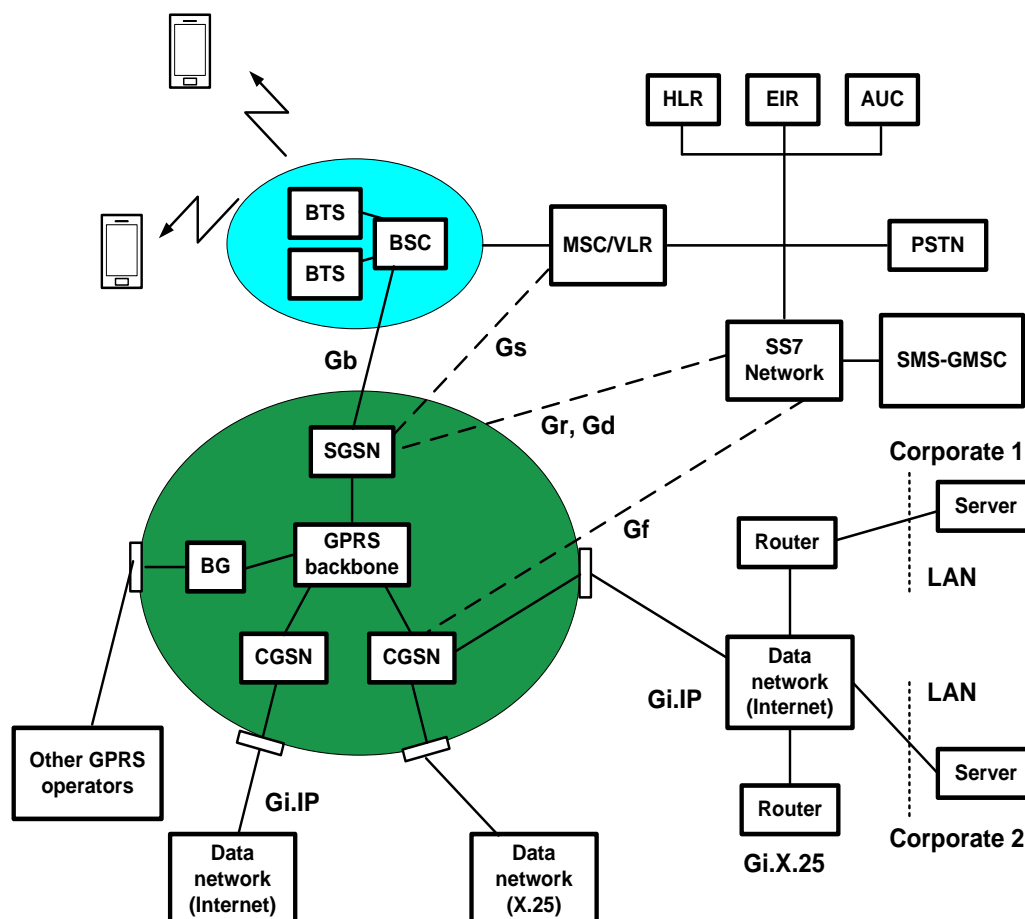
GPRS (General Packet Radio Service) communication

The packet switched radio system is one of the most widely used types of mobile data transmission which replaced the circuit switched solution.

The traffic consists of bigger data sets transmitted by optional intervals so the channel is used only when they are being transmitted. The GPRS system applies new channel coding policy. Through the GSM system as many as 8 time slots may be used from the TDMA frame. Reserving time slots is not fixed but can be chosen dynamically depending on the load. The active subscribers sharing all the time slots and upload and download slots are reserved independently from each other. The following chart illustrates the system structure.

Instead of the theoretical 171,2 kbps of eight time slots, service providers provide in practice 40 kbps channels with three time slots.

Through packet switching a permanent virtual connection is established and the fee is based on data traffic.

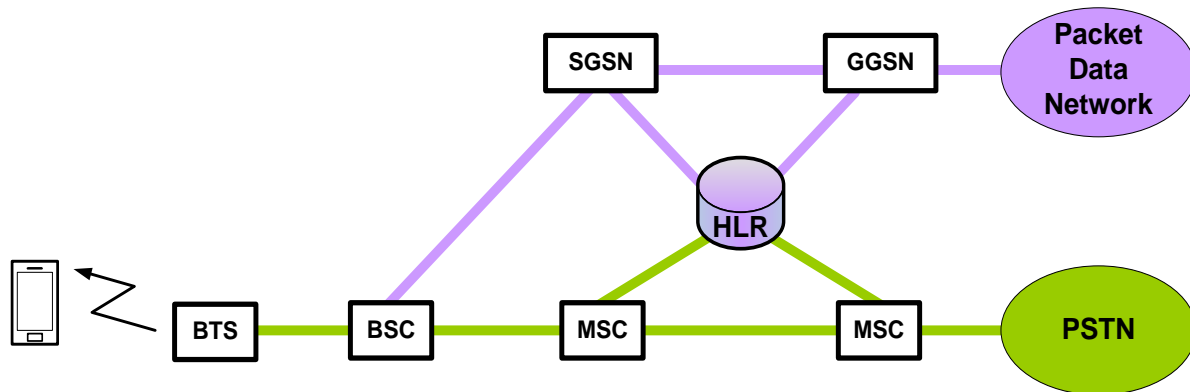


40. Figure: Structure of the GPRS system

The internal structure of the GSM system is completed with two main elements SGSN and GGSN, as indicated in the following figure.

SGSN (Servicing GPRS Support Node) is connected to a BSS subsystem through Gb interface. Its task is to managing mobility, directing packets and encryption and authorization.

GGSN (Gateway GPRS Support Node) connects to external networks and functions as a gateway to other packet switched networks. It is responsible for assigning IP addresses and invoicing.



41. Figure: Using GPRS system

EDGE (Enhanced Data rate for GSM Evolution)

This is an enhanced version of GPRS to increase the speed of GSM system data transmission, which replaces the two-level modulation (GMSM) of GSM to 8-level PSK modulation. A pre-condition of this is the better signal to noise ratio, which means it has to be close to the cell. 8PSK and combining additional time slots 384 kbps speed can be achieved. In practice the transmission is 20-25 kbps. In all other elements, the system is based on GPRS. However, far from the base station, the traditional modulation with lower speed must be used.

GPRS routing

GPRS network is based on IP basis which requires special routing on the mobile network. The mobile device is identified by IP address, which may change by each connection. Packets from external network get into the GPRS network through GGSN. GGSN must know the geographical position of the mobile device so that it can transmit the packet to the appropriate SGSN, and then a logical connection is established between the device and SGSN.

Packets transmitted by the terminal reaches SGSN first, and after the packets are made, GGSN transmits them to the packet switched network.

Third Generation mobile phones

The aim of the third generation mobile network is high speed data transfer, excellent quality of voice transfer and ensuring multimedia services. ITU and 3GPP are responsible for standardization, but standardization is promoted all over the world for compatibility reasons. The speed achievable using this technology depends on the movement of the device, with maximum of 2 Mbps for a home user in a fixed place, 384 kbps for people walking and 144 kbps for drivers in a moving car.

UMTS and EDGE (as well as the already existing GPRS) are technologies that complete and not replace each other. The backbone network of GSM system can be used while using UMTS.

In the GSM network forming the base of the previous systems, UMTS system means the option for extension.

Industrial standards

ZigBee (IEEE 802.15.4)

The development of the standard aimed to achieve small size and low consumption for small-sized networks using short-range radio devices. ZigBee can be used with radio frequency applications where the low transmission speed guarantees long battery life and safe network connection.

ZigBee uses ISM frequency band and its technology is very much similar to that of Bluetooth. Compared to a Bluetooth or Wifi station, about one-tenth of calculation capacity is required, which implies simpler control software occupying only 128 KB. Due to its simplicity, manufacturing costs are low.

Types of ZigBee devices by 802.15.4:

- ZigBee coordinator (ZC)
- ZigBee Router (ZR)
- ZigBee End Device (ZED)

The coordination device forms the basis of the network tree structure, the administrator. ZC ensures gateway to other networks and there may be only one of it in a network. The device stores information about the network and it administers and stores the encrypted keys.

The talks of ZR are to conduct data exchange between the terminals.

The terminal equipment can communicate with the device controlling it; routers and coordinators are suitable for this. It is unable to communicate with other terminal equipment.

ZigBee networks can connect to each other. The devices can form a network in two modes of operation.

In the first mode, there is not any beacon frame, and CSMA/CA is used to dissolve collision, they listen to the channel when they want to transmit data and it is only done when the channel is free.

In the beacon frame connection the routers (ZR) send beacon frame periodically to other hubs of the network. Between sending the frames the devices may switch off for energy saving reasons.

Physical structure

The standard uses 2,4 GHz ISM band dividing it into 16 channels, ensuring 5 MHz per channel. In addition, it uses the 915 MHz and 868 MHz bands. With the earlier it uses QPSK modulation, with the latter one BPSK modulation. The data transfer speed is about 40–250 kbps per channel. It uses the direct sequence spread spectrum coding with transmission distance between 10 and 75 meters. Maximal output is 1 milliwatt.

EnOcean

The main supporter of the standard is Siemens aiming to develop a device with the best energy utilization. The structure is battery-free wireless technology, especially designed for distant sensors.

Physical implementation

Energy supply may be provided by solar cell, piezo generator or thermo-battery. They do not need to be changed during the lifetime of the devices. It can transmit the sensor signals to 300 meters in appropriate reception conditions.

It transfers the data packets by 120 kbps speed, and they are altogether 14 byte long. There is not collision avoidance, the packet is sent in 3 pseudorandom intervals which ensures safe arrival.

The devices have unique, 32-bit identifiers which are sent in each packet. It uses 868 MHz frequency in the ISM band. The signals of the devices are received by a receiver that can be connected to a PC. The comparison of solutions is indicated in the chart below.

Standard (market name)	802.15.1 (Bluetooth)	802.11.b (WiFi)	802.15.4 (ZigBee)
Application focus	Cable replacement	Web, email, video	Control & monitoring
Bandwidth (Kbps)	1000-3000	11000	20-250
Transmission range (m)	20 (Class 2) 100+(Class 1)	100+	20-70,100+ (ext. amplifier)
Nodes supported	7	32	2*64
Battery life (days)	1-7	0.5-5	100-1000+
Power consumption (transmitting)	45mA (Class 2) <150mA (Class 1)	300mA	30mA
Suitability for low duty-cycle applications	Poor (Slow connection time)	Poor (Slow connection time)	Good
Spread spectrum technology	FHSS	DSSS	DSSS
Memory footprint (KB)	50+	70+	40
Success metrics	Cost, convenience	Speed, flexibility	Power, cost

10. Table: Comparison of different WiFi solutions

WiMax (IEEE 802.16)

IEEE standard is for broadband wireless communication. In contrast with the 802.11 standard, it is for connection with static installation and not for mobile phones; mobile WiMax is under design and has not been finished yet. It does not need to move between cells because it does not move. Equipment that can be mounted on buildings may be more expensive, with better radios. With WiMax, duplex communication can be used, in contrast with 802.11.

802.16 arcs over parts of towns or several kilometers so the signal output received at the base station may show strong deviation with different transmitters. Depending on the output, different modulation procedures must be used according to the signal-noise conditions.

In WiMax cells much more users can be expected than in 802.11 and as a result more bandwidth is needed than ISM band could provide, therefore it works in the much higher, 10 – 66 GHz range.

In the high frequency range wave-length is in the millimeters, the physical attributes of which are different from ISM-band waves and therefore different physical layer is needed. A characteristic of millimeter waves is that water absorbs them well. Managing errors plays a more important role than in an environment inside a building. High-frequency waves can be focused in directed waves.

Based on the 802.11 standard, the 802.16a standard supports OFDM in band range from 2 to 11 GHz, and 802.16b will operate in 5 GHz ISM band.

Based on the model of managing channels the base station controls the system. It can efficiently schedule the channels running towards the subscriber and it has a role in managing the upwards channels.

802.16 has been designed to be able to cooperate with both datagram protocols (e.g. PPP, IP and Ethernet) and ATM.

Physical structure

WiMax uses the band from 10 to 66 GHz and in this range, in contrast with longer waves, the wave propagation is linear. The base station necessarily has more aerial and each of them point towards a sector of its environment. Each sector functions independently of their neighbours.

Depending on the signal-noise ratio, different modulation solutions are used. QAM-64 for nearby subscribers, QAM-16 for medium close ones and QPSK for distant ones.

It offers flexible possibilities for distributing bandwidth, in particular, the frequency division duplex (FDD) and time division duplex (TDD). In the case of TDD the base station sends the frames periodically. Each frame contains time slots. Downwards time slots come first, then there is a guard interval which ensures time needed for changing direction of stations. It is followed by time slots of upward traffic. The number of time slots intended for various directions can dynamically be changed, so that they are in accordance with the bandwidth used in one direction.

Error correction is done already in the physical layer using the Hamming code.

Security and encryption are ensured by DES encryption and X.509 authentication. Later on DES encryption may be replaced by the more secure AES.

WiMax channel distribution is closely related to service quality.

Service classes of 802.16 system:

- permanent data transmission speed
- real time, alternating speed transmission
- non-real time, alternating communication speed
- service without guarantees.

In the WiMax standard all services are connection-based and each of them gets into one of the above classes, when the connection is established. Permanent speed transmission is intended for uncompressed speech transmission, such as the one

transmitted on T1 channel. It means it has to send a specified quantity of data at specified intervals. It can be achieved by reserving certain time slots for such type of connections.

Real time alternating data speed service has been designed for transmitting compressed multimedia materials and less intensive real time applications. The required bandwidth for them may change in any moment. To achieve this, the base station polls the subscribers by specified intervals how large bandwidth they need.

Non-real time alternating data speed service fits to applications where real time transmission is not needed but they move high data volume, such as moving large files. With this type the base stations poll the clients but not by fixed intervals. Stations with low traffic do not waste bandwidth.

With service without guarantee there is no polling but subscribers compete for bandwidth. Bandwidth demand may be reported and the base station will determine about it.

2.7. Questions of power supply and options for producing energy

Taking into account that the project aims at monitoring live waters, we intend to develop a system without harmful emission operating with electric energy which can be ensured by using renewable energy sources and solar cells. Apart from utilizing solar energy, we intend to use a 230V/50Hz a.c. residential network built on the installation sites to be chosen later.

An obstacle preventing the widespread use of solar cells is their high price, the two reasons of which is the energy- and cutting-edge demand of manufacturing them, and that they can produce energy only using arriving photons. Recently, however, especially due to mass production, the price of solar cells is permanently decreasing.

Yet, solar cell operated self-contained systems appear in higher and higher number. Good examples to this are parking meters, on-site weather monitoring stations and other light-current DC systems. Building an isolated system is an economical solution with favourable price and low energy consumption. There is no need for building additional mains, there is no electricity consumption from the mains and the system is totally self-contained, it can be left on its own. Using this solution monitoring and control systems can easily be installed in any part of the world.

Standalone automatic control systems typically have low output requirement and they can be left on their own. The system electronics performs and controls processes and automatically intervenes if needed. In addition, internet connection may be integrated to perform remote control and interventions or polling data. With a system with low output requirement power supply for and isolated system can be implemented with low costs.

2.7.1. Objective

Overviewing efficient solutions and methods, with the help of which a more efficient than before energy supply can be ensured for operating water quality monitoring systems. In this section only the most important features will be taken into account so that we can establish the structure required for the installation of the whole system.

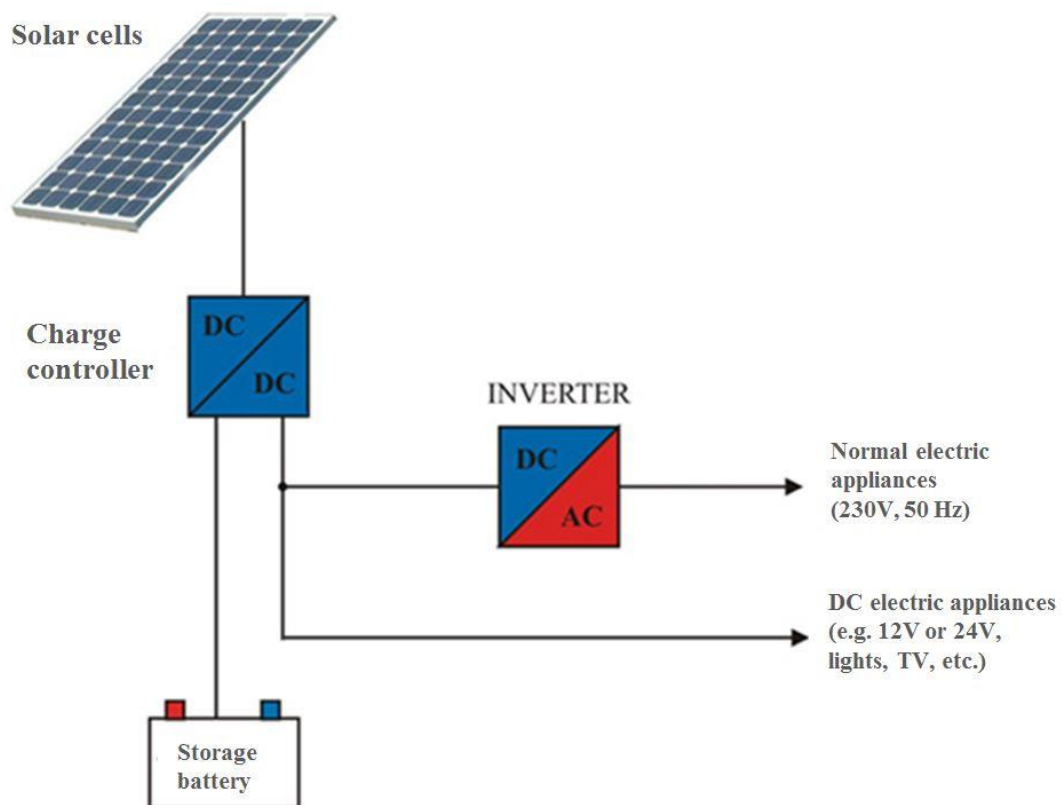
2.7.2. Structure design

System requirements can easily be provided by isolated solar cell systems. Isolated solar cell systems operate in a standalone, self-contained way, independently from everything, in contrast with solar cell systems connected on mains, which require connection to the public supply grid.

In isolated systems the only energy supply is provided by the solar cell unit and it can be stored in the batteries and used from them.

Isolated solar cell systems consist of 4 main units:

- Solar cell
- Energy-storage unit
- Voltage regulator, charging electronics
- Inverter - optional



42. Figure: Block diagram of an isolated solar cell system

The energy produced by the solar cell is stored in the battery with the help of battery charging electronics. Energy from the batteries can be used in several ways. With systems where alternating current is not necessary, the inverter can be omitted. If the direct current system works with 12 or 24V direct voltage, a better quality charging controller electronics is enough, which controls the voltage of the system, protecting users, itself and batteries from harmful load and irregular operation modes.

With traditional (230V) systems, the required 230V AC must be created, which is possible by a DC/AC inverter. Choosing proper load ability is important with inverters. The price of these inverters is very high because ensuring reliable permanent voltage is an important aspect. The field of use must be taken into consideration when we choose them. With regular electric consumer units it is important that they get real sinus voltage otherwise they go wrong. Signals from very cheap inverters are usually not sinus but trapeze or saw tooth which are not suitable for supplying power for all electric consumer units (e.g. frequency converters operated by DC).

The sizing of isolated systems must be based on consumption. We need to know what consumer units we would like to use, capacity and operation time. In addition, the period of energy use is important (day/night/both). The energy storage unit of the system must be sized in a way that it can meet expectations and as a rule of thumb, there should be at least 15% reserve in the system.

To determine the reserve accurately, the bridging time must be known, that is, how many days of reserve we want to have and use on days with weak sunshine. Upon sizing batteries, the calculated daily consumption must be multiplied by number of reserve days. We want to store the calculated energy but solar cells need to produce more because of additional losses (conductivity losses, batteries charging losses, efficiency of charger). Batteries have long lifetime if they are not discharged totally. Electronics in most cases take it into account and allow batteries to be discharged only to a certain percentage. Accumulator battery must be oversized according to this. If for example, we want to discharge the reserve by 50%, the battery size must be at least twice as high as the previously produced energy.

Selection of the inverter is very important for an isolated system but since the monitoring system in the first approach requires only direct current power supply, no inverter is needed for the power supply.

At the calculation of solar cell capacity the energy to be used, use of frequency and the position of the solar cell must be taken into account. The monitoring system must work on each day of the year, shutdown must be eliminated.

Solar cells must be sized in a way that they can ensure adequate energy. The position of the solar cell allows calculating the power it can produce in a year. Charts are available that indicate how much energy can be produced a day on average with a solar cell in a particular place, season, orientation, type, angle and capacity.

2.7.3. Availability of solar energy

Concerning solar energy utilization, Hungary is in a favorable situation because it has on average 2,100 hours of sunshine a year, and the heat energy per area unit per year is about 1,100-1,300 kWh/m². Sunshine is the most intensive in the Great Hungarian Plain (Alföld) region with usually fewer clouds than over higher areas.

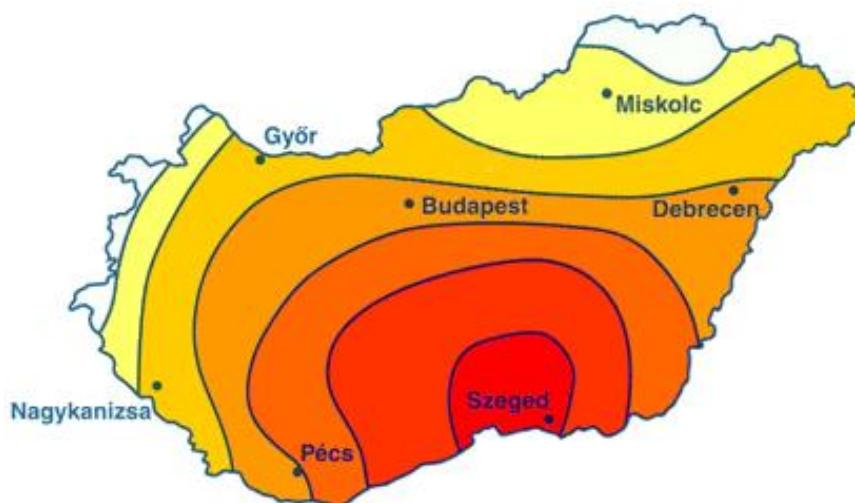
To use the principle, the maximum size of monitoring system to be developed must be defined ahead, including the number of measuring, data processing, power supply, samplers and communication devices.

The figure below shows the global annual distribution of (direct+scattered) sunshine capacity (kWh/m²).



43. Figure: Global annual distribution of sunshine capacity

For the yield, it is needed to determine the operation time of systems using solar energy, which depends on the hours of sunshine. The hours of sunshine in Hungary is distributed between areas as shown below:



44. Figure: Distribution of sunlit hours in Hungary

Zone	Number of sunlit hours
7	- 1900
6	1900-1950
5	1950-2000
4	2000-2050
3	2050-2100
2	2100-2150
1	2150-

11. Table: Distribution of number of sunlit hours in Hungary

Following the above distribution, we do not make a big mistake when we size the system, calculating 2,000 sunlit hours a year. It is in line with the average number of sunlit hours in the Great Hungarian Plain (Alföld).

2.7.4. Energy supply in the winter seasons

One of the biggest problems of solar cell systems is that in the temperate zone, in winter seasons, especially in December there are several days in succession without sunshine, and in such cases external help is needed, and in critical situations it must be considered.

Concerning the number of sunlit hours, Hungary has good conditions. It is relatively high completed with significant amount of scattered sunshine which can be utilized more or less by solar cells, depending on their types. Concerning the number of sunlit hours, the energy of sunshine on one m² in a year is over 1,000 in Hungary. The chart below shows the total intensity and specific energy of sunshine falling on a solar cell in 40° angle calculated by mean values of one day of a month. The table below shows the annual distribution of specific energy falling on 1 m² of optimally positioned solar cell.

Interval	Jan.	Febr.	March	April	May	June	July	Aug.	Sept.	Okt.	Nov.	Dec.
6-7	-	-	27	48	80	104	88	61	39	-	-	-
7-8	-	62	87	142	152	175	159	148	128	78	41	-
8-9	83	118	223	280	302	344	312	284	260	196	97	75
9-10	149	244	357	441	489	529	499	482	422	335	195	120
10-11	223	335	478	582	682	768	692	657	578	456	243	189
11-12	276	389	542	662	810	952	840	750	655	552	316	229
12-13	269	376	530	644	787	932	834	745	631	525	309	225
13-14	224	323	439	548	637	744	653	616	531	441	253	187
14-15	143	224	319	393	460	508	457	440	390	321	171	113
15-16	69	108	190	253	294	328	287	265	237	176	77	55
16-17	-	45	76	130	155	179	157	140	115	65	40	-
17-18	-	-	21	47	82	105	88	57	31	-	-	-
Total Wh/m²/ day	1436	2220	3288	4170	4930	5668	5066	4645	4017	3145	1742	1203

12. Table: Annual distribution of specific energy

An efficient monocrystal solar cell utilizes sunshine by 15-17% efficiency, which is regarded good. Its lifetime may be 30 years. The lifetime of the solar cell is the period for which the manufacturer offers guarantee, meaning the solar cell can provide 80% of its nominal performance during this period.

The position and angle of the solar cell is very important in terms of achievable efficiency. With improper setting the quantity of electric energy produced will decrease. In our country positioning solar cells in southern orientation (180°), and $40\text{--}45^\circ$ angle compared to horizontal ensures optimal operation in each season. Taking the features of the roof into account a slight deviation is allowed. Turning the solar cells so that solar rays reach the solar cells at right angles in the morning and late afternoon may increase efficiency. In the above-mentioned periods sunshine intensity is much lower so significant increase in performance cannot be achieved compared to solar cells with fixed installation. Building solar tracker system adjusting the angle in Hungary does not bring advantages, and what is more, it means extra costs and a more complicated structure.

Solar cells are usually installed and worth installing on the roof for saving space. In this case large support stands are not needed. There is a high probability that nothing will shade the cells. Wind-proofness, however, will be much stronger and it also gives protection. Positioning of solar cells in Hungarian conditions are the most efficient at $40\text{--}45^\circ$ angle and southern orientation.

Depending on what types of solar cells are used to build the solar cell module, it has different surface requirements to ensure a unit of performance. In case of the need of 1 kW nominal performance, depending on the type, the following surface is needed for solar cells:

- monocrystal modules: 8 m^2
- polycrystal modules: 10 m^2
- amorphous silicon modules 15 m^2

The following chart shows the energy radiated on a monocrystal, 8 m^2 module, calculated by the mean values of one day of a month.

Jan.	Febr.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
11,49	17,76	26,30	33,36	39,44	45,34	40,53	37,16	32,14	25,16	13,94	9,62

13. Table: Energy radiated on 8 m^2 surface (kWh/day)

If we design the above 8 m^2 solar cell module with efficient monocrystal elements, the maximal output we can obtain calculating 17% efficiency will be as follows:

Jan.	Febr.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1,95	3,02	4,47	5,67	6,70	7,71	6,89	6,32	5,46	4,28	2,37	1,64

14. Table: Output gained from monocrystal solar cell (kWh/day)

3. Evaluation of technically applicable sampling systems in the EWS, taking into account different riverbed types, furthermore sample and data archivation system types and introduction of design options

3.1. Elements to be integrated

Within the framework of a feasibility study the areas listed below are to be defined:

- which elements and
- under what conditions

and how they should be applied in the EWS system implemented in the Tisza River Basin/ catchment area:

- already operating automatized monitoring stations
- physical-chemical, biological and toxicological parameters
- widespread measurement methods.

3.1.1. Formerly developed system

In 1999 on the border section of the Hernád, Szamos and Berettyó Rivers and in 2003 next to Técső on the Tisza River on-line monitoring stations suitable not only for measuring general water-chemical parameters but also measuring some special contaminants and giving early warning were installed.

The stations are equipped to measure the following general parameters: water temperature, pH, dissolved oxygen, electrical conductivity, turbidity, ammonium ion, TOC, surface oil, chlorophyll-a, biomonitoring (toxicity).

In addition, the station on the River Szamos is equipped with a heavy metal analyser (zinc, cadmium, lead and copper) as well as nitrate and cyanide analysers.

The station on the Tisza River is suitable for measuring water temperature, pH, dissolved oxygen, conductivity, ammonium ion, TOC and heavy metal.

The stations send measurement data through telephone line and they can be checked on the Internet.

Apart from measuring general parameters, these stations are suitable for detecting a part of expectable special contaminations, though the installed instruments are old (10-13 years old) and their modernisation has become timely.

3.1.2. Water quality parameters

To determine the parameters to be measured by the on-line monitoring stations to be installed on surface waters the Water Framework Directives are authoritative.

Based on an ecological approach the Water Framework Directive divides the water-chemical attributes into two groups: the background physical-chemical parameters supporting the ecological status and the specific pollutants typical of the particular water catchment area.

The parameters characterizing the chemical status of the water body are divided into three main groups:

1. **General physical-chemical parameters:** water temperature, pH, electrical conductivity, dissolved oxygen, total suspended solids, COD_p, COD_k, TOC, BOD₅, total dissolved solid (TDS), total water hardness, dissolved iron, dissolved manganese, calcium, magnesium, sodium, potassium, alkalinity, chlorine, sulphate.

2. **Nutrition indicators:** ammonium, nitrate, total nitrogen, orthophosphate, total phosphorus, chlorophyll-a.
3. **Priority Hazardous substances (by „33“-list and the list of “other hazardous substances”):**

„33“ list organic:

Polyaromatic hydrocarbon (PAH) compounds: Naphthalene, Anthracene, Fluoranthenevi, Halogenated polyaromatic hydrocarbons: Benzo(a)pyrene 1,2,4-trichlorobenzenes, Pentachlorobenzene, Hexachlorobenzene, Pesticides: Alachlor, Atrazine, Chlorfenvinphos, Chlorpyrifos, Endosulfan (alpha-endosulfan), Hexachloro-cyclohexane, Gamma lindane isomer,

„Other hazardous substances“ organic: DDT compounds, Aldrin, Dieldrin, Carbon-tetrachloride, tetrachloro-ethylene,

„33“ list (heavy metals): cadmium, lead, mercury, nickel.

„Other hazardous materials“ (heavy metals): total chrome, arsenic, zinc, copper

3.1.3. Typical measurement methods applied for the most important parameters

1. pH

Typical value for middle-size and large rivers on lowlands 6,5-9,0 pH.

Recommended measurement range: 0...14 pH.

Typical maintenance requirement:

- cleaning and calibration (buffer solution 2 x 0,5 litre/year)
- replacing pH-sensor head or reference electrode every second year

Measurement is conducted by traditional electrochemical method. Glass electrode or ISFET semi-conductor sensor can also be used. With combined electrode it is practical to choose big-sized, porous sensor with Teflon diaphragm or self-cleaning on-line sensor. Several devices designed for measuring pH are available in the market. It is practical to build in a device which is suitable for all system types, thus it is not needed to store spare-parts of several different devices during the operation, which results in simpler operation and lower operating costs. Accordingly, it is practical to build in pH-sensors that also contain the electronics integrated into the sensor body. These sensors themselves store calibration parameters and communicate with the data processing electronics digitally. Sensors designed for fieldwork have extremely low energy consumption, thus they can easily be used in battery and solar-cell powered monitoring stations as well. Digital communication is optimally carried out according to SDI-12 or MODBUS RTU standards because these standard communication protocols are widespread.

2. Redox potential (ORP)

There is no typically characteristic value for this parameter.

Recommended measurement range: -2.000...+2.000 mV.

Typical maintenance requirement:

- cleaning and calibration (standard solution 0,5 litre/year)
- replacement of sensor head or reference electrode every second year.

For the measurement a possibly self-cleaning on-line platinum electrode with large surface is recommended. With combined electrode it is practical to choose big-sized, porous

sensor with Teflon diaphragm or a self-cleaning on-line electrode. In this case it is also practical to take into consideration the power supply and communication needs of the sensor as described at the pH measurement aspects. In many cases pH and redox sensors are integrated in one sensor body, thus mounting and integrating them into the communication system is simpler.

3. Electrical Conductivity (EC)

Typical value for middle-size or large rivers in lowlands <900 $\mu\text{S}/\text{cm}$.

Recommended measurement range: 0...2,000 mS/cm .

Typical maintenance requirement:

- cleaning and calibration (standard solution 0,5 litre/year)
- replacement of sensor head or reference electrode.

The most widespread method to measure it is using conductive electrodes but using inductive sensors is also widespread. Though the investment cost for the latter one is higher than for conductive cells but higher cost is counterbalanced by lower maintenance requirement for inductive cells. Conductive cells are very sensitive to contamination sticking onto the surface of electrodes (suspended solids, biology), which in turn changes the cell constant by blocking the surface of electrodes, thus accurate measurement requires relatively frequent cleaning and calibration. Inductive sensors are not in a direct galvanic contact with the medium to be measured, thus these sensors are much less sensitive to contamination settling onto the surface and therefore, cleaning and re-calibrating them is necessary every few months only. Both types of sensors are available in digital versions where the compensation of raw measurement data is carried out with the help of the electronics in the sensor head, just like described with pH-electrodes, and the data obtained digitally from the sensor is already the calibrated, compensated data that can be used directly. For both measurement methods, digital sensors with extremely low energy consumption are available, which are ideal for fieldwork use.

4. Dissolved Oxygen (DO)

Typically for middle-size and large rivers in lowlands >7,0 mg/l , saturation 70-120 %.

Recommended measurement range: 0...20,00 mg/l , 0..200% saturation.

Typical maintenance requirement:

- cleaning
- replacing sensor head every second year

To measure dissolved oxygen concentration optical sensors are used almost exclusively nowadays. Though the investment cost of these are higher than electrodes using electro-chemical methods, the higher cost is largely counterbalanced by the lower maintenance requirement and operating costs of optical sensors. A key element of traditional amperometric or galvanic sensors is the special gas permeable membrane (usually made from thin Teflon foil), through which oxygen in the external space diffuse into the internal space of the sensor filled with liquid, where the electro-chemical reaction on the electrodes will result in electric signal. This membrane is the most critical part of the traditional sensors because it is extremely vulnerable. It is highly sensitive to suspended solids or biofilm settling on its surface, because this layer decreases the speed of gas diffusion, which changes the

calibration constant by changing the ratio of the dissolved oxygen concentration between the external and internal space.

The basis of optically measuring dissolved oxygen is that the membrane at the end of the sensor contains a transition-metal complex which fluoresces when exposed to visible (blue) light. If some material enters into the membrane which allows the induced complex to give off energy in another, non-luminescent way, the intensity of perceivable fluorescence reduces. The extinguishment of fluorescence is proportionate to the oxygen concentration in the membrane which allows measuring the oxygen concentration around the membrane. An advantage of measuring optical dissolved oxygen concentration is that the membrane is less sensitive to damages and deposits settling on its surface, and cleaning is needed less often and calibration is stable for a longer period (half to one year) thereby.

5. Total Dissolved Solids (TDS), Turbidity

There is no characteristic value for this parameter.
Recommended measurement range: 0...200,0 NTU.
Typical maintenance requirement:
- cleaning.

Measurement of suspended solids concentration is related to measurement of turbidity. Optical sensors measuring turbidity use standard nefelometric method. As with all optical sensor, automatic cleaning is recommended, which can be either some sort of mechanical "windscreen wiper, ultrasound or compressed air solution. Ultrasound cleaning is the most durable and requires minimal maintenance. It is also practical to take into account energy supply and communication needs as detailed in the considerations concerning pH-measurement.

6. Chlorophyll-a

There is no typical value for the parameter of middle-size and large rivers in lowlands. With stagnant waters the limit value is typically <30 µg/l.
Recommended measurement range: 0...200 µg/l.
Typical maintenance requirement:
- cleaning.

The most widespread on-line method to measure chlorophyll-a concentration is using fluorescent sensors. The sensitivity of fluorescent sensors is suitable for measuring chlorophyll concentration in surface waters. With this method the water sample is exposed to 470 nm wavelength inducing light. The chlorophyll-a, in the water sample exposed to the inducing light, emits light at about 685 nm wavelength. The intensity of the light emitted due to the induction is proportionate to the chlorophyll-a concentration in the water sample.

7. Blue algae

There is no typical value for this parameter.
Recommended measurement range: 0...500 µg/l.
Typical maintenance requirement:
- cleaning.

The most widespread on-line method to measure blue alga concentration is using fluorescent sensors. The sensitivity of fluorescent sensors is suitable for measuring blue alga concentration in surface waters. With this method the water sample is exposed to 620 nm wavelength inducing light. The blue alga in the sample exposed to the inducing light emits light about 655 nm wavelength. The intensity of the light emitted due to the induction is proportionate to the blue alga concentration in the water sample

8. Polyaromatic Hydrocarbons (PAH)

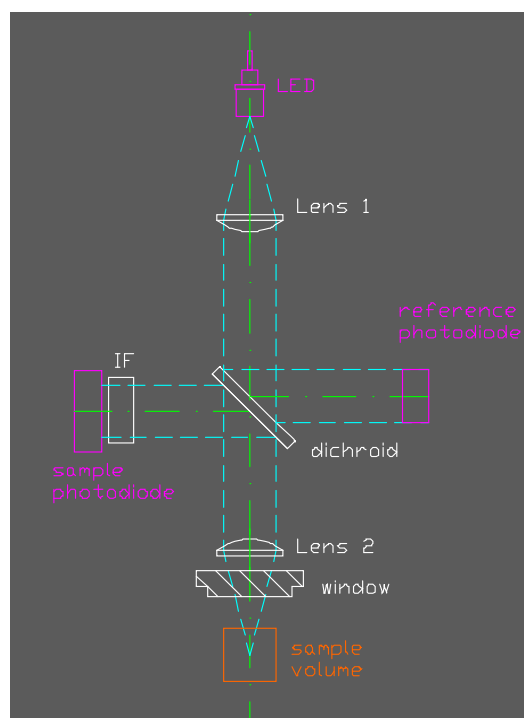
There is no typical value for this parameter.
 Recommended measurement range:
 0...500 µg/l.
 Typical maintenance requirement:
 - cleaning

The most widespread on-line method to measure polyaromatic hydrocarbon concentration is using fluorescent sensors. The sensitivity of fluorescent sensors is suitable for measuring PAH concentration. With this method the water sample is exposed to 254 nm wavelength inducing light. The polyaromatic hydrocarbons in the sample exposed to the inducing light emits light about 360 nm wavelength. The intensity of the light emitted due to the induction is proportionate to the PAH concentration in the water sample.

9. SAC254, UV-spectrum

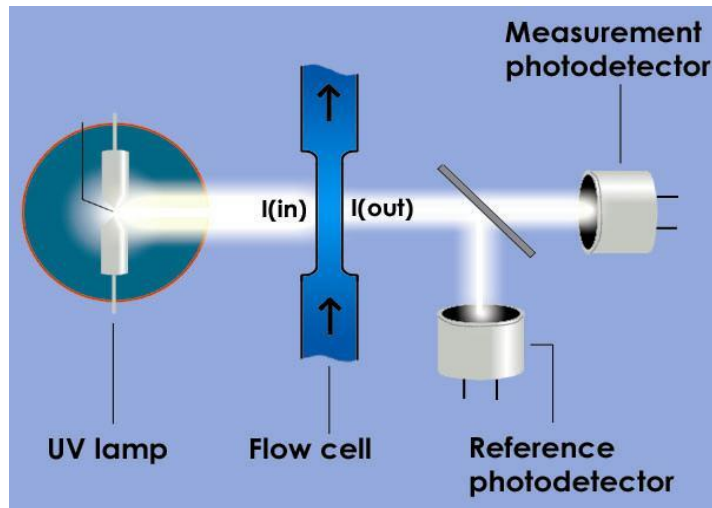
There is no typical value for this parameter.
 Recommended measurement range: 0...150 mAbs SAC254.
 Typical maintenance requirement:
 - cleaning.

It is the parameter indicating the organic substance content in the water sample. Depending on the functional groups and concentration the organic compounds with different composition absorb a part of light falling into the UV range. The wavelength dependence of light absorption is different in different organic compounds. However, in the case of a water sample containing a large number of different organic compounds, if the ratio of contaminating components is relatively constant, there is a correlation between absorption measured at 254 nm wavelength and the organic substance content of the water. With the help of calibration factors determined for the summative parameter (COD or TOC) measured in the laboratory and measuring SAC254, the changes of COD or TOC concentration in the water sample can be monitored. With regular calibration SAC254 can sufficiently be correlated to COD or TOC parameters, and at the same time, measuring it is considerably cheaper and simpler compared to chemical analysers. A general solution is when the UV light source is a xenon bulb, the lifetime of which may be as long as 10 to 15 years with



45. Figure: Fluorescent measurement method principle

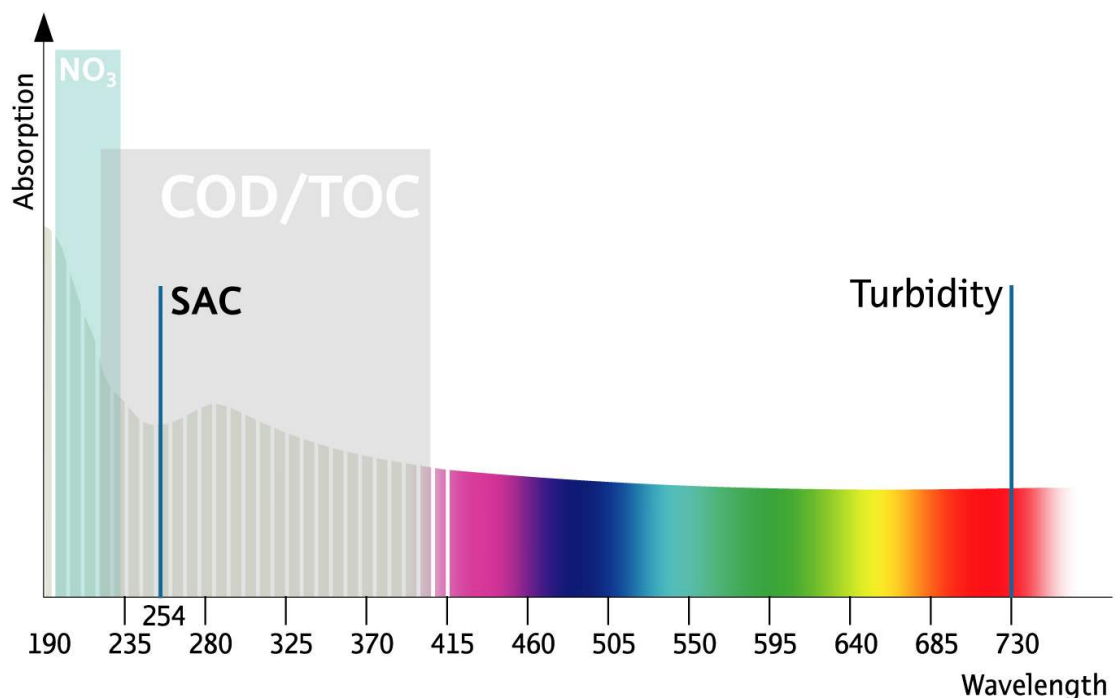
normal measuring frequency. The measuring cell is a special quartz flow-cell or with immersion sensors, an open measuring unit with quartz windows. In front of the detector, with the help of a semi-permeable mirror a reference beam is created, the intensity of which is measured at 600-800 nm wavelength, measuring the light absorption resulting from the turbidity of the sample thereby. The interference filter placed in the main beam transmits 254 nm-wavelength light and SAC254 is measured here.



46. Figure: UV-absorption measurement at one wavelength

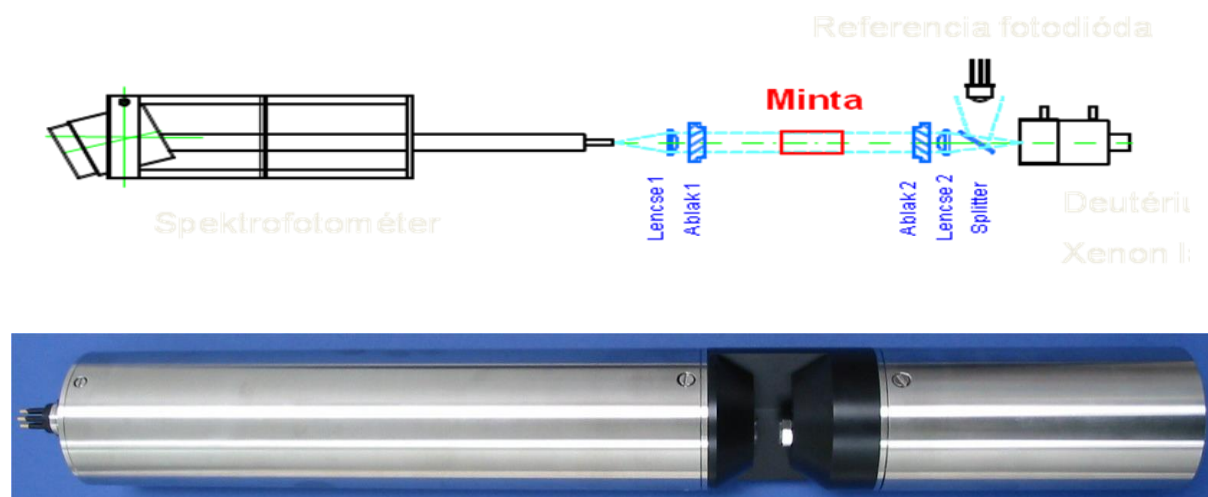
Modern UV-absorption sensors use UV LED as a light source, so the lifetime of the sensor parts may be as long as several decades. In addition, interference filters are not necessary so further costs can be saved.

All devices automatically compensate the measured value with the turbidity of the water. At the same time, just like with all optical sensors, cleaning the optical surface is highly important and with regular measuring it is to be done by automatic control at regular intervals or manually by adequate frequency.



47. Figure: Applicability of UV-absorption measurement method

Measuring SAC254 is done at one wavelength, thus it can be solved by using a simple, low-cost device. Registering the full UV-spectrum requires a more expensive device (on-line UV-spectrophotometer) but with this method the concentration of several components can be defined by mathematically analysing the spectrum. The organic substance content (COD, TOC) can be measured more accurately at SAC254, and in addition, nitrate, nitrite humin acid concentration and the concentration of all components absorbed in the UV spectrum can be measured. This measuring method can be used efficiently if the expectable contaminant has an intensive and typical UV absorbance.



48. Figure: Up-to-date in-situ spectrophotometer

10. Chemical Oxygen Demand (COD)

Typical value for middle-size and large rivers in lowlands 25 mg/l COD.

Recommended measuring range: 0...150 mg/l COD.

Typical maintenance requirement:

- with optical sensors: cleaning
- with chemical analysers: cleaning, checking, refilling reagents, replacement of wearing parts according to the manufacturer's instructions.

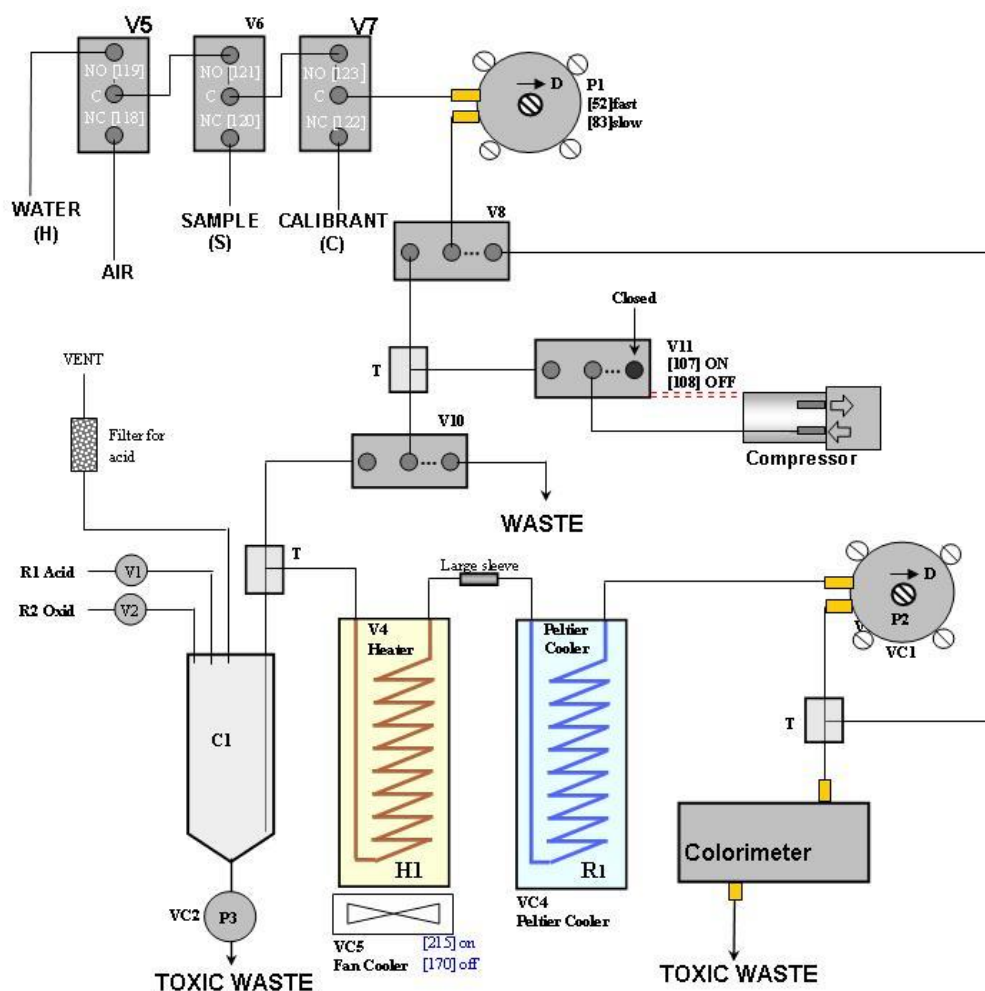
Chemical oxygen demand is one of the most important parameters, which is characteristic of waters' organic substance load. Measuring it in-situ, however, requires expensive devices or devices with high operating costs, or less expensive devices that provide less accurate data that are primarily suitable for monitoring trends.

To measure chemical oxygen demand the on-line analysis with standard method can be used. Since these devices are used for measuring according to laboratory COD standard, they contain expensive, hazardous and carcinogenic reagents (dichromate and concentrated sulphuric acid) which also appear in the sewage water leaving the device, thus its disposal requires special care.

Measuring frequency is influenced by digestion time so it cannot be shorter than 1 hour even with high-temperature digestion.

Due to the relatively high energy demand, power supply can primarily be solved with mains. If only battery and solar cell supplies are available, their capacity must considerably be increased compared to the basic demand.

Maintenance requirement of such devices is typically high and their investment expenses are higher than those of the devices using UV-absorption, but the correlation of obtained data is the best in this method compared with laboratory measurements.



49. Figure: Draft of on-line device for measuring dichromate COD

Another option is using UV-absorption method either with one wavelength (SAC254) or by the full UV-spectrum analysis. The data obtained using the latter method has a considerably better correlation to COD obtained through standard laboratory method than SAC254, but the investment cost of this device is higher. The principle of COD measuring by UV-absorption method is described in the previous section.

11. Total Organic Carbon (TOC)

There is no typical value for this parameter.

Recommended measuring range: 0...20 mg/l.

Typical maintenance requirement:

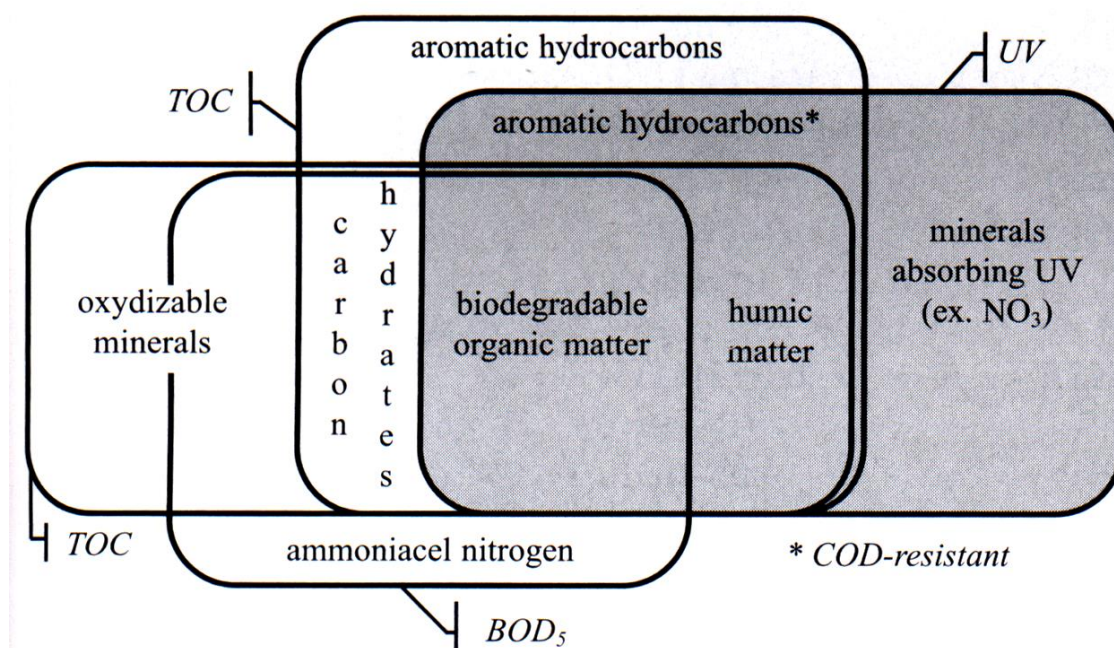
- with optical sensors: cleaning
- with chemical analysers: cleaning, checking refilling reagents every second week, replacement of wearing parts according to manufacturer's instructions.

On-line analysis with standard UV-persulphate oxidation method can be used to measure total organic carbon (TOC). The maintenance requirement of these devices is typically higher and their investment cost is also higher than devices using UV-absorption but the correlation of obtained data is the best in this method compared with laboratory measurements.

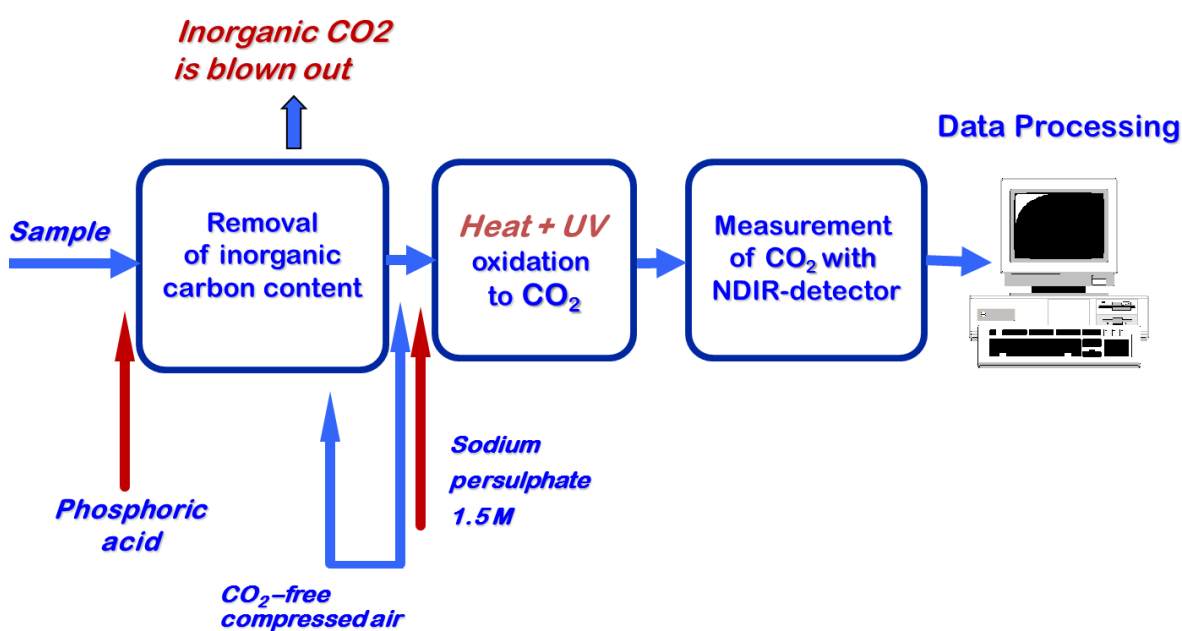
UV-persulphate oxidation is a standard TOC measuring method used in several laboratory and on-line analysers. In this method the pH of the water sample is first reduced by adding acid and the released inorganic carbon-dioxide is blown out then. After removing the inorganic carbon-dioxide, persulphate is added to the sample and it is radiated with 254 nm UV light. As a result of UV radiation, persulphate is transformed into hydroxyl radical which is an extremely strong oxidizing agent, and in the reactor it oxidizes the carbon of the organic components in the water sample into carbon-dioxide. The quantity of the generated carbon-dioxide is usually measured by an IR-detector and using the obtained data the organic carbon concentration in the sample is calculated then.

On-line TOC measuring is a simpler measurement method compared to on-line COD measurement, less harmful reagents are needed and measuring accuracy and reproducibility are better.

Both TOC and COD parameters characterize the organic content of the water sample. Accordingly, there is a correlation between them and the chemical oxygen demand of the water sample can be calculated from TOC using a calibration factor which is most often 3 or 4. Since the two measurement methods are theoretically different from each other, the correlation factor between them is constant only if the water sample has constant composition, but the correlation in most cases is considerably better than between UV-absorption and chemical COD measurement. Therefore, it is practical to use on-line TOC measuring instead of chemical on-line COD-analyser.



50. Figure: Connection between TOC, COD and BOD parameters



51. Figure: Principle of On-line UV-persulphate TOC measurement

Another option is using UV-absorption method either at one wavelength (SAC254) or by analysing the total UV-spectrum and using the obtained data to calculate TOC with the calibration factor determined by the laboratory total measurement. The UV-absorption measurement method is described in Article 9.

12. Measuring oil pollution

There is no typical value for this parameter.

Recommended measurement range: 0...5,00 mg/l, or alarm for surface oil.

Typical maintenance requirement:

- cleaning
- calibration every quarter year.

Oil pollution can be on the surface, emulsified into the water or absorbed on the surface of the suspended solids.

To detect oil pollution on the surface IR-reflective or the more sensitive fluorescent measurement methods are suitable, but the latter one can only detect aromatic components of oil. In general cases, however, inaccuracy resulting from this can be tolerated, taking into account the simplicity and low maintenance requirement of this measurement method.

The principle of infrared reflective method is that the measuring unit floating on the surface is kept by the floating structure permanently at a defined distance. The measuring unit emits to the surface infrared radiation of specific wavelength and monitors the intensity of the radiation reflection. If an oil spill is floating on the surface, the oil layer absorbs a part of infrared radiation and the intensity of the reflected radiation reduces.

The principle of UV-fluorescent method is that the measuring unit floating on the surface is kept by the floating structure permanently at a defined distance. The measuring unit radiates UV radiation at 254 nm wavelength and monitors the intensity of the radiation of 360 nm wavelength reflected back from the surface. If an oil spill is floating on the surface, the aromatic and polyaromatic components emit fluorescent radiation due to the influence of UV radiation.

The strong turbulence of the water surface may cause interference with both measuring methods but UV-fluorescence is less sensitive to this interference.

The most sensitive method to detect emulsified oil or oil absorbed on the surface of suspended solids is using fluorescent measuring method. Several devices applying this measurement technique for detecting oil pollution are available on the market. Based on their design they may be analysers built in a panel or immersion sensors. With analysers built in a panel it is possible to apply automatic cleaning, calibration and zeroing, but with sensors, zeroing and calibration must be done manually.

13. Ammonium-nitrogen

Typical value for middle-size and large rivers in lowlands 400 µg/l NH₄-N

Recommended measurement range: 0...2,0 mg/l NH₄-N.

Typical maintenance requirement:

- cleaning, checking, refilling reagents,
- replacement of wearing parts according to manufacturer's instructions.

Ammonium ions found in surface waters may get into the water partly as metabolic products of living organisms or degradation products of deceased organisms. Appearance of ammonium ions in the water usually indicates fresh pollution. Thus, it may function as an indicator to show the increase of the concentration of other polluting compounds.

Ammonium is toxic to water wildlife, especially to fish, even in low concentration.

The concentration of ammonium in surface waters is typically very low. To detect such a low concentration the appropriate measurement method is standard photometry, and its on-line application is widespread.

Standard photometry uses the indophenol blue method. The principle of the method is based on the fact that ammonia which develops from ammonium in alkaline medium forms chloramine with chlorine released from the reagent, and chloramine with salicylate forms a blue indophenol compound.

The intensity of the blue colour is proportionate to the ammonium concentration.

14. Nitrite-nitrogen

The typical value for middle-size and large rivers in lowlands is 60 µg/l NO₂-N.
Recommended measurement range: 0... 200 µg/l NO₂-N.

Typical maintenance requirement:

- cleaning, checking, refilling reagent,
- replacement of wearing parts according to manufacturer's instructions.

Nitrite ion pollution rarely occurs in surface waters because it is unstable and becomes easily oxidized. Therefore, it usually appears in surface waters in catastrophe, either directly or through the transformation of other nitrogen forms developed in-situ. It has a toxic effect on living organisms even in low concentration and therefore, its presence is extremely hazardous. Nitrite ion concentration in surface waters is typically very low. The appropriate measurement method to detect such a low concentration is using standard photometry, the on-line use of which is widespread.

Standard photometry applies sulphanilamide/NED method. In this method, in slightly acidic medium sulphanilamide and then naphthyl-ethylenediamine is added to a solution containing nitrite ions and as a result, colourful azo dye develops.

15. Nitrate-nitrogen

Typical value for middle-size and large rivers in lowlands is 2 mg/l NO₃-N.
Recommended measurement range: 0...10,0 mg/l NO₃-N.

Typical maintenance requirement:

- cleaning, checking, refilling reagents,
- replacement of wearing parts according to manufacturer's instructions.

To measure nitrate ion concentration, there are several measurement methods ensuring nearly the same precision.

Applying ion-selective sensor can be used with adequate precision but it is recommended integrating a system with automatic calibration and chloride ion compensation. Nitrate ion-selective electrodes are sensitive to the interference of chloride ions and chloride ions cause positive measurement error.

UV-absorbance measurement method is also simple and requires little maintenance. UV-absorbance has already been described in Article 9. The typical absorption maximum of nitrate ion is at about 200 nm, therefore substances absorbing at lower wavelength (e.g.: organic compounds causing absorbance at about 254 nm wavelength) cause an increase in the baseline. When measuring nitrate ion UV-absorbance, their interference must be taken

into account. Therefore, the devices used for measuring nitrate with UV-absorption are more complicated than the ones used for measuring COD.

The most accurate result is provided by on-line photometry. In on-line devices several photometry methods are used. In most cases nitrate ion is reduced to nitrite, and the developed nitrite ion concentration is measured by standard sulphanilamide/NED method. The basic difference is the way of reduction.

In one of the widespread methods reduction is applied on a traditional cadmium column. Since this method requires the relatively frequent regeneration of the cadmium column and cadmium has a toxic effect, its on-line use is not widespread.

In the other method nitrate ion in alkaline medium is reduced to nitrite by hydrazine. Reduction is catalysed by copper(II) ions.

In the method considered the most up-to-date, nitrate ions are transformed into nitrite by photochemistry reduction. This latter method is less sensitive to several interferences that cause considerable errors with the previous two ones.

16. Total nitrogen

Typical value for middle-size and large rivers in lowlands is 3 mg/l TN.

Recommended measurement range: 0...10,0 mg/l TN.

Typical maintenance requirement:

- cleaning, checking, refilling reagent,
- replacement of wearing part according to manufacturer's instructions.

Measuring total nitrogen concentration is done by a standard method, digestion. Digestion is done by most analyser type using UV-persulphate method as described at TOC measurement. During digestion nitrate develops from inorganic and organic compounds containing nitrogen, the concentration of which is determined by one of the methods described previously at nitrate analysis.

The other solution is applying high-temperature digestion where in the presence of a catalyst at 650-850 °C or at 1,200 °C without catalyst organic substances in the water sample are oxidized. This is also the basis of high-temperature TOC measurement. During the process, organic substances are transformed into carbon-dioxide and nitrogen bound in compounds are transformed into nitrogen-dioxide. Nitrogen-dioxide concentration is determined by electrochemical or chemiluminescent methods.

The investment cost, operating cost and energy demand of devices using high-temperature oxidation are higher therefore devices using low-temperature UV-digestion are more widespread.

Due to the complicated analytical procedure, the investment cost of devices measuring total nitrogen is high and operating them is complicated. Due to the digestion procedure their energy demand is high therefore it is practical to use them in measurement stations where electric supply mains are available.

17. Orthophosphate-phosphorus

Typical value for middle-size and large rivers in lowlands is 120 µg/l PO₄-P.

Recommended measurement range: 0...500 µg/l PO₄-P.

Typical maintenance requirement:

- cleaning, checking, refilling reagent,
- replacement of wearing parts according to manufacturer's instructions.

Orthophosphate can be found in surface waters as pollution of human origin. Its sudden increase indicates the presence of communal sewage or other chemical pollution. Orthophosphate concentration in surface waters is typically very low. To detect such a low concentration the proper measurement method is using standard photometry, the on-line use of which is widespread.

In the most widespread photometry method, orthophosphate in acidic medium is reacted with ammonium molybdate and the created compound is reduced with ascorbic acid. During the reduction molybdenum blue develops the colour intensity of which is proportionate with the concentration of orthophosphate.

18. Total phosphorus

Typical value for middle-size and large rivers in lowlands is 250 µg/l TP.

Recommended measurement range: 0...1.000 µg/l TP.

Typical maintenance requirement:

- cleaning, checking, refilling reagents,
- replacement of wearing parts according to manufacturer's instructions.

Measuring total phosphorus concentration is carried out with a standard method, digestion. Digestion is carried out by most analyser types using UV persulphate method already described at TOC measurement, whereas the digestion of polyphosphates is carried out in acid medium at high temperature. During digestion, organic compounds containing phosphorus and polyphosphates are transformed into orthophosphate, the concentration of which is determined with photometric method described earlier at orthophosphate analysis.

Due to the complicated analytical procedure, the investment cost of devices measuring total phosphorus is high and operating them is complicated. Due to the digestion procedure their energy demand is relatively high therefore it is practical to use them in measuring stations where electric supply mains are available.

19. Total hardness, calcium, magnesium

There is no typical value for this parameter.

Recommended measurement range: 0...400 mg/l Ca/Mg.

Typical maintenance requirement:

- cleaning, checking, refilling reagents,
- replacement of wearing parts according to manufacturer's instructions.

Calcium and magnesium is of natural origin in surface waters. Measuring them may be necessary in high altitude streams or abstraction of surface drinking water. Total hardness, calcium and magnesium ion concentration can be measured using electrochemical method, ion-selective electrodes. However, their on-line application requires

frequent calibration for adequate accuracy therefore it is practical to use an analyser with automatic calibration.

Another solution is using on-line photometry. In the one of the solutions, the on-line photometer uses methylthymol blue and ethanolamine to determine calcium concentration, and measures the intensity of developing blue colour at 630 nm. To determine total hardness it uses the Mg-EDTA/calmagite method described in standards, where adding Mg-EDTA the calcium is bound into the compound and the same amount of magnesium is released. Magnesium concentration is determined by measuring the intensity of crimson complex colour at 525 nm after adding calmagite.

A significantly more accurate solution is using on-line titrimetry. On-line titrators apply the standard laboratory titration method and the obtained data shows a very good correlation to laboratory data.

20. Alkalinity

There is no typical value for this parameter.

Recommended measurement range: 0...20 mmol/l.

Typical maintenance requirement:

- cleaning, checking, refilling reagent,
- replacement of wearing part according to manufacturer's instructions.

Measuring alkalinity in flatland rivers is usually not necessary. It may become necessary with mountain streams or abstraction of surface drinking surface waters. On-line titrimetry is suitable for measuring alkalinity. On-line titrators use the standard laboratory titration method and the obtained data show a very good correlation to laboratory data.

The device is simple; its maintenance cost is relatively cheap.

21. Chloride

Typical value for middle-size and large rivers in lowlands is 60 mg/l.

Recommended measurement range: 0...200 mg/l.

Typical maintenance requirement:

- cleaning, checking, refilling reagents,
- replacement of wearing parts according to manufacturer's instructions.

There are several alternatives to measure chloride concentration. The simplest one is to use ion-selective electrode. Its stability and accuracy is appropriate if we install an analyser which allows regular automatic calibration.

Colorimetric methods and titrimetric methods use mercury, silver compounds and chromate that are hazardous to the environment. Though these methods provide more accurate data than ion-selective measurement, due to their hazardous reagents, using them is recommended only in really justified cases.

22. Sulphate

There is no typical value for this parameter.

Typical measurement range: 0...500 mg/l.

Typical maintenance requirement:

- cleaning, checking, refilling reagents,
- replacement of wearing parts according to manufacturer's instructions.

The Water Framework Directive does not specify limit value for sulphate but the change in concentration may indicate the presence of various industrial pollutions. On-line photometry is suitable for measuring sulphate concentration. The method is based on measuring turbidity. In proper circumstances barium-chloride is added to the water sample which forms a microcrystal precipitate with the sulphate in the sample. Barium-sulphate concentration is determined by measuring turbidity.

23. Dissolved iron

There is no typical value for this parameter.

Recommended measurement range: 0...500 µg/l Fe.

Typical maintenance requirement:

- cleaning, checking, refilling reagents,
- replacement of wearing parts according to manufacturer's instructions.

The most widespread measuring technique is on-line photometry which is typically based on standard photometric methods. In one of the most frequently applied methods, using hydroxylamine-hydrochloride, dissolved iron is reduced to iron(II) and reacted with orthofenanthroline or TPTZ. The intensity of the developed red colour (blue colour using TPTZ) is proportionate to the iron(II) concentration. This measurement technique is simple and widely known.

24. Dissolved manganese

There is no typical value for this parameter.

Recommended measurement range: 0...500 µg/l Mn.

Typical maintenance requirement:

- cleaning, checking, refilling reagent,
- replacement of wearing parts according to manufacturer's instructions.

The most widespread measuring method is on-line photometry which is typically based on standard photometric methods. This measurement method is simple and widely known.

25. Heavy metals

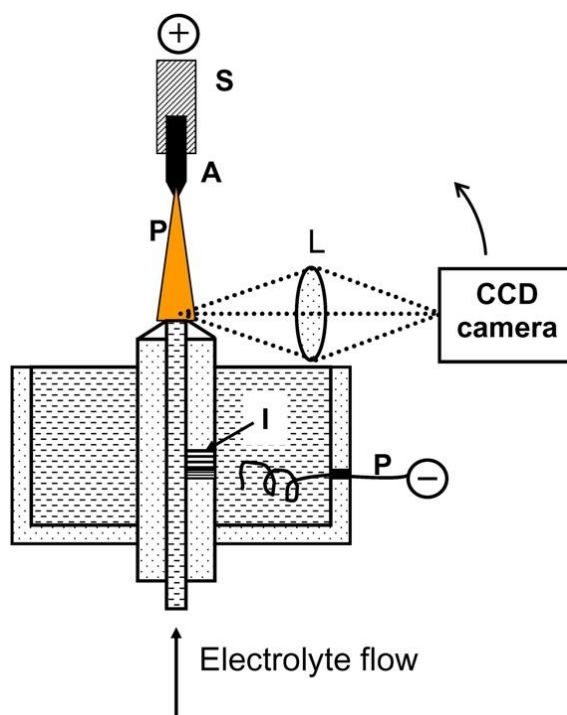
Typical values for middle-size and large rivers in lowlands for the following parameters:

- cadmium and its compounds
- lead and its compounds
- mercury and its compounds
- nickel and its compounds
- dissolved zinc
- dissolved copper
- dissolved chromium
- arsenic

Recommended measurement range:
0...500 µg/l.

Typical maintenance requirement:

- cleaning, checking, refilling reagent,
- replacement of wearing parts according to manufacturer's instructions.



52. Figure: Operating principle of ELCAD heavy metal monitoring device

In surface waters heavy metal pollution may occur in dissolved or suspended solid forms. It is possible to detect heavy metals in suspended solid form after exploration. Its automatic application makes measurement procedure complicated and therefore, if possible, it is practical to restrict detection of heavy metals to dissolved heavy metals.

To measure heavy metal concentration a monitoring device based on ELCAD (Electrolyte Cathode Atmospheric glow Discharge=ELCAD) is used. The water sample pumped into the device using a peristaltic pump keeps circulating in the reactor, the open surface of which functions as a cathode for glow discharge. The spectrum emitted by the discharge contains the atomic lines of heavy metals dissolved in the sewage water, and measuring their intensity the heavy metal concentration can be determined.

The investment cost and operating cost of the device are high but the advantage is that the concentration of several heavy metals can be determined in one time.

An alternative option is using on-line stripping voltammetric analysis.

The rapid expansion of computerized data processing and the development of electronic measuring devices allowed the widespread use of anodic stripping voltammetry. During the measurement, it is necessary to measure extremely accurately and frequently very low current intensities. During enrichment, metal ions are separated at negative potential for the electrode (reduction) and then the separated metal is dissolved by switching the electrode potential to positive (anodic) direction (oxidation). In this way, we can determine the heavy metal concentration of several dangerous heavy metals. An advantage of this measurement method is the relatively low investment cost and low limit of detection.

26. Toxicity and biomonitoring

There is no typical value for this parameter.

Typical maintenance requirement:

- cleaning, checking, refilling reagents,
- replacement of wearing parts according to manufacturer's instructions.

Toxicity is one of the key elements of early-warning system. According to the ecological approach of Water Framework Directive detection of any pollution damaging the ecosystem is essential. Analysing each hazardous chemical component individually would be impossible and therefore analysers measuring summary parameters and within this, biomonitoring systems measuring toxicity are important parts of on-line systems.

Toxicity measuring devices determine substances harmful to organisms by monitoring vital functions of organisms at different level of the evolution.

The most frequent monitoring organisms are various bacterium strains, algae, daphnia magna, Unionoida and fish. Since the sensitivity of these organisms is different, it is practical to use several monitoring organisms to have reliable signals.

The investment cost and maintenance demand of each device are high but the information provided by them is not available in any other way.

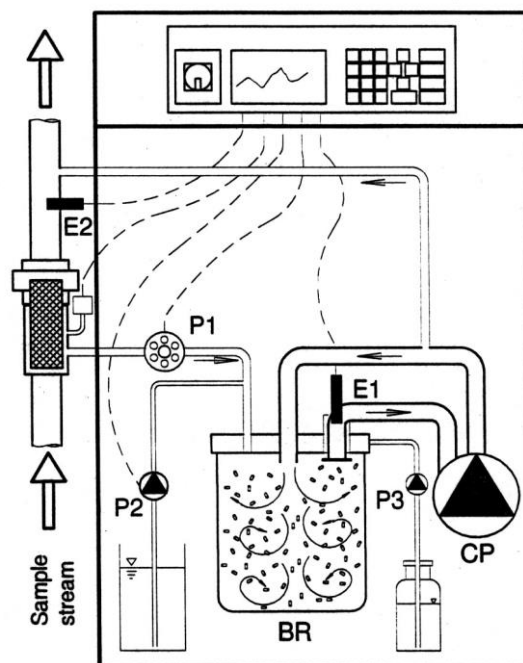
Bacteria:

Bacteria as monitoring bio-organisms have several advantages. One of them is that keeping them alive and keeping the quantity of biomass at a constant level is relatively simple. Another advantage is that due to high population number the different sensitivity of single organism becomes statistically compensated, thus we get a system with relatively constant sensitivity. However, a disadvantage is that bacteria are less sensitive to several pollutants than higher species.

In the most frequently applied solution the amount of oxygen used up during biomass breathing is measured. Biomass may be *Pseudomonas Putida* or other special strains or nitrification strains.

In another also frequently used solution biomass is a strain having bio-luminescence, for example: *Vibrio fischeri*. In this case bio-luminescence is measured and its reduction may indicate the toxicity of the sample.

A widespread measuring method is that oxygen-saturated samples to be studied are pumped through the biomass fixed in a tempered bioreactor, and the dissolved oxygen concentration of the water leaving the bioreactor is monitored. If the dissolved oxygen concentration is lower than the value characteristic of the reactor, the sample contains toxic pollution. An advantage of this



solution is that measurement is completely continuous. However, there is a disadvantage that the biomass exposed to permanent effect adapts to the permanently existing low-concentration pollution and its sensitivity reduces. Therefore, if we use this solution, the biomass needs to be reinstalled from time to time.

In the other solution the biomass is kept in a separate bioreactor and the sample is blended with biomass of a specified amount in a separate measuring cell.

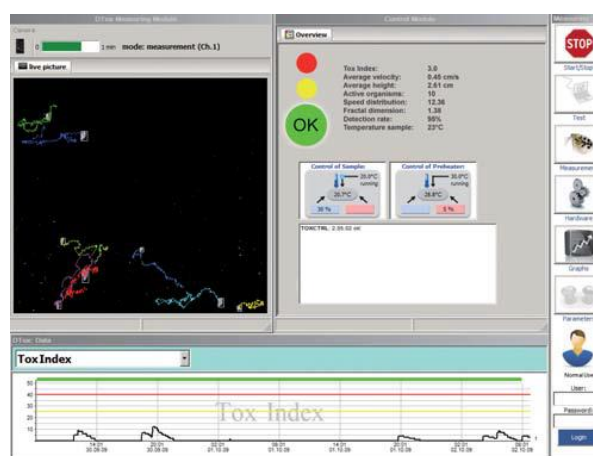
The advantage of this latter method is that the water sample always gets into contact with fresh biomass and the biology cannot become adapted

Algae:

Algae as bio-organisms are also widely used for monitoring toxicity. During on-line monitoring, in the tempered and permanently lit bioreactor chlorophyll-a activity is measured by fluorescent method, thus a biomass with constant activity is maintained. A part of the biomass is blended with the water sample in a separate reactor. If the sample contains toxic pollution, the photosynthesis activity reduces. The changes of photosynthesis activity may indicate the toxicity of the sample.

Daphnia Magna:

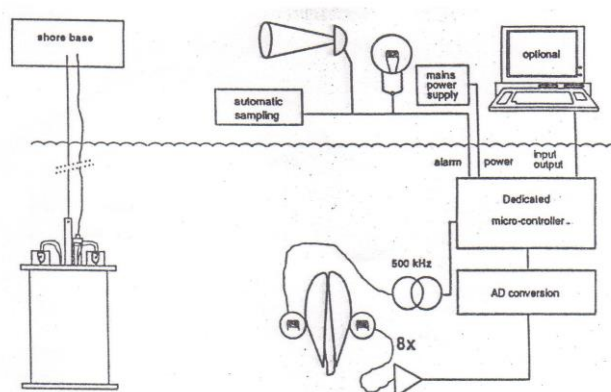
Daphnia as a toxicity measurement biology has long been used but using this method on-line faced difficulties before modern video-recorder and computers were introduced. In this measurement method, the movement of individuals of the biomass is monitored in a tempered pool, and conclusions are drawn to the toxicity of the water sample by the frequency of movements. Modern devices use CCD cameras to detect movement and data processing is done by high-capacity computer software.



H₂O + UV

Unionoida:

Unionoida as higher organisms are sensitive to several toxic compounds that the previously mentioned ones are not or just to a slight extent. When the measuring device is designed, sensors are mounted on the shell, with the help of which opening and closing of shells are monitored. Apart from the above-mentioned advantage of biomonitor built with shells, there are several disadvantages. The number of individuals used is limited thus the different sensitivity of individuals may influence the result. Looking after the shells requires frequent (once a couple of days) maintenance, so maintenance cost is high.



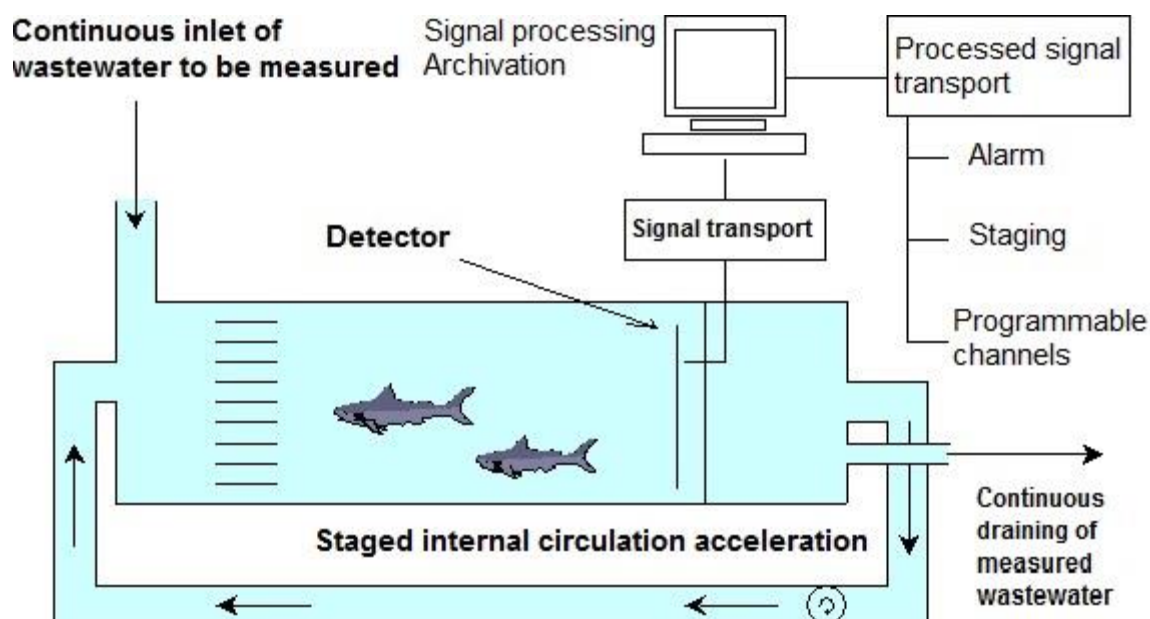
53. Figure: Continuous-flow bioreactor with fixed biomass

Fish:

An advantage of monitoring system using fish is the use of a biological system at a high level of evolution which is even more sensitive to certain toxic compounds than the previously mentioned organisms. In one of the technical solutions, the movement of fish placed in the fish-tank in the device is monitored by a video-recorder and conclusions are drawn to sample toxicity from the fish's movement intensity how deep the fish swim.

In the other method the impairment of fish's rheotaxis ability is monitored. Exposed to toxic pollution this ability is impaired first in fish, and this principle allows designing devices that are more sensitive than other methods.

Fish swimming in the stream try to keep their position in relation to the streaming water. If the water sample contains toxic pollution, fish lose this ability and the stream sweeps them away. The device alternately provides relaxing and streaming periods ensuring an environment close to natural state.



54. Figure: Toxicity monitoring principle of fish's rheotaxis ability

27. Other organic pollutants

Since it includes several components individual measurement methods are to be used. To detect most hazardous organic pollutants, on-line gas-chromatography is the most suitable. Investment and operating costs of on-line gas-chromatograph are quite high, therefore using it is practical only in strongly justified cases.

The parameter to be measured most frequently is the phenol index.

On-line analysers measuring phenol index usually use photometric method. In this method they are reacted in alkaline medium with potassium-hexacyano-ferrate and 4-aminoantipyrin reagents. The generated colour is measured at 510 nm wavelength.

3.2. Basic principles

3.2.1. "Basic CookBook" approach

CookBook is an IT-based catalogue system that recommends a pre-modelled, detailed and applicable scenario for particular situations. It provides ready-made solutions for sub-basin areas where the page matching the particular typology, risk, task and budget can be found or can be filtered electronically.

Based on the parameters typical of the sub-basin area (typological classifications, bed morphology) it outlines installing opportunities and recommends sampling procedures, indicator parameters or measurement techniques for expert users by over-viewing pollutants into account.

The system to be installed provides information about the number of monitoring stations, sampling frequency, sampling intervals and parameter list minimally required for managing the situation.

The system works with alternatives, which means that out of the possible and considered solutions it creates an order from the point of view of environmental impact and economic efficiency.

The electronic page includes the basic specification of the measurement system necessary at the particular monitoring points, but at the same time, the alternative solutions allow puzzle-like configuration of stations linked to the various monitoring spots choosing from the applicable devices. All this is made complete by providing parameters for the integrated documentation and rules of procedures, completing the forms, authority and assigning responsible persons and their tasks (e.g. managing warnings).

Based on the stored specific data, these are made complete by schedule, logistic and economic analyses connected with installing, with the help of which the time for accomplishment, calculable resource demand and costs can be determined.

3.2.2. „LEGO” principle approach

All replaceable and changeable parts of the network system to be installed must have a predefined standard interface in their own operating area. The fixed connection surfaces allow us to choose element sets from several different manufacturers during the modification, expansion and maintenance of the system according to the design of the expected configuration. Standard, defined interfaces must be used:

- Sensor level. Defining communication method towards the data transmitters and/or the interpreting electronics. Defining power supply and voltage/current strength. Managing sleeping/hibernated states.
- Power supply level. Predefining output level of renewable energy sources (e.g. solar cells), determining physical parameters (mounting, size). Way and type of storing generated/available energy. Defining settings, sizes and topologies.
- Level of autonomous measurement system. Interchangeability, replacement, redundancy and the possibility for this must be ensured. It includes factors concerning delivery, installation and maintenance.
- Level of mobile measurement laboratories. Defining ways of measuring (validation, repeated measuring). Defining instruments, measuring methods, procedures, ways of water abstraction.
- Communication level. Defining the system used for communication between the autonomous measurement systems and the data centre. Defining and recording ways of

communication, types, applied standards. Stating physical connection of applied devices.

- Level of top servers: data centre interfaces, applied database systems, database structures and way of accessing them are to be defined.
- HMI (Human-Machine Interface) level: Due to the monitoring extended to several countries the displaying/evaluating/intervening/querying software surfaces must be defined. Information exchange between the applied programme modules can be ensured with application packages. The same language must be used to display the user interface.

3.2.3. „Pre-Installed host” principle

During the implementation the defined monitoring sites and measurement places are designated and the necessary parameters are available any time by the “Basic CookBook” principle. The quantity of devices installed during the establishment of sites does not need to have a full configuration. During the investment period it is enough to establish the infrastructure required for the monitoring station.

Fixed support points for hosting instrument boxes are built. They may be concrete pedestals, platforms, poles or camouflage places blending into the environment. The pipe system for the abstraction of water with necessary physical protections and the power supply accessories can be built here.

The basic level of deployment of the hosts must be defined or registered in the database. Afterwards each established host is suitable for "drag & drop" installation, that is, the delivered instruments can be connected to the connection points (by the Lego principle).

During the installation process technical (water sampling, power supply, communication/remote monitoring/safety) connections must be established, too. Thus, putting the elements into operation later on, joining them to the installed infrastructure becomes a cost-effective and simple solution.

3.2.4. Rack case principle

In the system established by using the Pre-Installed host principle, the Lego principle and the Basic CookBook principle any element of the measurement system can be replaced, just like the server or network elements in the rack cases widely used in the IT sector. The securely fixed connection points determine the complete structure of sampling boxes, so the instruments, sensors, sampler, batteries, communication and information technology devices (required for the measuring programs) can be replaced just like in a rack. This principle allows avoiding sensor calibration in the field because the device calibrated and cleaned at laboratory conditions during maintenance can be connected to the place of operation. The spare part can be one distributed by another manufacturer, too where the part has the same mounting, power supply, communication and technological connection surface.

3.3. Sampling systems taking different riverbeds into account

It is to be noted that with automatic monitoring systems, the stability and safety of the system must be ensured. It primarily means the safety and representativeness of water sample supply (it cannot change from chemically and biologically while reaching the measuring devices). Reliability/accuracy of the measuring devices can be ensured by proper maintenance, but improper sampling may largely influence measuring results, therefore special attention must be paid to the implementation of this system.

The sampling system of the automatic monitoring station suitable for large rivers established in the Tisza River Basin/catchment area has been assessed, and sampling systems suitable for other different bed structures have also been evaluated. For proper feasibility all installation circumstances must be checked separately.

In the case of monitoring the Tisza River, water sample is taken from the standing pipe sunk into the riverbed (perforated structure), in which a separate float ensures the surface sample (it ensures that the sample is always taken from the same water level) to detect surface oil, and another takes the sample from deeper water for the devices. Water sample is taken in one hour cycles. Before the measurement process the system is rinsed and cleaned using water and compressed air. In the Técső station the sample is taken from the pipe embedded into the riverbed standing out 15 cm from it.

In establishing the sampling systems we apply the „Cookbook” principle and we standardize designs by types.

Taking the riverbed structure into account the following solutions are suitable for water bodies for the installation of monitoring stations

- standing water sampling pipe knocked down in the main streamline, in which a float ensures taking the sample (sample is taken continuously from the specified water level). In this case samples can be taken from the surface and below the surface. A protective pipe must be installed in front of the standpipe fixed in the bed to catch flotsam/driftwood. Sampling pump is placed in the building of the monitoring station. This method can be used in winter, too.
- The formerly used impeller pumps – due to the strong vacuum and heating the sample water – cause error in certain parameters, so it is not recommended using them.
- Instead of the above-mentioned pump, a peristaltic pump in proper size is suitable. Its installation is more expensive but maintenance demand is low.
- In riverbeds with low water output, instead of the above method, it is recommended laying high-pressure Hard Polyethylene pipes embedded into the bed and closing the end with a filter (e.g. protection against clogging, catching flotsam).

The sampling procedures listed in the sampling section serve only as an overview and give a general view of the options. It is definitely practical to choose the optimal sampling method individually for various water bodies. Cost, of course, is an important aspect here, too. The most robust design would be concrete water extraction works which resist floods, floating objects and would ensure sampling with a bouy on the surface, under the surface from a certain depth. Its cost, however, is so high that it is not used almost anywhere. Instead of this, in smaller water courses, samples are taken using standing pipes with slots hammered into the bottom or anchored floaters. This latter one is cheap but drifting objects may rip off or damage the device. Another solutions used often is the protecting pipe

reaching nearly the bottom, fixed to the ramp. It is properly protected but allows taking samples only from a specific point. Basically, they are the main types and they can be fine tuned for the specific task.

Property protection and safety technology are major influencing factors of the implementation of installations. Therefore, it is essential to explore already installed systems and using them, if possible, in the EWS system, because then only a proper connection is needed to be installed on the sampling branch.

In the case of technically applicable sampling systems the following logical considerations are necessary:

Placing aspects

If the monitoring station is placed directly in the stream, we cannot speak about sampling.

If it is not possible, the following steps are to be taken:

- type of water body to be monitored, e.g. river, streams, creek, periodical watercourse (e.g. riverbed width, water depth, structure of riverside sector)
- natural or artificial riverbed (e.g. level of riverbed deployment, possibilities to fix sampling tube)
- if it is possible to take samples from the main streamline of the small stream
- flow rate/current speed (highest–lowest water level, water output)

In the case of taking water sample, it is to be examined how many pieces of measuring devices will be served at the monitoring station and how much water is to be provided for the measuring devices.

Aspects of design

1. The diving pump is placed in the water streamline and water is conveyed to the monitoring station
2. A peristaltic pump is used when only one sampling tube is placed in the streamline and the pump can be found in the monitoring station.
Capacity must be taken into account: 8 m lifting height and 15-20 m distance.
3. In the case of small streams sampling tube is fixed to the bed wall and the sample is taken is from main current line. A proper filter is to be placed at the end of the sampling tube so that big-sized suspended solid and flotsam should not block the tube.
4. To have representative water sample, it is necessary to define the material of the tube to be used so that the water sample is not polluted.
5. When choosing the current speed of the water sample, it is to be taken into account that the whole tube system should be flushed with the fresh water sample and no stagnant water should stay in the system (e.g. growth of algae).
6. When choosing measuring frequency, the velocity of pollutants spread is examined and we take into account the measuring time of measuring systems.
7. Choosing the pumping time of the pump is vital because if general parameters (pH, conductivity) are determined inside the monitoring station, the water sample should be available for adequate time and adequate amount of water should be in the sample storing dish to serve the measurement systems/analysers.
8. With high embankment: e.g. using lever-type system: a concrete shaft if built at the riverside and a steel tube is fixed in it which stretches into the water body. At the end of the steel tube there is a float which ensures that the sample is always taken from the same depth. A deflector element can be used for protection.
9. In winter operation to prevent freezing the sampling tube is insulated or equipped with heating coils.

Apart from establishing the sampling system, distilled water is necessary for calibrating and cleaning measurement systems. Therefore, it is also to be established and automatized.

3.4. Establishment of EWS monitoring stations

3.4.1. *Special aspects of installation*

Primarily there are two purposes to install on-line monitoring stations on the water body. One of them is to continuously monitor the water quality data and thus the chemical state of the water body as specified in the Water Framework Directive, and the other is the early detection of pollutions caused by catastrophe situations and the related early warning. Measurement sites based on the Water Framework Directive are practical to fit to water sampling points specified in the national monitoring network. During the preparation of the installation of the on-line monitoring system installed for early-warning purpose, the recommended site of installation should be determined.

The following major aspects are to be taken into account when choosing the site:

1. To detect catastrophe-type pollutions as early as possible the installation site should be near the potentially polluting sources. Apart from nearby installation, it is also to be taken into account to what extent the potentially infiltrating pollution spreads until reaching the sampling site, where is the sampling point in the developing pollution tail, or if the tail avoids the sampling site.
2. The installation site should be protected from extreme water levels and it should allow sampling even at very low water level. Another important aspect is the safe anchoring of floating (buoy-type) measurement stations, and providing adequate sample supply and safety for the riverside systems. With the latter ones, providing samples must be solved with pumps, which – with power supply independent from mains – requires taking into account further energy saving aspects. Based on general practice, delivering the sample should be solved in the shortest possible way. It is not recommended establishing sample pipe longer than 30-50 meters and the sample mustn't stay in the pipe longer than 10-20 seconds. If required, the installation site must be established in the flood plain, adequately protected from floods.
3. The installation site should be easy to access for regular maintenance. If the device is a floating one, it can be accessed by boat. Occasional maintenance must be carried out on the water from a boat.
4. Power supply should possibly be solved with mains current. If mains current is not available a cheap alternative energy supply must be provided (solar cell, battery, fuel cell).
5. An easily accessible communication channel should be available (satisfactory signal strength for GSM, telephone-line, WIFI-, etc.). Possible alternatives of sending measurement data are GPRS communication through GSM network or radio transmission in free frequency band or, if WIFI is available, directly on the Internet. Data collection and final data processing is done on the server connected to the Internet. The data stored on the server are available through the Internet with access rights.
6. The installation site should be protected against sabotage. The protection may contain active and passive elements. The protection of the floating unit can be ensured at several levels. The appropriately robust design can provide the primary mechanical protection. Upon opening, separating from the anchor or changing the GPS position, it may give SMS alarm or local sound alarm. The device may be monitored by a camera connected to the Internet placed at the riverbank.

After locating the appropriate site, the parameters to be measured should be determined as described below:

1. The measured parameters and measurement ranges should fit the type of pollutants infiltrating from the polluting source into the water body and the expectable concentration. If the pollution causes the changes of several different parameters, it is advisable to choose the one parameter which is the most simple to measure (e.g. conductivity) and ensure catastrophe warning by continuously measuring it. In this case, exploring the potential polluting sources of the water catchment area is highly important, with special regard to the material quality and concentration of the expectable polluting components. Whey pollution originating from a cheese factory can be detected by on-line COD measuring but considering that whey pH is very low, it may be enough to measure pH in many cases. The sudden change in the pH of the water body may indicate the arrival of the pollution tail.
2. If the measurement of one parameter can be solved using several different methods, it is advisable using the solution with the lowest maintenance demand and lowest operating cost, with low accessory and energy demand, even in cases when it provides results less accurate than the other (more expensive) solution. It often occurs that a chemical analyser to measure a particular parameter is available, and using standard measurement procedure which is suitable for determining the concentration of a particular component nearly as accurately as laboratory measurements. At the same time, there are one or several alternative measurement methods that are not standard but more suitable for on-line measurement demands. The latter ones require less maintenance, have lower operating costs and simpler structure but measurement results have weaker correlation to laboratory results. A typical example is to measure COD with standard dichromate method or UV-absorption. The standard dichromate method gives results that are closer to laboratory results, but the investment cost of UV-absorption is half, the operating cost is just a fraction of the analyser working with dichromate method, and its measurement frequency, in contrast to maximum one measurement per hour of the dichromate method, may be as frequent as one measurement per minute and its accuracy may also be satisfactory in many cases.
3. From the point of view of early-warning operation, measuring summarized parameters is more beneficial (TOC, COD, BOD, TN, TP, PAH, aromatic, phenol index). From this point of view, on-line measurement of toxicity is essential.
4. To safely identify pollutions, it is recommended to integrate into all systems automatic water samplers which automatically stores the water samples needed for laboratory analyses when limits are exceeded.

During the establishment of the monitoring system, using typified solutions, it is advisable building several modularly expandable systems at different levels (thus with different cost demands), and taking into account the particular site, install the appropriate type and a version specialized for the related parameters. It is also advisable unifying the instruments integrated into the typified solutions. If the devices of several different manufacturers are installed, during the establishment of the typified monitoring system, unified hydraulic and electric connecting points, unified power supply and unified communication protocols or analogue signals as alternative options. If these devices are different in these features, suitable connection systems must be established. If the replacement of the devices is needed in the field, it can easily be built in with the unified connection points and with the devices prepared and calibrated in the laboratory.

3.4.2. Recommended types of monitoring stations

1. Simple system built in buoy

A simple system built in a buoy, with extremely low energy consumption for measuring one or maximum two parameters. Energy supply is provided by solar cell and battery. The measureable parameters must be selected from the ones that require sensors with low energy demand.

Measurable parameters: water temperature, pH, redox potential, conductivity, dissolved oxygen, turbidity, chlorophyll-a, blue algae, SAC254, PAH, parameters measurable with ion-selective electrodes (ammonium, chloride, nitrate).

2. Multi-parameter system built in buoy

Multi-parameter system built in buoy with extremely low energy consumption for measuring multiple parameters. Energy is provided by solar cell and battery. The measureable parameters must be selected from the ones that require sensors with low energy demand.

Measurable parameters: water temperature, pH, redox potential, conductivity, dissolved oxygen, turbidity, chlorophyll-a, blue algae, SAC254, PAH, parameters measurable with ion-selective electrodes.

3. Simple multi-parameter measurement system built in device case installed on the riverbank

Simple multi-parameter measurement system built in device case installed on the riverbank; the central unit is based on the central unit applied with the measurement system installed on buoy. Energy supply is provided by mains or solar cell and battery.

Measurable parameters: water temperature, pH, redox potential, conductivity, dissolved oxygen, turbidity, chlorophyll-a, blue algae, SAC254, PAH, oil pollution, parameters measurable with ion-selective electrodes.

This system allows connecting an automatic sampler with especially low energy demand.

4. Measurement system installed into small-sized mobile container

A measurement system installed into small-sized mobile container, which can easily be relocated to critical locations, if needed. The measurement system contains the central unit of the multi-parameter buoy, energy is provided by battery and solar cell.

Measurable parameters: water temperature, pH, redox potential, conductivity, dissolved oxygen, turbidity, chlorophyll-a, blue algae, SAC254, PAH, oil pollution, parameters measurable with ion-selective electrodes.

This system also allows connecting an automatic sampler with especially low energy demand.

5. Complex measurement system installed into a brick building or large container

Complex measurement system installed into a brick building or large container, which is able to operate chemical analysers using complicated measurement techniques. This system has energy demand bigger than the above ones, therefore the power supply must be solved from electric mains. In special cases energy can be supplied by solar cells but

several large solar panels are required for safe operation. As an alternative option, fuel cell energy supply can also be used.

Depending on the installed analysers, the connection of pure technological water may also be necessary.

Measurable parameters: water temperature, pH, redox potential, conductivity, dissolved oxygen, turbidity, chlorophyll-a, blue algae, SAC254, PAH, oil pollution, parameters measurable with ion-selective electrodes.

Apart from the above, these systems are suitable for operating complicated chemical analysers, too: TOC, COD, toxicity, heavy metal analyser, on-line gas-chromatograph, special analysers suitable for measuring individual parameters.

6. Automatic samplers

This system allows connecting an automatic sampler which takes water sample and stores it cooled in standard circumstances in case limit values are exceeded or on operator's remote instruction.

7. Passive samplers

See Article 3.5 in detail.

Suspended solids as interfering effect must be taken into consideration only with a few monitoring methods.

With the various recommended configurations with designs using simpler sensor measurement, suspended solids may affect optical sensors. Manufacturers took this effect into consideration and compensate the raw measurement result with the value of turbidity. With other sensors suspended solids have only polluting role, the dirt that settled on sensor surfaces must be periodically removed.

The measured parameters and related measurement procedures (e.g. ammonium, nitrate, orthophosphate and other ions) refer to dissolved components, regardless of the size of pore built in the sample preparation chain.

Measuring with UV-absorption SAC254 (KOl) method also shows the dissolved organic matter content.

Taken the suspended solid concentration into account is necessary with monitoring system installed in large container or brick-building.

Providing sample for these systems can be solved by pump and the water sample from the container gets into the analysers through a sample preparation system. A part of the sample preparation system is a filter with appropriate pore size.

To prepare the sample of various components we recommend the following while following the applicable standards:

- TOC/KOI: 100 μm pore size filter. Here we measure not only dissolved organic matter but organic matter content in particles smaller than 100 μm . If we need to measure only dissolved matter, a filter of 0.45 μm pore size must be integrated into the sample preparation system.
- Total phosphorus (TP), total nitrogen (TN): 100 μm pore size filter. We measure the dissolved phosphorus and nitrogen content and their content in particles smaller than 100 μm . If we need only the dissolved content a 0.45 μm pore size filter must be integrated into the preparation system.
- Heavy metals: In surface waters a significant part of pollution can be found in suspended solids. At the same time, dissolved forms are significantly more dangerous for the environment than solid forms, and the usually used analytical methods can be used for measuring dissolved heavy metals. Therefore in online monitoring systems dissolved heavy metal content is measured most often. Because of this a filter with 0.45 μm pore size is needed to be integrated into the sample preparation system. If heavy metal content in suspended solid is also needed, the water sample channelled through a rough (usually 100 μm pore size) filter is explored in a digestion reactor and measure the heavy metal content transformed into dissolved form.
- In case of measuring toxicity and biomonitoring dissolved components are important, compounds bound to suspended solids cannot be taken by organisms used for monitoring. For measurement technique reasons it is practical to channel the water sample through a rough filter (100 μm pore size).
- In the tests of other organic matter PAHs, or the aromatic ones are emphasized only because these are the pollutants appearing most often with oil pollutions and detecting them is relatively simple and cheap using fluorescent sensors. If we want to test a specific compound because the potential polluting source is a chemical or pharmaceutical plant, an expensive and maintenance intensive analytical procedure (gas chromatography, fluid chromatography) is to be integrated. It is practical only with water bodies exposed to high risk.

3.5. Types of sample archiving systems and establishment options

3.5.1. Sample archiving systems

Placing Automatic Refrigerated Samplers in the monitoring stations.

Several sampling options can be configured.

- Sampling is done when limit values are exceeded (the system is started automatically or by remote desktop access)
- Samples are taken automatically at the monitoring stations using the sampling intervals, e.g. every hour. If limit values are not exceeded, the system gets emptied. Thus, 24 storing dishes are available in cooled storage. A dish is 2,5 litre. If the system is not self-draining, the collected samples are taken to the laboratory and analysed then.

Signal types of EWS systems:

Water quality signals

- signal (normal) when a warning is sent in SMS (text or voice message) or e-mail when a specified limit value is exceeded
- signal of sampling when in predefined situations the sample is stored with the help of the installed cooled sampler, and the operator takes the water sample to the laboratory (e.g. hourly sampling, 24-hour average sample, sampling is always done and if problem occurs, it keeps the sample and gives a signal). If the sample is stored, the type of dish concerning the physical-chemical parameters to be determined must be specified (e.g. glass or plastic)

Signals concerning the measurement system

- signal for failure of measuring device
- signal for erroneous sampling (e.g. no water sample, pump problem)
- battery level is low
- signal for running out/replacing reagent
- signal for calibration

Safety signals

- signal for opening door
- signal for changing GPS coordinates
- signal for power supply problems

False alarm

- Operating problem (contamination of probe-head sensor, blocking of sampling tube, failure of measurement system)

It is to be taken into account that technology and environmental protection of countries are largely different.

3.5.2. Passive samplers

Introduction of passive samplers

Most aquatic monitoring programmes rely on collecting discrete grab, spot or bottle samples of water at a given time. Often, where pollutants are present at only trace levels, large volumes of water need to be collected. The subsequent laboratory analysis of the sample provides only a snapshot of the levels of pollutants at the time of sampling. However, there are drawbacks to this approach in environments where contaminant concentrations vary over time, and episodic pollution events can be missed.

Passive sampling methods have shown much promise as tools for measuring aqueous concentrations of a wide range of priority pollutants. Passive samplers avoid many of the problems outlined above, since they collect the target analyte in situ and without affecting the bulk solution. Depending on sampler design, the mass of pollutant accumulated by a sampler should reflect either the concentration with which the device is at equilibrium or the time-averaged concentration to which the sampler was exposed.

Any sampling technique based on free flow of analyte molecules from the sampled medium to a receiving phase in a sampling device, as a result of a difference between the chemical potentials of the analyte in the two media. The net flow of analyte molecules from one medium to the other continues until equilibrium is established in the system, or until the sampling period is stopped. Sampling proceeds without the need for any energy sources other than this chemical potential difference. Analytes are trapped or retained in a suitable medium within the passive sampler, known as a reference or receiving phase. This can be a solvent, chemical reagent or a porous adsorbent. The receiving phase is exposed to the water phase, but without the aim of quantitatively extracting the dissolved contaminants.

There are two kinds of passive samplers from the viewpoint of design: equilibrium-passive samplers and kinetic passive samplers. The former the exposure time is sufficiently long to permit the establishment of thermodynamic equilibrium between the water and reference phases. In the latter it is assumed that the rate of mass transfer to the reference/receiving phase is linearly proportional to the difference between the chemical activity of the contaminant in the water phase and that in the reference phase.

It should be noted, that passive samplers use no electricity or chemicals, need no or almost no maintenance, and are very useful for the measurement of specific chemicals, even in extremely low concentrations. However, the measurements themselves are made in a laboratory with the help of analytical devices, meaning they can not be used as early warning sensors nor as parts of on-line monitoring systems. Also, the measurement results are the sum of the pollutants absorbed during the whole exposure period, meaning no temporal diversification can be made.

Passive sampler types for organic pollutants

Semi-permeable membrane (SPMD) devices comprise lay-flat tubing made of low-density polyethylene (LDPE) filled with a high-molecular weight lipid, typically high-purity synthetic triolein. LDPE is a non-porous material with no fixed pores, only transient cavities with a typical size of 1 nm. This solute size limitation excludes large molecules as well as those that are adsorbed on colloids or humic acids. Only truly dissolved and nonionised contaminants diffuse through the LDPE membrane and can be separated by the sampler.

Polar organic chemical integrative sampler (POCIS). The POCIS is used to monitor hydrophilic contaminants, such as pesticides, prescription and over-the-counter drugs, steroids, hormones, antibiotics and personal-care products. Such compounds are entering water and ecosystems on a global scale and some have been linked with chronic toxicities. POCIS samples from the dissolved phase and thereby enables the biologically available fraction to be estimated.

Chemcatcher (organic version). This system uses a diffusion-limiting membrane and a bound, solid-phase receiving phase. Accumulation rates and selectivity are regulated by the choice of both the diffusion-limiting membrane and the solid-phase receiving material; both are supported and sealed in place by an inert plastic housing. For a range of priority pollutant classes, a number of designs are available with different combinations of receiving phase and diffusion-limiting membrane

Solid-phase microextraction (SPME) is a simple extraction method with several advantages over liquid–liquid extraction and solid-phase extraction. The use of organic solvents is diminished and the SPME technique is simple, precise, and it may be automated easily, and the apparatus is inexpensive. The extraction medium is a thin layer of a polymer coating on an optical silica fibre, with a typical volume of 10–150 nL. Extraction equilibrium may generally be reached in 30 min. The mass of analyte on the fibre can be measured by either gas chromatography (GC) or high-performance liquid chromatography (HPLC)

Membrane-enclosed sorptive coating. This adaptation of the SPME technique to enable integrative passive sampling of hydrophobic organic pollutants has been reported. The device, referred to as the MESCO (membrane-enclosed sorptive coating), comprises a Gerstel Twister stir bar used for stir-bar sorptive extraction (SBSE) or a silicone polymer rod enclosed in a membrane made of regenerated cellulose. The receiving phases may be surrounded by air or water within the bag. The miniature MESCO sampling system combines sampling with solventless pre-concentration. The sampler enables direct analysis of the accumulated contaminants by thermodesorption coupled on-line to GC, thereby avoiding time-consuming sample preparation and clean-up.

Ceramic dosimeter. The ceramic dosimeter uses a ceramic tube as the diffusion-limiting barrier to enclose a receiving phase comprising solid sorbent beads. Recently, the utility of the ceramic dosimeter as a robust groundwater-sampling device was demonstrated for benzene, toluene, ethyl benzenes, xylenes (BTEX) and naphthalenes, using Dowex Optipore L-493 as the receiving phase.

Polyethylene diffusion bags. There is potential for loss of volatiles during the collection of VOCs from groundwater. Polyethylene diffusion bag (PDB) samplers help to eliminate this problem. The sampler comprises a membrane sealed in the form of a long cylindrical bag, filled with deionised water. The bag is made of LDPE and acts as a semi-permeable membrane allowing the passage of most chlorinated VOCs. VOCs in groundwater diffuse across the membrane into the de-ionised water in the bag until equilibrium is reached.

Passive sampler types for inorganic pollutants

Dialysis in situ. Equilibrium dialysis is a simple, size-based separation method applicable to the study of trace-metal speciation. Sampling with a dialysis cell is based on a diffusive flux of species able to pass through the cell membrane towards a small volume of water as the acceptor solution, until equilibrium is reached.

Dialysis with receiving resins. An alternative configuration to the above is to add a receiving phase (e.g., a chelating resin) with a high affinity for the species being measured in the cell. Under these conditions, the diffusion rate is theoretically directly proportional to the metal concentration in the water being sampled.

Supported liquid membranes (SLMs) pre-concentrate trace elements from water and have been developed to mimic uptake across biological membranes. This system comprises an organic solvent with a complexing agent that is selective for the target element and is immobilised on a thin macroporous hydrophobic membrane

Diffusive gradient in thin films. The diffusive gradient in thin-films (DGT) device is a development of a similar sampler – the diffusion equilibrium in thin-films (DET) device. The DGT device comprises a gel-layer incorporating a binding agent (which acts as a solute sink) and a hydrated acrylamide diffusion gel separating it from the water column. This creates a diffusion layer of well-defined thickness.

Passive integrative mercury sampler. Attempts have been made to use the passive integrative mercury sampler (PIMS), originally designed for air sampling, to sample neutral

Hg species in water. The device comprises lay-flat LDPE tubing containing a reagent mixture of nitric acid and gold stock solution.

Chemcatcher (inorganic version). An alternative configuration of the Chemcatcher has been developed for the separation of metals. The device comprises a commercially available 47 mm diameter chelating extraction disk as receiving phase and a cellulose acetate diffusion-limiting membrane. The sampler has been used to monitor Cd, Cu, Ni, Pb and Zn, in various aquatic environments, such as a storm-water pond, where the uptake of metals was compared with flow-weighted bottle samples.

Uses

Chemical monitoring: Currently available passive sampling devices are applicable to monitoring chemicals with a broad range of physicochemical properties and the detection limits obtained or the lowest measured concentrations suggest that passive samplers may find application in monitoring programmes.

Contaminant speciation: Speciation of environmental contaminants includes not only physicochemical speciation of the forms in which analytes are present in the sampled matrix (e.g., freely dissolved, colloidal and particle-bound forms), but also chemical speciation (e.g., the valency state of metals in the sampled water). Trace metals are present in water in various forms (hydrated ions, and inorganic and organic complexes) together with species associated with heterogeneous colloidal dispersions. The particulate phase also contains elements in a range of chemical associations, from weak adsorption to binding in the mineral matrix. These species coexist, although they may not necessarily be in thermodynamic equilibrium. The difficulty in differentiating the various forms arises from the low levels present in natural waters. The fractionation of species is recognised as an essential step in assessing bioavailability and toxicity in water. A problem is that solution equilibria may change after sample collection through adsorption or desorption of analytes to particulate and colloidal surfaces.

Passive samplers can be applied to characterise the distribution of organic contaminants between particulate, dissolved and colloidal phases in the water column. The selectivity of devices may be adjusted to sample a desired fraction of an analyte present by choosing membrane materials with desired properties (e.g., pore size and charge on the surface). Most passive samplers collect only the truly dissolved fraction of chemicals, since the truly dissolved molecules become separated from colloids and particles during their diffusion across the membrane that separates water from the receiving phase; and, only dissolved molecules are sorbed by the receiving phase

Passive samplers have been used to gain understanding of the species of metals in the aquatic environment. Speciation of metals with the DGT device relies on two effects: the relative difference in diffusion coefficients; and, the relative difference in affinity to the binding agent between the species to be characterized. It is possible to differentiate between inorganic labile species and organic labile species by employing a systematic variation of diffusion gel pore sizes, resulting in a size-discriminating uptake in a similar fashion to voltammetry. However, diffusion coefficients of the model species have to be determined individually to make accurate measurements of the concentration of the labile species

Quantification of concentrations in water. Passive sampling methods can be used to calculate the concentrations of compounds in the aqueous phase. However, it is important to recognise that, in most cases, the aqueous concentration estimated using passive samplers reflects only the truly dissolved contaminant fraction and is not necessarily equal to the concentration measured in spot samples, particularly in very hydrophobic compounds in the

presence of elevated levels of dissolved organic matter. Nevertheless, the comparison is possible, if all species and fractions of contaminants present in the sampled matrix are characterized. In many aquatic systems, contaminant concentrations are not constant, but fluctuate or occur in the form of unpredictable pulses. Concentrations reflected by integrative passive samplers are TWAs over the exposure period, but more research is needed to quantitate the uptake in passive samplers in scenarios involving pulsed and discontinuous exposure. Such research will provide sufficient evidence of realistic concentration estimates using passive samplers and convince the regulators of the application of passive samplers in monitoring programmes.

Estimate of organism exposure. Biomimetic equilibrium sampling approaches using SPME and Empore disks can mimic partitioning of contaminants between the pore water and the organism. Both approaches assume that the freely dissolved contaminant concentrations will represent bioavailability. However, for substances that may be biotransformed in the organism, the methods will overestimate the concentration in the organism. For organisms that have several routes of uptake (in addition to via the water phase), the biomimetic method will underestimate the concentration in the organisms.

Bioassays. The pre-concentrated extracts obtained from the elution of receiving phases of passive samplers (particularly those used to measure organic pollutants) can subsequently be combined with a variety of bioassay procedures to assess both the level and the biological effects of water contaminants. In some in vitro bioassays used to assess the health of an ecosystem, problems can occur due to the difficulty of obtaining suitable water samples for testing. For example, most hydrophobic organic contaminants are present in aquatic environment only at trace levels (i.e., $<1 \text{ } \mu\text{g/L}$). The extraction of several litres of water would be required to yield sufficient amounts of analyte for subsequent bioassay. The use of “bio-mimetically” separated extracts from passive samplers can overcome this problem. It has been shown that the baseline toxicity of chemicals can be predicted (based on total body residue estimates) from the concentration of contaminants separated by passive samplers.

3.6. Instrumentation of EWS monitoring stations

The implementation of the “Preinstalled host” principle allows establishing a large number of monitoring stations procuring relatively few, expensive instruments/sensors/probes. During the implementation process, the instruments (sensors, probes, complete measurement devices or analysers), by a determined installation program, can easily be installed or relocated (quickly and with limited cost) – scheduled or in rotation, in extreme situations or catastrophe – from one monitoring station (or from a central warehouse) to the target monitoring point.

It makes it possible that in the typical monitoring points to be designated in the water catchment area only devices should be installed that are suitable for detecting basic indicator parameters being in the narrow focus of EWS. Applying the LEGO and Rack principles ensures the flexibility and economical operation of the system.

- mobile measuring containers can simply be fitted to the prepared infrastructural elements (e.g. cementing, water sampling)
- using the standardized adapters to be made, the new instruments or the instruments designed for different tasks (replacement) can simply be installed into the containers or they can be separated with the help of the prepared unified mounting and connection interfaces (water in- and outlet, power supply)
- the SW interface can be parameterized to manage the changes of measurement system elements
- the user interface can be parameterized (e.g. setting the warning limit value connected to the monitoring point)
- on-the-spot test and self-diagnosis can be carried out

If needed, the stations can be equipped with accessory equipment necessary for analysis, and the obtained data can be integrated, (GPS, time can be matched)

- measuring water level,
- measuring current,
- precipitate sensor.

3.7. EWS monitoring information

Designating places and establishing the network may ensure detailed information of appropriate quality about the state of surface waters. Data series obtained at a relatively low cost and additional information may contribute directly and indirectly to working out action plans aiming to ensure good ecological and chemical state of surface waters.

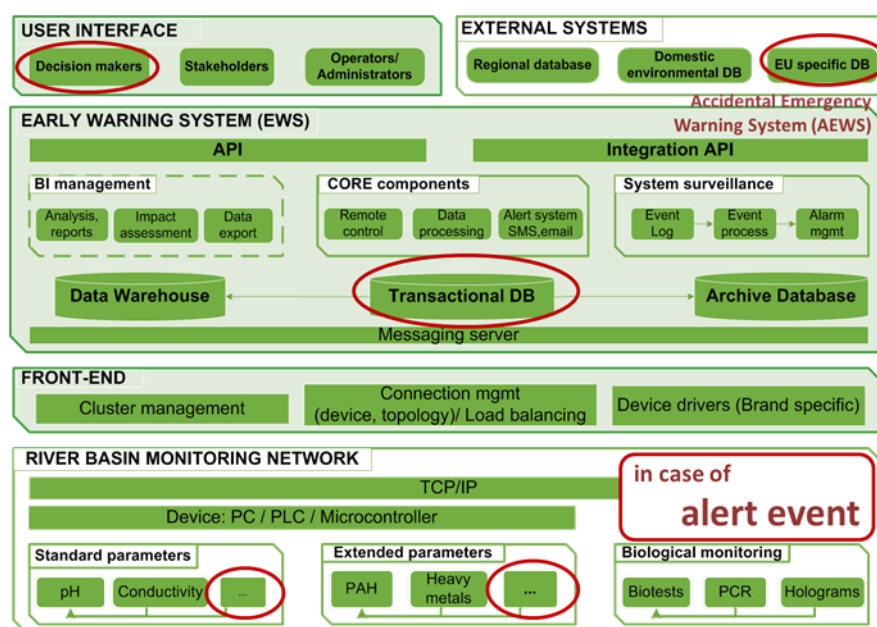
Information obtained from various monitoring points, directly (raw data) or in processed form (aggregate, periodical average, etc.), typically as real-time data can be shared at several levels for the stake holders designated within a particular country or in the affected countries. Interoperability and appropriate data processing and interpretation cooperation of different systems can also be ensured.

Filtering device failure, measurement procedure error, erroneous/faulty data and false alarm as well as detecting the cause of error, identifying it with the help of the remote monitoring system and its central trouble shooting are also needed to be solved.

3.8. Procedure model (working out scenarios)

- Scenario is prepared automatically
- Warning procedure (e-mail, SMS). Responsible persons receiving the warning are assigned, and higher management initiates measure procedures.
- Integration into international warning systems:
 - PIAC, Principal Industrial Alarm Center,
 - AEWS, Accidental Catastrophe Warning System
- Complementary data (e.g. weather, precipitation) and their integration into the system plays an important role because if precipitation is expected, the location where the leaching of intensive pollution is calculable can be indicated in advance (e.g. stopping sampling can be signalled)

If relocation is needed, the related procedure is also worked out.



55. Figure: Logical architecture of Early Warning System

4. Calculation of investment and operational costs for the monitoring system to be developed

4.1. Project costs: investment and operation

Looking at the monitoring system to be developed and the various stations from the point of view of investment and operation costs, a few significant statements must be done, typically concerning these systems. Both the investment (CApital EXpenditure CAPEX) and operating cost (OPeration EXpenditure - OPEX) and their high or low values can seemingly be combined independently from each other.

Due to the scale of the project, keeping the investment (C) and maintenance and operating (O) costs at a low level is out of question as an implementation alternative, because neither the technology, nor the safe operation of the system developed using low capital cost will meet the demand expected from a system to be developed.

The monitoring technology to be developed does not require high costs in both expense categories at the same time; in contrast to the systems which are typically operating and process control systems requiring large infrastructure and resources and carrying and bearing high risks, with considerable expert team in the background.

We do not regard the above-mentioned two extreme combinations applicable for the specified task even in the early phase of planning, therefore, we have different ideas about financing.

Keeping the capital cost (C) at a low level while planning higher operating cost (O) is typical of experimental systems operable in short term and becoming outdated quickly, thus choosing it is not favourable for monitoring.

The best solution for developing a monitoring system is to invest upon starting the project a higher amount (C) into more expensive material, hardware and software building a robust system, and then operate the system using a lower budget (O), in accordance with the "Install and forget it" philosophy, with little human resources and maintenance demand, which usually works well in practice with robust and durable systems working in long term. This is our basic concept in designing the system.

The system to be developed consists mainly of sensor elements, intelligent data collector, evaluating electronics and radiofrequency communication units. Since monitoring stations in a catchment area may be far from each other, the devices are equipped with radiofrequency transmission considerably reducing the number of locally installed devices and installation costs thereby. Apart from the technical requirements of the system, price of devices can also be determined which must be reduced to a level which is competitive with the costs of fieldwork laboratory tests.

4.2. Portfolio cost estimation of EWS monitoring system

Characteristics:

- Monitoring system (fixed installation) installed on well-defined sampling sites (monitoring points)
- Suitable for: minor streams, rivers, lakes and reservoirs.
- The water output and flow profile influence the placement of various elements (electrodes measuring physical parameters and current meter) in the water body.

4.2.1. Large container (Mobile monitoring laboratory)

Standard (ISO) size container capable of sampling/measuring, collecting and processing data, in the length of 20 or 40 feet depending on the level of installation.

An advantage is that transporting standard-size containers is a technology applicable almost all over the world. It is advisable installing it on a place where it should work in long-term providing data. The advantage of the size is that a bigger quantity of instruments and reagents can be used, and systems (thermal insulation, power supply, thermometer regulation) improving safe operation can easily be mounted in the container. A disadvantage is the higher transportation-installation cost and higher operating cost.

I. The sampling system includes: pump, refrigerated samplers, heating coil

II. Measuring general physical parameters: temperature, pH, conductivity, dissolved oxygen, turbidity sensor

III. Installing different types of analysers: TOC, COD, ammonium, nitrate, nitrite, orthophosphate, heavy metal analyser, Robot Analyser (RWA)

The maintenance and operating cost of the system specifiable by demands must be taken into account, e.g. calibration and maintenance of analysers.

Price depending on level of installation: 23,5 – 51 kEUR

(13.9 kEUR basic price/measurement container, or 18,3 kEUR/brick building with interior and 9.6 – 37.1 kEUR equipment).

Average cost ratio: 30 % instrument and material cost, and 35 % installation cost.

4.2.2. Mobile monitoring container/station

The aim is that it is easy and fast to transport anywhere, that is, it should fit on the platform of a 4WD pick-up van, two persons can move it manually and the integrated or attached energy supply (e.g. battery, solar cells) can provide power to the measuring system. It can continuously provide fresh water samples for the measuring devices, it is placed directly into the water body.

Standard installation:

- pH, temperature, conductivity, dissolved oxygen, turbidity probe and current sensor).

Optional devices:

- Flow rate, UV spectrophotometer (measuring nitrate, chemical oxygen demand)
- UV fluorescent probe (chlorophyll-a, determining PAH concentration)
- Ion-selective electrode (chloride, ammonia)
- Automatic Refrigerated Samplers (storing water samples if further analysis is needed)

The integrated industrial computer unit ensures remote communication with the system, (remote monitoring, remote control, measure result validation, warning management: SMS, e-mail). In case of an emergency (catastrophe) it can function as a central unit.

Systems improving safe operation (thermal insulation, power supply, thermal regulation) can also be installed accepting some compromise.

Price depending on level of installation: 16,7 – 33,5 kEUR

(7,9 kEUR basic price and 8,8 – 25,6 kEUR installation).

Average cost ratio: 30 % instruments and material cost and 35 % installation cost.

4.2.3. Micro container

The aim is to obtain information about the water quality of the largest possible catchment area. The system is installed in net-like form and we take into account the various pollution sources. The micro container has the basic functions of the mobile monitoring container. It conducts measurements, collects and sends results and gives warning if limit values are exceeded.

Due to its small size, sensors with low energy demand are applied so that the largest possible number of measurements can be applied. Batteries and solar cells are planned as energy sources.

The micro container can be extended to maximum 3 parameters but the selected components are pollution indicators, e.g. using ion-selective electrode – chloride, ammonium concentration.

Though the installed sensors are less sensitive, they are suitable as pre-signalling systems for signalling pollution waves.

Price depending on level of installation: 11,3 – 27,9 kEUR

(7,9 kEUR basic price and 3,4 – 20 kEUR installation).

Average cost ratio: 30 % instrument and material cost, ill. 35 % installation cost.

4.2.4. Autonomous water quality monitoring buoy - multiparameter

A floating monitoring system installed at a well-defined sampling place (specified point). Suitable for: rivers or lakes. It is suitable for taking sample from different depths (taking layering profile)

After installation the water quality monitoring buoy is capable of continuously and autonomously monitoring the particular water body. Energy supply is provided by batteries and solar cells.

Through GPRS connection the buoy sends the values measured at specific intervals to the central EWS monitoring system. Upon warning event (exceeding limit value, unauthorized intervention, considerable relocation compared to GPS coordinates) it sends SMS to the predefined telephone numbers.

Using the integrated sensors, it is suitable for measuring the following parameters:

- Planned standard measurement parameters: water temperature, pH, redox potential, conductivity, salinity, turbidity, dissolved oxygen.
- Planned complex measurement parameters: chlorophyll-a, PAH, COD, nitrate, nitrite and, if needed, parameters measured by ion-selective electrode.

Price depending on level of installation: 9,7 – 26,3 kEUR

(6,3 kEUR basic price and 3,4 - 20 kEUR installation).

Average cost ratio: 30 % instrument and material cost, and 35 % installation cost.

4.2.5. Standard buoy

A simplified and with some compromise a considerably cheaper version of multiparameter buoy. It has basic buoy functions. It cannot be installed as an autonomous unit only in network in lakes and reservoirs. According to our plans, just like the method well-

known in computer technology, it is expandable by slots and parts are replaceable, that is, cheaper but replaceable sensors will be built in it. Thus, always the required parameters can be measured, for example, dissolved oxygen, oxygen saturation, temperature, chlorophyll-a, and as a result, users can get more information by changing sensors periodically.

Price depending on level of installation: 3,2 – 5 kEUR (3,2 kEUR basic price and 3,4 - 20 kEUR installation).

Average cost ratio: 30 % instrument and material cost and 35 % installation cost.

4.3. Recommended implementation life-cycle of EWS monitoring network

According to our recommendation based on our previous experience, the EWS monitoring system would be advisable to be implemented in 4 stages. The individual stages can be controlled, that is, their duration is calculable, thus visible results can be demonstrated in a relatively short time, and their budget is also clearly defined, so they are projects with relatively little risk. The budget of the first 3 stages was calculated with the rule of ten multiplier, whereas with duration, double multiplier was used.

Recommended stages:

1. Detailed feasibility study

- Comparison of regulations of countries in the Tisza River Basin (classification, limit values)
- recommendation for the infrastructure installation and indicator list of parameters connected with determining the monitoring sites in the total River Basin
- installation plan and itemized budget calculation by monitoring sites
- working out CookBook in detail.

Estimated budget: 84.000 EUR

Project duration: 9 months (2014)

2. The pilot project to be implemented in the Tisza HU-SK River Basin

- determining the unified monitoring system characteristics worked out by taking national regulations and features into account, laying down rules
- fixed and (re)installed (by schedule) mobile monitoring stations prepared for 20-25 monitoring points,
- individual instrumentation fitted to polluting sources
- testing novel, innovative, sensor-based instruments
- using mounted, dismounted or relocated devices
- implementation of parameterizably configurable control SW
- installation of up-to-date communication infrastructure
- using central, multilevel database layer (load distributor, raw database, data warehouse)
- establishing user, information, notification and warning interface
- high-priority management of mobile remote monitoring elements (smart mobile tablet/phone) both centrally and locally in the field
- involving the affected local/regional and central authorities and supervisory organizations of the two countries
- developing the related database communication channels

- warning system simulation
- trial operation for six months
- recording experience, feedback
- project dissemination.

Estimated budget: 840.000 EUR

20 pcs x 27 kEUR/pcs = 540 kEUR monitoring stations

5 pcs x 5 kEUR/pcs = 25 kEUR preparation of the
monitoring stations

34 kEUR material cost

134 kEUR ICT development cost

107 kEUR implementation cost.

Project duration: 18 months (2014 - 2015)

3. Developing the basic EWS infrastructure covering the total River Basin of Tisza

- adapting pilot project stages
- fixed and (re)installed (by schedule) mobile monitoring stations prepared for 100 or installed for 50 monitoring stations
- test operation of new, recently developed, novel and innovative measurement devices with low maintenance cost
- trial operation for a year
- recording experience, feedback
- project dissemination.

Estimated budget: 8.400.000 EUR

Project duration: 36 months (2016 – 2018)

4. Establishing multiparameter, complex EWS monitoring system covering the total Tisza River Basin.

- expanding basic EWS infrastructure
- fixed and (re)installed (by schedule) multiparameter mobile monitoring station prepared or installed for 150 monitoring points
- test operation of new, recently developed, novel and innovative measurement devices with low maintenance cost
- trial operation for six months
- recording experience, feedback
- project dissemination.

Estimated budget: 4.200.000 EUR

Project duration: 12 months (2019)