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Monitoring of Surface Water Status in the Lower Danube Basin

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Abstract

Water pollution demands emergency actions for better water resource management to respect the concept of sustainable development. The aim of the Water Framework Directive, as long-term water policy of the European Union, is to assure the good quality of surface waters. Each state from Europe has to identify all the river basins lying within their national territory and to assign them to individual river basin districts. In this respect, an effective integrated system and monitoring technology, analysing, interpreting data and utilizing the results to make decisions related to the water resources protection, were developed. The main objectives are focused on the expansion of monitoring activities and obtaining more detailed information on the state of surface waters. Specific recommended equipment which enables to perform the analysis of recommended water quality parameters should be placed on the monitoring stations of the Lower Danube Basin. Respectively, this lack of equipment provides a challenge in the development of effective methodologies for collection and analysis of water quality data. The main priority was the development of an integrated water catchment area management strategy and to build up the online continuous monitoring system. Some of the technical goals for continuous water monitoring were reached in Hungary and Romania and are presented here.

Keywords: surface water monitoring, water quality, early water system, water management

1. Introduction

The main objective of humanity is to find solution for environmental issues especially the ones related to water pollution which demands emergency actions for a sustainable development of the society. Protection and management of water resources are the key elements of sustainable development. The Water Framework Directive (WFD 2000/60/EC) was created as the long-term water policy of the European Union (EU) [1]. The aim of the WFD is that the quality of surface waters achieve good ecological and chemical status by 2015 (2021, 2027). All countries from Danube riverbanks should have an inventory of all the river basins lying within their national territory and should assign them to individual river basin districts.

The most international river basin in the world is the Danube River Basin which covers more than 800,000 km² and covers 10% of European territory including 19 countries. The Danube River is divided into three 'reaches'. The Upper Danube stretches from the Danube's source in Germany to the 'Porta Hungarica' east of Vienna. The middle Danube then flows until the dam namely 'Portile de Fier' (Iron Gates) in Romania. The Lower Danube then runs into the Black Sea. Taking into consideration the huge dimensions of the Danube catchment area and the number of the countries with different specific conditions, transboundary river basin management requires a special attention [2–4]. In 1994, the Danube River Protection Convention was signed by the main stakeholder countries from the region with the goal to enhance transboundary cooperation to protect the river and its basin. The EU and 14 countries from the Danube Basin are contracting parties of the International Commission for the Danube River (ICPDR). The Commission works to manage the waters of the Danube Basin sustainably [2]. The preparation of the Danube River Basin District Management Plan (DRBMP) was the most important task in the implementation of the Water Framework Directive [4]. To reach the set goals, the first DRBMP was prepared in 2009, and it is reviewed every 6 years. The first review was made in 2015, when activities were investigated which had negative effects on the quality of Danube Basin waters, and the Commission also evaluated the current status of water bodies and the effects of interventions. Based on the results, Danube countries have prepared action plans together to be implemented in the upcoming period. The examination of important pressures in the Danube River Basin (DRB) is the crucial elements of the plan. In this respect, the development of an effective integrated system consisting of monitoring technology, data analysis, interpretation and result utilization system is essential to make decisions to protect water resources. Nowadays, due to the advanced progress of science and technology, new measurement and communication techniques were developed, leading to real-time decision-making tools. In this chapter, our attention is focused especially on the aspects related to integrated river basin monitoring. The main objectives are focused on the expansion of monitoring activities and obtaining more detailed information on the status of surface water [2].

1.1. Danube River Basin status-monitoring process

The main hazards to water quality in the Danube River Basin are the following: nutrient pollution, hazardous substances, hydro-morphological alterations and organic pollution.

There are many anthropogenic sources which affect the water quality of the Danube catchment area [4]. Overlooking the state of waters, economical water utilization analysis, monitoring system planning and designation and joint program measures were all planned, so that the objectives of the Water Framework Directive could be reached [4]. Monitoring programmes provide appropriate information about the status of the Danube Basin; the subprogrammes are in harmony with the implementation schedule of the WFD. The goal of the TransNational Monitoring Network (TNMN) system is to provide a comprehensive picture about pollution events, the long-term changes in water quality, and main pollution loads of the Danube basin. It provides the comparability of data, that is, uniformity of data acquisition and exchange. Every year TNMN prepares an annual report from the measurement data of national laboratories, which include sampling location, measurement parameter list and the processing of measurement results. The requirements of the WFD have to be met both by the Danube River Protection Convention and the TNMN (revised) surface water surveillance monitoring programmes. Meanwhile, Joint Danube Survey (JDS) contains investigative monitoring results.

Investigative monitoring is mainly a national task, but to fulfil the goals of the basin level, JDS was established, which is repeated every 6 years. Surveys performed by JDS in 2001, 2007 and 2013 gave a snapshot from the whole length of the Danube and the significant tributaries. The goal of the JDS is to fill missing information from the monitoring networks of the Danube River Basin, to harmonize monitoring methods already used, to evaluate the effects of novel chemical compounds or elements in various matrices and to test new devices and methods. JDS programmes enhance the reliability of data and information provided by the TNMN system.

1.1.1. TransNational Monitoring Network

The TNMN of the ICPDR monitors water quality of the Danube River Basin regularly. The TNMN is able to act as the basis of an integrated water quality measurement network in the whole catchment, and it not only provides data of water quality and pollution trends but also helps in harmonizing water quality assessment and evaluation methods in the affected area. The laboratories in the network are allowed to use analytical methods of their choice as long as these meet certain pre-agreed criteria, and enable the analysis of physical-chemical quality elements and priority substances. A system-wide quality control programme (performed yearly) was established to ensure that data have high quality across the basin. Data are stored in a database established by ICPDR. National laboratories provide data to information managers, who collect, check and convert the data into a data exchange file format (DEFF file), which are then sent to the data centre for final checking and processing. When the ICPDR gives its approval, these data are sent to the website of the project [4]. Measurement points for water quality assessment within the TNMN are presented in **Figure 1** [5]. Shown in **Figure 1**, there are 114 surveillance monitoring stations, where water quality components are analysed and 12 measurements per year are reported in TNMN yearbook [6].

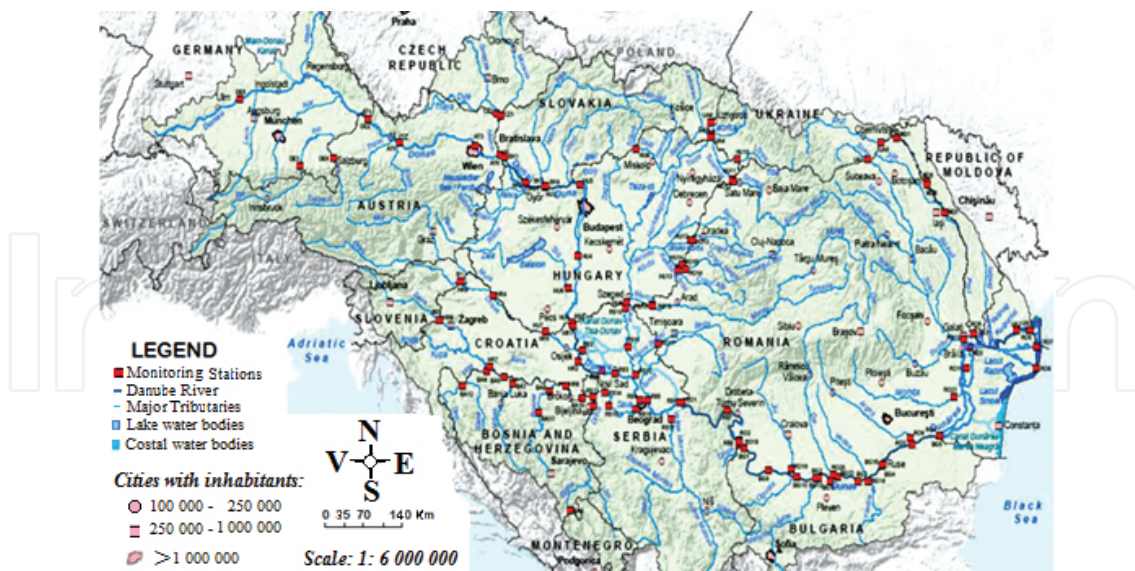


Figure 1. The map of surveillance monitoring stations in the Danube Basin (TNMN) (adapted from [6]).

1.1.2. Joint Danube Survey

Annual water quality evaluation has been complemented by JDSs to provide a picture of the ecological status of the Danube. They obtain biological and microbiological, chemical, hydro-morphological and toxicological data. They are the world's largest river research expedition, with the goal to give comprehensive and reliable data and information from the whole length of the Danube and its several tributaries, about both water quality and causes of pollution. The other tasks of JDS are to provide information about parameters which are not present in the continuous monitoring plan, to help the work of ICPDR and to call attention to water quality management. The first Joint Danube Survey was in 2001. A total of 140 various parameters (chemical, biological, microbiological) were measured on the entire length of the river, thereby providing a considerable amount of data [3, 4]. The survey is supposed to be repeated every 6 years, thus another snapshot was made in 2007 and 2013 about the status of the Danube and its tributaries. The surveys have shown that the quality of water in the Danube River Basin show an improving tendency, but it showed also that special problems have to be tackled at several tributaries and near large cities in the lower section. JDS improves available databases, and thus helps evaluation of water quality [3].

1.2. Water quality of Danube River Basin

TNMN, which gives national data, and the three JDS surveys provide information for the status assessment of the Danube River Basin. The upstream water pollution has negative consequences on the downstream protected areas, especially on the Danube Delta Nature Reservation. At the same time, riparian localities that use water from the Danube for anthropic activities are influenced. Around 65% of the whole length of the Danube is at risk of nutrient pollution, this makes it a challenge which needs urgent attention, especially, that it connects freshwater and marine habitats. The development of novel solutions and nutrient management strategies

are needed to reduce the N and P content of the DRB [7]. Agglomeration, agriculture and industry are the main sources of nutrients. There are two kinds of pollution sources: diffuse and point sources.

The measurement results of TNMN between 2001 and 2009, and the JDS1 (2001) and JDS2 (2007) results were processed from the viewpoint of nutrient pollution [8]. The measured parameters are N-ammonium, N-nitrite, N-nitrate, P-orthophosphate and two total forms total nitrogen and total phosphorous, and all of them show that there is an improving tendency of nutrient load.

Regular laboratory measurements taken in the TNMN system show larger concentration values than JDS expedition measurement results. From the evaluation of the TNMN between the 2001 and 2009 timeframe, it can be seen that there is a minimal decrease in the concentrations nearing the lower river section, but in the Lower Danube section itself in the case of $\text{NO}_3\text{-N}$ and $\text{PO}_4\text{-P}$ concentrations there is a more frequent occurrence of extreme values [8]. From the evaluations prepared by Hamcevic et al, 2015, it can be also seen that there are more extreme values in the Lower Danube region, meaning that local effects are more extreme. This highlights the importance of continuous monitoring and its *raison d'être*. Urban, municipal and industrial run-off can contain heavy metals, which cause harm to water ecosystems when their concentration becomes larger than the tolerance limits [9]. A number of surface water bodies in the Danube River Basin District have not reached good chemical quality status (2013/39/EU), as they were heavily affected by priority substances (heavy metals, pesticides, industrial pollutants, other pollutants). The goal of heavy metal monitoring is to measure its effect on the Danube Delta. The 2008/105/EC directive prescribes concentration limit values for 33 priority and 8 other pollutants. The modifying directive 2013/39/EU broadened the list with 12 new substances. On the Danube and its tributaries in respect of Annual Average Environmental Quality Standards (AA-EQS) and Maximum Allowable Concentration Environmental Quality Standards (MAC-EQS), the critical pollutants are cadmium, mercury, lead and copper [9]. From the analysis prepared by Mr. László Ferenc, 2015, it can be seen that in the timeframe of 2008–2011, dissolved cadmium load decreased, while dissolved lead, mercury and copper load increased. From the viewpoint of heavy metals, tributaries have significant loads. Tributaries are the most affected from the viewpoint of heavy metals (e.g. tributaries: cadmium, 33; lead, 25; mercury, 33; and nickel, 15) [4], so they do not accomplish the goals set by WFD.

These surveys support future strategies and the elaboration of action plans, and they also help in the selection of location and measured indicator parameters of continuous monitoring systems.

1.3. Some aspects concerning the progress of transboundary monitoring in the Tisa Basin

It is known that the basin of the Tisa River brings a high hydrological contribution to the water balance of the Danube Basin. However, special attention is needed on the Tisa Basin due to the environmental issues associated with the pollution generated by accidents within the mining industrial areas located in the basin. In this way, it was necessary to prepare a strategy for the management of the emergent problems related to transboundary pollution accidents.

This strategy envisaged to set up the measures for the elimination or diminishing of dangerous substances, in line with the overall trend of the environmental issue and of European legislation, based on a variety of approaches correlating with the different particular cases. Therefore, in the European Member States, the Integrated Pollution Prevention and Control Directive (IPPC) and the Dangerous Substances Directive were implemented. Other directives such as the Urban Wastewater Treatment Directive and other environmental management tools, such as the Best Available Techniques (BAT) for industrial sectors and Best Environmental Practices for Agriculture, played an essential role in the diminishing of environmental impact of hazardous substances in the Tisa River Basin [10, 11].

1.4. The Danube Accident Emergency Water System

In the frame of the International Commission for the Protection of the Danube River (ICPDR), some measures for accident prevention have been considered for the Danube and Tisa countries. The Danube Accident Emergency Water System (DAEWS), which during transboundary pollution accidents is able to alert stakeholder countries, was also established by the ICPDR.

Particularly, decision-making tools are very useful for a better management of surface waters, including the Danube Basin, where an Accident Emergency Warning System (AEWS) was implemented. This AEWS represents a mode of putting in practice the decisions from the Helsinki Transboundary Convention of 1992 and the Sofia International Danube Protection Convention of 1994 [5].

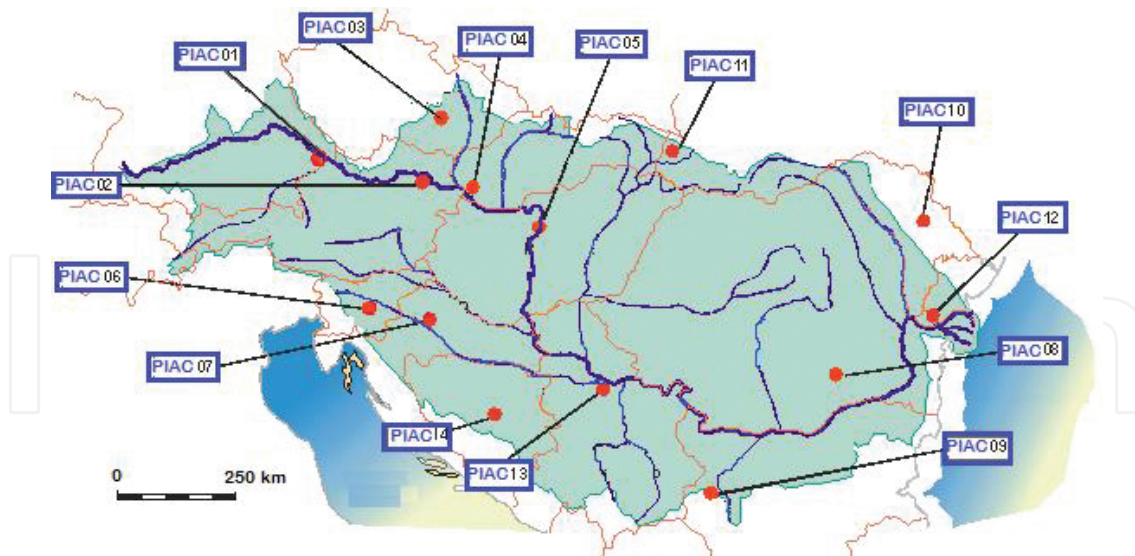


Figure 2. Implementation of the Accident Emergency Warning System (AEWS) within the Danube River Basin adapted from [12].

When a risk of transboundary water pollution is detected by the AEWS, a warning message is transmitted to the countries belonging to the affected river, via through a Principal International Alert Center (PIAC) located in each country (see **Figure 2**). These structures play an

important role in the decision process concerning the action measures for public protection. PIAC includes a non-stop communication unit for warning messages, an expert unit for impact assessment and a decision making to determine a situation for which an international warning should be launched [12].

This system will make timely and effective damage prevention and mitigation possible, which can be the results of transboundary pollution disasters, for which we have seen examples in the last two decades [4].

1.5. Areas of use of real-time preventive water monitoring systems

The most important tool of water quality protection and quick detection of pollutants is the periodical measurement or monitoring of water pollutant concentration. Because of this the laboratories of national authorities perform national and international, so-called, cross-border water quality measurements. These information are used in the preparation of annual TNMN reports, also, countries prepare their water management plans based on data provided by the authorities. Based on the applied long-term and expedition-like monitoring activities, we think that the currently available equipment park and informatics services make it possible to apply a real-time preventive warning monitoring system on the Danube Basin. There are operating automatic water quality monitoring stations on the Danube water basin, but in this chapter, we show you a cost-effective method with a modular solution, which can be used effectively

- in the areas where based on the results of traditional monitoring, there is a large number of extreme results
- in areas where actions are implemented, to check the results of the action
- at critical emission locations (ARS points)
- on tributaries.

The forecasting monitoring system which we introduce here is suitable for the prompt detection of pollutants, and for alarm duties, as it is operating continuously, as only real-time monitoring can ensure forecasting and detection of pollutants.

The methodology of such a cost-effective system was elaborated for the largest tributary of the Danube, the Tisza [11]. The adaptation and application of the forecasting continuous early warning-monitoring system in the Lower Danube region could influence effectively the improvement of the quality of the Black Sea, the reduction of eutrophication by timely interventions.

2. Water-monitoring network methodology

In the Lower Danube Basin, the main priority is to build a water quality network system of water catchments areas, which involves specific analytical equipments designed for water quality parameters selected for each particular station. The following aspects should be considered to support the above-mentioned objectives:

- Most important background information of the catchment area. Description of river basin (or catchment area)
- Application of adequate international standard methods
- Assessment of existing monitoring systems
- WFD typology of water bodies (high-, mid-, lowland altitude)
- Identification of pollution sources (hot spots; diffuse sources)
- Determination of pollutants (physical-chemical, biological parameters)
- State of tributaries
- Assignment of sampling sites and water sampling methods
- Power supply/power consumption
- Optimization of operational and maintenance cost.

The Early Warning System (EWS) is a key tool in surface water management, with a different mechanism. Overall, the two components—early warning function and effect-based monitoring of water analysis—form a cost-effective integrated system, which could perform sampling, analysis and toxicity testing of surface waters [11].

It should be noted that EWS contributes to the evaluation of different scenarios and to solving specific issues. To assure accurate analysis of the scenarios, the elements of the EWS should be in conformity with European regulations. Compatibility between the elements of the EWS, including information systems and databases from each country should be assured when considering implementation and information communication within EU countries.

Implementing the EWS on the Lower Danube water basin substitutes the lack in the monitoring system of surface water bodies, as related to the following aspects [11]:

- Limited timelines and insufficient frequency for realistic evaluation of the quality progress of water streams.
- Lack in appropriate details regarding the water quality parameters for pollutant modelling.

2.1. Special installation aspect

When installing an EWS, several aspects should be taken into consideration [11]. Special installation aspects: overall, two objectives are envisaged when the online monitoring station is installed on a water body. One objective is the monitoring of water surface quality according to the WFD (measurement locations are set in the national monitoring network), while the other objective is to provide early warning of accidental pollution (e.g. early detection of pollutant generated by different types of pollution sources).

Particular installation aspects: In the case of online monitoring systems used for early warning detection, there are several recommendations:

- The early warning detection system has to be near the potential polluting sources, which allows rapid detection of pollution phenomena.
- Installation of such systems should allow sampling from low water levels; in the same time, the measuring systems should be anchored against high water flows and floods; for the systems that are located on the riverside, it is necessary to provide the feeding systems with technological water for analysis purposes. In these cases, specific sampling pumps with autonomous power supply (not connected to the electricity network) should be considered. Long sampling lines should be avoided, as the dwelling time of the sample within the pipe should not be more than 10–20 s. For this reason, sampling pipes shorter than 30–50 m are usually recommended.
- Generally speaking, the installation layout should ensure easy access to the system to perform regular maintenance. In the case of floating systems, these should be easily accessible by boats.
- Power supply should be provided from different sources, for example, electrical networks, solar cells, batteries etc. When a source is not available, it could be replaced by another one.
- In terms of communication technology for sending measurement data, several alternatives can be considered: GSM signals, telephone line, WIFI, etc. Data are collected and processed via a server that is connected to the Internet, being accessible by a user having necessary access rights.
- Moreover, the system should be equipped with specific defence elements against any sabotage act, such as alarms, camera connected to the Internet, etc. For example, the changes in the Global Positioning System (GPS) coordinates of the floating unit or in the integrity structure can trigger sound effects or SMS alarms.

2.2. Determination of the measuring parameters

Determination of the measuring parameters at the sampling site should be performed by taking into consideration the following aspects [11]:

- The measurement range, the type and concentration of the pollutant. In contrast to predictable scenarios, in the case of complex environments with frequent changes in the different parameters due to the pollution phenomena, measurement of conductivity (or of other easily measureable parameters) for process monitoring is often recommended, due to its simplicity.
- The potential polluting sources of the water catchment area are also important in establishing the measuring parameters. For example, the measurement of pH only, instead of both chemical oxygen demand (COD) and pH could be performed in the waters with low pH, such as those associated with whey pollution emitted from a cheese factory, due to low pH. The change in the pH could indicate the presence of pollution.
- When several methods are available for a measured parameter, a low-cost alternative should be considered, even if there is a loss of accuracy. This is the case, for example, when we

compare a chemical analyser versus a standard method. In some cases, there are non-standard methods that could perform better for online measurement because of easy maintenance, low operating costs and simple design, but at the cost of a weaker correlation with the laboratory results. For example, when measuring COD with standard dichromate method, the results are closer to laboratory results than in the case of using UV absorption. However, the investment and operating costs associated with the use of UV absorption are lower than in the case of the analyser working with the dichromate method. In addition, the measurement frequency can increase from one measurement per hour of the dichromate method to one measurement per minute in the other case, at a similar accuracy.

- Measuring summarized parameters (TOC: total organic carbon; COD: chemical oxygen demand; BOI: biological oxygen demand; TN: total nitrogen; TP: total phosphorous; PAH: polyaromatic hydrocarbon; phenol index) or online measurement of toxicity appears to be essential in the case of early warning detection systems.
- Also, all automatic water samplers should be integrated for better diagnosis of the pollution.

Modular expandable systems are currently being proposed for use at particular sites, where specific parameters have to be monitored. Appropriate integration of different units (including those related to different manufacturers) is supposed to increase the efficiency of the overall monitoring system. For different devices, suitable connection systems should be provided. Also, the system should be modular, so when a device needs replacement, the spare item should be easily placed into the unified signalling system, precalibrated in line with metrological standards. Several more aspects are presented in literature data in Water Quality Early Warning System on Transboundary Watercourses of Tisza River Basin, 2014 [11].

3. Monitoring of water quality aspects

Online water analysis advantages:

- Indication of short-term and long-term changes in water quality as a basis for water management measures
- Early detection of incidents and illegal discharges
- Assessment of hazard potential arising from discharges
- Clues to identity of water pollution offenders
- Sampling platform
- Prevention: continuous monitoring of water bodies has a deterrent effect that helps prevent illegal discharges or other water pollution
- Continuous data collection for decision making
- Others: for example, verification of success of water conservation measures.

A new analytical monitoring concept is required, as at a single point, pollution peaks can usually be detected for 0.5–2 h, some of which occur at night and in the weekend. Therefore measurement intervals should be on an hourly basis if possible, operating 24/7.

The main priority is to develop integrated water catchment area management plans, and to establish the network of online continuous monitoring system of the water catchment area. Online monitoring systems indicate long and short-term changes of water quality parameters, the data obtained this way can be used to establish a basis for water management measures and activities.

3.1. Water quality parameters (WFD)

To determine the parameters which should be measured by the online monitoring stations to be installed on surface waters the Water Framework Directive should be referred to [1]. Based on an ecological approach, the Water Framework Directive divides hydro-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 reduction of dangerous substances from point sources can basically be achieved by regulatory actions. The 2008/105/EC directive [13] contained environmental quality regulations and water pollution immission limits. This was modified by the 2013/39/EU directive, in respect to priority substances (12 new substances in the list).

The parameters characterizing the chemical status of the water body are divided into three main groups, according to **Table 1**.

General physical-chemical parameters	Nutrition indicators	Priority hazardous substances (by “33+8” list and the list of “other hazardous substances”)
Water temperature, pH, electrical conductivity, dissolved oxygen, total suspended solids, COD _p , COD _k , TOC, BOD ₅ , total dissolved solid (TDS), total water hardness, dissolved iron, dissolved manganese, calcium, magnesium, sodium, potassium, alkalinity, chlorine, sulphate	Ammonium, nitrate, total nitrogen, orthophosphate, total phosphorus, chlorophyll-a	<p>“33” list organic:</p> <p>Polyaromatic hydrocarbon (PAH) compounds: naphthalene, anthracene, fluoranthene(VI), 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</p> <p>“Other hazardous substances” organic:</p> <p>DDT compounds, aldrin, dieldrin, carbon-tetrachloride, tetrachloro-ethylene</p> <p>“33” list (heavy metals): cadmium, lead, mercury, nickel</p> <p>“Other hazardous materials” (heavy metals): total chrome, arsenic, zinc, copper</p>

Table 1. The parameters characterizing the chemical status of the water body [1, 13, 23].

These essential quality parameters for water pollution assessment are used in different ways. It is imposing that in all of the cases the set value is lower than the limited values specified in environmental legislation in each country in strong correlation with the European legislation [14]. In order to have a better evaluation, the usage of a global water quality index should be taken into consideration according to literature data [15]. The methodology for determining these water quality parameters is also presented in detail in technical literature, but some particular achievements of authors, with application in the water quality monitoring will be presented in the following paragraphs.


4. Overview of applicable low cost surface water monitoring technology and methodology

The range of devices suitable for continuous on-line monitoring, which are shown in this chapter were developed in Hungary and utilized on the stream Veszprémi-Séd in 2013, and the river Ipel in 2015. The development of a heavy metal monitoring device has taken place in Romania, which was used for quality measurements on the Bahlui River. By unifying these systems and connecting them to expert systems on national levels an effective water management system could be established on the Lower Danube Basin.

The versatile character of the mobile water quality station is accomplished by the modular structure of the station, being designed to work in extreme weather conditions. Further requirements for the monitoring stations without human intervention are related to continuously and reliably ensuring the operation of equipment, the maintenance of devices and the optimal consumption of reagents. The initial investment costs are moderate, but the operating and maintenance costs are significant. The station can be moved easily, and therefore, it can be relocated within hours if necessary. It allows operation for long periods, with low maintenance and in isolated places.

4.1. Types of monitoring stations and signals for EWS systems

In **Table 2** are presented the most recommended types of monitoring stations [11].

Type of monitoring station	Measureable parameters	Technical characteristics
Multi-parameter system built in buoy 	Multi-parameters selected from the following: water temperature, pH, redox-potential, conductivity, DO, turbidity, chlorophyll-a, blue algae, SAC254, PAH, parameters measureable with ion-selective electrodes (ammonium, chloride, nitrate)	Energy supply: solar cell and battery. Sensors with low energy demand

Type of monitoring station	Measureable parameters	Technical characteristics
Simple multi-parameter measurement system built in device case installed on the riverbank	Water temperature, pH, redox-potential, conductivity, DO, turbidity, chlorophyll-a, blue algae, SAC254, PAH, oil pollution, parameters measureable with ion-selective electrodes	Energy supply: solar cell and battery. Central unit with the measurement system installed on buoy. An automatic sampler with low energy demand is considered
Measurement system installed into small-sized mobile container	Water temperature, pH, redox potential, conductivity, dissolved oxygen, turbidity, chlorophyll-a, blue algae, SAC254, PAH, oil pollution, parameters measureable with ion-selective electrodes	Energy supply: solar cell and battery. Versatile system, which can be easily relocated to critical locations, according to the necessity. Central unit with the measurement system installed on buoy. An automatic sampler with low energy demand is considered
Complex measurement system installed into a brick building or large container	Water temperature, pH, redox potential, conductivity, dissolved oxygen, turbidity, chlorophyll-a, blue algae, SAC254, PAH, oil pollution, parameters measureable with ion-selective electrodes Complex measurements carried out by chemical analysers: TOC, COD, toxicity, heavy metal analyser, online gas-chromatograph, special analysers suitable for measuring individual parameters	Higher energy demand than the above ones. Energy supply by electric power supply connected to the following electricity sources: solar cells with large solar panels and fuel cell Complex measurement system installed into a brick building or large container. The connection of pure technological water may also be necessary
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	

Table 2. The recommended types of monitoring stations.

The advances of flow techniques for analysis of persistent pollutants (organic pollutants as pesticide, drugs, dyes, etc. or inorganic pollutants as heavy metal ions) from surface waters [16] are presented in detail in a book chapter, vol. 3, edited by C. Zaharia.

A more comprehensive presentation about organic pollutant detection using flow injection analysis techniques could be found in our review [17]. Also, for total content of organic (measured as COD by flow analysis with chemiluminescence detection), a new pulsed xenon flash lamp photoreactor was developed together with Warmya and Mazurya University from Olsztyn, Poland [18].

For detection of heavy metal ions, new electrochemical sensors were developed according to our review [19]. Among the electrochemical techniques, potentiometry and voltammetry are the most suitable for monitoring of heavy metal ions in surface waters. Therefore, special solid-contact ion-selective electrode for copper(II) detection in water samples were developed as potentiometric sensors, together with the University of Barcelona, Spain [20]. Among the monitored heavy metals, mercury plays an important role due to its toxicity, bioaccumulation and hard biodegradability. The methodologies for mercury analyses in water samples are complex, need expensive equipment and require qualified operators. Taking into consideration all the above aspects, our attention was focused on a voltammetric technique suitable for mercury detection and quantification of their concentration in water samples involving the experiences of our colleagues from the oldest university in Iasi and in Romania [21].

The signal types for EWS systems are presented in **Table 3**.

Water quality signals	Signals concerning the measurement system	Safety signals	False alarm
- 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)	- 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	- Signal for opening door - Signal for changing GPS coordinates - Signal for power supply problems	- Operating problem (contamination of probe-head sensor, blocking of sampling tube, failure of measurement system)

Table 3. Signal types for EWS systems [11].

4.2. Methodology for EWS

When considering the equipment and technology from different countries, EWS approach could be changed according to several aspects such as [11]:

- Automated simulation of different pollution scenarios. Different kinds of warning procedures, including SMS, e-mails, etc. and different responsibility levels; the person in charge will receive warning messages to perform the corresponding management tasks according to the procedure.
- Integration of each national EWS within international warning systems:
- Existence of some alarm centres as Principal Industrial Alarm Centre (PIAC) and Accident Emergency Water System (AEWS).
- Complementary data (e.g. weather, precipitation) and their integration into the system are necessary when precipitation is expected; also the pollution front could be estimated according to the distance of the location from the pollution source.

The Early Warning System has user friendly features, and its logical structure is presented in **Figure 3**.

The development of an expert system for monitoring of surface water in the *Lower Danube Basin* was an imperative for a better management of water resources, taking into account the higher degree of pollution in this area, which was caused by the anthropogenic activities (industry and agriculture) from the riverine countries. Therefore, the specialists from the Technical University of Iasi (Romania), Technical University of Chisinau (Republic of Moldova) and University of Pannonia from Veszprém (Hungary) brought their contribution to the development of such an advanced monitoring expert system [22].

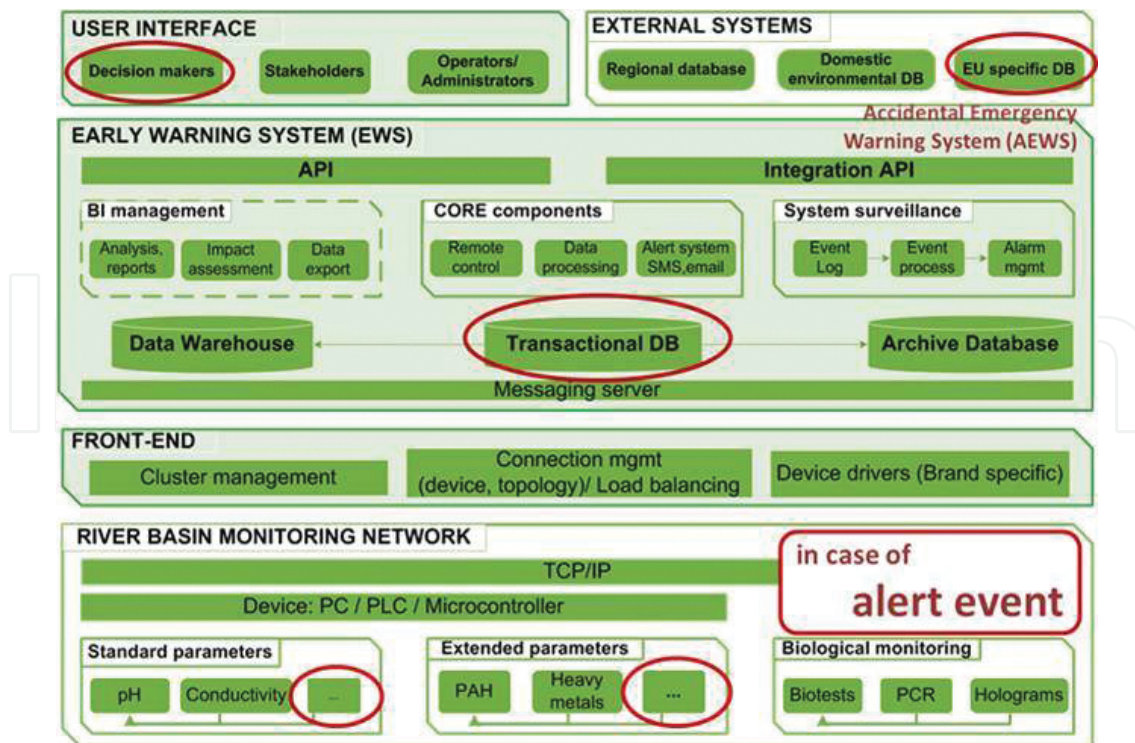


Figure 3. Logical architecture of Early Warning System [11].

5. Conclusion

According to the objective stipulated in the Water Framework Directive (WFD), good chemical and ecological status/or potential has to be ensured and achieved for all surface water bodies. Monitoring results serve the validation of the pressure analysis. An overview of the impacts on water status is required to initiate measures. In this context, the issues addressed in this manuscript could be of real interest for specialists. Implementing the Early Warning System (EWS) on the Lower Danube water basin would significantly improve our abilities to detect any kind of accidents related to surface water bodies.

In the 'Overview of applicable low cost surface water monitoring technology and monitoring methodology' section, some technical achievements for continuous water monitoring made in Hungary (mobile water quality stations, water monitoring buoy, robotic analyser ship, continuous monitoring and EWS methodology) and Romania (flow techniques for analysis of persistent pollutants and water quality expert system) are described. Also, some aspects concerning the development of a monitoring expert system designed for the surface waters in the context of sustainable management of water resources in Romania, Hungary and Moldavia are welcome in order to assure the complementarity with above mentioned technical achievements. Harmonizing these systems ensure the adaptation on the Lower Danube Basin. Moreover, in the previous papers of the authors, more details on the monitoring of water quality and the dispersion of common pollutants are presented; finally, the evolution of water quality indicators is predicted by using mathematical models.

In the light of WFD, the specialists from Technical University of Iasi (Romania), Technical University of Chisinau (Republic of Moldavia) and University of Pannonia from Veszprém (Hungary) brought their contribution to the development of an expert system for monitoring of surface water in the context of sustainable management of water resources in the *Lower Danube Basin*.

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