

Chapter 15

Water Quality of the Lower Drava River



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Abstract The tendencies of change in river water quality are difficult to establish since the evaluation systems has changed on several occasions in the past decades. At present, according to the comprehensive assessment system of the EU Water Framework Directive (WFD), on the upper and middle sections (in Austria and Slovenia), the Drava has good and the Mura somewhat worse water quality. In 2010, a campaign found the Croatian section of the Drava River in excellent condition based on the Water Quality Index. Regular data collection on water quality of the Hungarian Drava section began in the 1960s at three sampling sites (Órtilos, Barcs and Drávaszabolcs) and soon continued in international cooperation with Yugoslavian authorities. The monitoring and evaluation systems changed in 1981 and again in 1994. In 2001, an automatic Drava Monitor Station (DAM) began to operate at Barcs and complex (hydromorphological, physico-chemical, biological, and biochemical) monitoring according to the WFD guidelines was introduced. The influence of tributaries on the quality of the Drava water is represented on a map series. A case study illustrates the water quality problems of oxbow lakes in the Drava floodplain.

Keywords Water quality monitoring · Chemical status · Research history
National standards · Water Framework Directive

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15.1 Introduction

Water pollution disturbs the natural renewal of water resources. Since the 1950s diffuse contamination of agricultural origin (from wastes, fertilizers and pesticides—Novotny 2005) in Hungary has reached the same dimensions as point-source pollution (HAS 2017). For instance, two-thirds of diffuse phosphorus load comes from soil erosion (both agricultural and natural) and the rest from municipal wastewater treatment plants. Sampling campaigns measuring pesticides in Hungarian surface waters including streams, rivers and lakes have also been performed (e.g. Maloschik et al. 2007).

The pressures are manifested in water quality regularly monitored on the Drava since the 1960s (Dolgosné Kovács 2008). The comparability of data is made difficult by the fact that in the meantime the official system of assessment has changed on several occasions (Kovács 2002). In 1994 the Hungarian Standard 12749 (Surface water quality, quality indicators and assessment), based on chemical indices and less concerned with biological and ecological conditions, was introduced. After Hungary's accession to the European Union the EU Water Framework Directive (WFD—EC 2000) has been followed. In addition to chemical status, the WFD assesses ecological conditions and is meant to ensure sustainable water use. Instead of point sampling, it strives to collect information on entire water bodies within the framework of river basin management plans.

15.2 Water Quality of the Upper and Middle Drava

Naturally, the water quality of Hungarian rivers strongly depends on the quality of river inflow into Hungary, a country in the centre of the Carpathian Basin. Since the adoption of the EU WFD, which allows comprehensive ecological assessment, it is easier to compare the status of water bodies in the member countries of the European Union, including those in the upper Drava catchment.

In *Austria* river water quality is assessed by the Federal Office for Environment (Umweltbundesamt) in six-year cycles (Bundesministerium 2006). Temporal trends can be reconstructed from the previous cycle, the years 2007, 2010 and 2013 (Bundesministerium 2015). Although there are no fixed quality classes, for the Drava and Mura rivers the chemical parameters (monitored on a yearly basis) show good status (Table 15.1). The hydromorphological characteristics, however, did not present an improvement for 40% of Austrian rivers by the end of the cycle in 2013.

In *Slovenia*, the Environmental Agency of the Republic of Slovenia is responsible for water quality monitoring and evaluation of water quality status (Urbanič 2011). Monitoring programmes are designed in accordance with European directives and include assessment and pressure analysis for each individual water body (rivers, lakes, sea, groundwater and water bodies in protected areas—ARSO 2008). Priority substances were monitored monthly, while nationally relevant substances

Table 15.1 Chemical status of the Drava and Mura Rivers in Austria, 2013 (Bundesministerium 2015)

<i>River</i>	<i>Monitoring Site</i>	<i>Metals</i>	<i>Organic solvent</i>	<i>PAHs</i>	<i>Pesticide</i>	<i>AOX</i>	<i>Other</i>
Drava	Lavamünd	good	good	good	good	good	good
Drava	Rosegger Schleife	good	good	good	good	good	good
Mura	Leoben	good	good	good	good	moderate	good
Mura	Kalsdorf	good	good	good	good	moderate	good
Mura	Spielfeld	good	good	good	good	poor	moderate

	poor chemical status	AOX, Adsorbable Organic Halogens
	moderate chemical status	PAH, Polycyclic Aromatic Hydrocarbons
	good chemical status	in sed.: upward trend in sediment
	very good chemical status	FS, phenol substances
	the monitoring site was not included in the monitoring programme	

four times a year. The findings show that the water quality of the Mura and Drava meets the standards proposed by the European Commission and they are in good chemical status (Table 15.1), but some parameter values are worse than in Austria (Table 15.2).

Surface waters are monitored by the Hydrometeorological Institute at more than 100 sampling sites along the main rivers. The main parameters which indicate pollution are dissolved oxygen, chemical oxygen demand (COD), biochemical oxygen demand (BOD), phenols, nitrogen compounds, detergents, formaldehyde and mineral oil. Surface water quality is referred into four classes: Class I can be

Table 15.2 Chemical status of the Mura and Drava Rivers in Slovenia, 2002–2006 (after ARSO 2008) (for legend see Table 15.1)

<i>River</i>	<i>Monitoring site</i>	2002	2003	2004	2005	2006
Mura	Ceršak	AOX	Cd in sed.	good	AOX	AOX
Mura	Petanjci	good	good	good	good	good
Mura	Mota	good	good	AOX	AOX, FS	AOX
Drava	Dravograd	good	good	good	good	good
Drava	Brezno	good	good	good	good	n.a.
Drava	Mariborski otok	good	good	good	good	good
Drava	Duplek	good	good	good	good	n.a.
Drava	Ptuj	good	good	n.a.	n.a.	n.a.
Drava	Borl	good	good	good	good	n.a.
Drava	Ormož	Hg, Cd in sed.	Hg in sed.	good	good	good

used as drinking water; Class II water needs pre-treatment before used as drinking water; Class III includes water polluted with degradable compounds from domestic sewage, which does not necessarily preclude its use in agriculture or as industrial cooling water; Class IV is polluted water not suitable for any direct use.

The monitoring of groundwater quality is carried out by the Hydrometeorological Institute of the Slovenian Republic. Along the Mura and Drava, agricultural activities directly influence water quality. NO_3 concentrations are between 31 and 242 mg L^{-1} , and some pesticides also exceed EU drinking water standards. Potassium and zinc concentrations are increasing along the Drava.

In 2010, an investigation using the Water Quality Index (CCME 2001), calculated from a mathematical formula, found the *Croatian* section of the Drava River in excellent condition (Tomas et al. 2013). In the Water Quality Index six main parameters (pH, dissolved oxygen, biochemical oxygen demand, nitrate, total nitrogen and total phosphorus) are combined. Sampling was conducted mainly in the Croatian-Hungarian border at seven monitoring sites.

The Croatian surface water regulations identify five quality classes depending on the usage of water (Gvozdić et al. 2011). Their goal is to achieve that the Drava River should remain in Class II on the long run. This means that after purification river water can be used as either drinking or industrial water. Authors emphasize that for the consideration of water quality of the Drava River the largest tributary, the Mura, which is classified as Class IV exerts a huge effect on the Drava.

According to the most recent data, the physico-chemical properties of the Drava in Croatia were invariably in the 'very good' category in 2012 (Table 15.3—Republika Hrvatska 2013).

Table 15.3 Physico-chemical properties of the Drava River in Croatia, 2012. *Source* Republika Hrvatska (2013)

Monitoring site (Drava)	Chemical and physico-chemical properties									
	Conductivity	Alkalinity	pH	dissolved oxygen	COD	BOD	NH_4^+	NO_3^-	N	P
Donji Miholjac	very good	very good	very good	very good	very good	very good	very good	very good	very good	good
Belišće	very good	very good	very good	very good	very good	very good	very good	very good	very good	good
upstream Osijek	very good	very good	very good	very good	very good	very good	very good	very good	very good	good
before the Danube	very good	very good	very good	very good	very good	very good	very good	very good	very good	good
boundary profile	very good	very good	very good	very good	very good	very good	very good	moderate	very good	good

15.3 History of Water Quality Research in Hungary

15.3.1 Water Quality Assessment Before 2000

In Hungary, water pollution was first prohibited in a government decree of 1952. In 1963, an observation network was established by the National Water Management Directorate (OVF 1965) and in 1965 regional water quality planning started in the most polluted regions. Water quality was primarily studied from the aspect of public health. The assessment for the Drava in 1960 was based on oxygen budget and coli number and claimed that the Drava water had a low sodium concentration; bacteriologically it was slightly polluted, but after proper treatment and disinfection suitable for drinking water or utilization in food industry, bathing and water sports (OVF 1965).

The basic network of sampling (of constant components and with defined frequency) was established in 1968 (Katona 1984). Sites for weekly sampling for the Drava were appointed at Órtilos, Barcs and Drávaszabolcs (Fig. 15.1). (In 1982 sampling at Órtilos was stopped, but resumed in 1994.) From 1990 heavy metal content was also measured in every three month by the South Transdanubian Environmental Protection Directorate. Although Kiss (1974) described the Pécsi-víz stream as the most polluted in the catchment, he claimed that the Pécsi-víz and Fekete-víz streams only have a minimal influence, but the Mura River, under serious pressure upstream, has a serious impact on the water quality of the Drava. Uherkovich (1974) proposed an evaluation system which, along with physical and chemical techniques, also uses hydrological methods to describe water contamination. The international coordination of measurements became necessary and



Fig. 15.1 Sampling sites on the Hungarian Drava section 1, sampling sites

between 1966 and 1977, Croatia and Hungary conducted analysis separately four times a year at the Letenye–Goričan road bridge on the Mura and at the Drávaszabolcs–Donji Miholjac road bridge on the Drava (Stundl 1976). The findings were jointly evaluated twice a year. However, biological properties (such saprobity index available since 1970) were not included in water quality assessment yet. Between 1978 and 1989 sampling frequency was raised to 10 occasions per year at the same locations and once a year joint sampling was also performed.

In 1981, a new system was introduced with a reduced number of sampling sites (from 300 to 120) in Hungary but with increased frequency. Criticizing the system, Katona (1982) claimed that the assessment of natural waters only shows the conditions during the sampling period. To follow the changes in quality tendency and

Table 15.4 Parameters to measure (after Hungarian Standard 12749, by Dolgosné Kovács 1993)

<i>Water quality properties</i>	
Group A: oxygen properties	
Dissolved oxygen; Oxygen saturation; Biological Oxygen Demand (BOD ₅); Chemical Oxygen Demand (COD _{ps}), (COD _k); Total Organic Carbon (TOC); Saprobity (Pantle-Buck) index	
Group B: nitrogen and phosphorus properties	
Ammonium-nitrogen (NH ₄ -N); Nitrite-nitrogen (NO ₂ -N); Nitrate-nitrogen (NO ₃ -N); Organic nitrogen; Total phosphorus, Orthophosphate-phosphorus (PO ₄ -P); a-chlorophyll	
Group C: microbiological properties	
Coliform number per 1 ml; Fecal coliform number in 1 ml; Fecal streptococcus in 1 ml; Salmonella in 1 L; Colony count at 37 °C; Colony count at 22 °C	
Group D: micropollutants and toxicity	Group D ₁ : inorganic micropollutants
	Group D ₂ : organic micropollutants
	Group D ₃ : toxicity
	Group D ₄ : radioactive material
Aluminum; Arsenic; Boron; Cyanide; Zinc; Mercury; Cadmium; Chromium; Chromium (VI); Nickel; Lead; Copper	
Phenols; Detergents (anion active, non-ionic); Hydrocarbon derivatives (mineral oil and its products, PAHs, benzo(a)pyrene); Volatile chlorinated hydrocarbons (chloroform, carbon-tetrachloride, trichloroethylene, tetrachloroethylene); Pesticides; PCB; PCP	
Daphnia test; Seedling plant test; Static fish test	
Total β-activity; Cesium ¹³⁷ ; Strontium ⁹⁰ ; Tritium	
Group E: other properties	
pH; Specific conductivity (20 °C); Iron; Manganese	
Water temperature; Air temperature; Total suspended matter; Turbidity; Alkalinity; Hardness; Sodium; Potassium; Calcium; Magnesium; Carbonate; Bicarbonate; Sulphate, Chloride	
Colour; Odour; Transparence	

pollution load tests should be made. In international comparison, Hungary has the least strict duration values (80%). Somlyódi et al. (1990) suggested that it should be raised to 95%.

In 1979, heavy metal measurements began and in 1986 became regular. Total nitrogen and phosphorus were also covered. Because of political issues, measurements were only performed on the Hungarian side between 1989 and 1992. Biological parameters (like Liebmann's saprobity system) were also included in water quality assessment in 1994, when the Hungarian Standard 12749 (1993) came into force (see below). In 1992, joint sampling resumed and in 1995, a joint Hungarian-Croatian committee was formed and confirmed the protocols of analyses. Organic micro-pollutants, residues, and hydrobiological data were collected 36 times a year (Table 15.4). In the case of river sediments chemical tests, organic micro-pollutants, residuals were studied with variable sample numbers. For the Drava oxbows and five major gravel pits chemical and hydrobiological tests were carried out. From 2000, the studied parameters were extended to additional biological properties. In 2001, an automatic Drava Monitor Station (DAM) began to operate at Barcs, which measures chemical and hydrometeorological parameters (Kovács 2002; Dolgosné Kovács 2003).

15.4 Assessment According to the Water Framework Directive

In the EU member countries water management has been basically transformed after the adoption of the European Water Framework Directive (WFD, Directive 2000/60/EC) (Urbanic 2011). The most important change is that the emphasis placed on the ecological status of waterbodies. Previously, physico-chemical properties were the main basis of determining water quality, supplemented with only a few biological parameters. Since plant and animal communities respond sensitively to the change of main aquatic components, the focus on ecological status results in a more complex and reliable overall picture of river water quality.

After Hungary's accession to the European Union, the WFD (EC 2000) was introduced in Hungary too. The WFD ensured the protection of all kinds of water bodies with the purpose to reach a 'good state' for them by 2015. It is nature-oriented and ecologically based. Another important difference from the system previously applied in Hungary (based on Hungarian Standard 12749) is that the entire water body should be monitored for water quality instead of defining the status at individual monitoring sites (Dworak et al. 2005; Allan et al. 2006).

In order to establish the ecological status of waters, the definition of biological, hydromorphological, physico-chemical and biochemical parameters (Table 15.5) is necessary in five quality classes. Considering the ecological state, the worst biological and physico-chemical values have to be taken into account as an essential determinant of water quality. The determination of chemical status is based on

Table 15.5 Components of the chemical assessment of surface waters according to the WFD (EC 2000)

	Conditions	Parameters
Physico-chemical properties	Thermal	Temperature
	Oxygen balance	Dissolved oxygen
	Salinity	Conductivity
	Acidity	pH, alkalinity
	Nutrients	Total P, ORP, total N, nitrate and nitrite, ammonium
	Clarity	Secchi disk depth, turbidity, colour (for lakes)
	Other	Suspended matter, turbidity (for rivers)
Specific synthetic pollutants	All substances on the WFD priority list	
	Other substances dependent on the pressures affecting the drainage basin	
Specific non-synthetic substances	All substances on the WFD priority list	
	Other substances dependent on the pressures affecting the drainage basin	

further chemical parameters. In the final assessment, the ‘one bad, all bad’ principle prevails, i.e. the worst condition decides the status of the water body (Szilágyi 2005; Ijjas 2005; Clement 2005).

An important principle of the WFD is that the status of waters should be compared to undisturbed (reference) conditions. The member states should set reference criteria and ecological class limits for each type of surface water and all relevant quality elements. In 2005 16 and in 2006 84 water bodies were studied in the Drava subcatchment of the Danube basin. In 2007 the Integrated Drava Monitoring programme was launched and the use of the Hungarian Standard was officially terminated. However, due to cross-border conventions and the Government Decree 2066/1999 (31 March), at some sampling sites data collection and evaluation on the Drava and its region still has to follow the Hungarian Standard. Moreover, joining the Transnational Monitoring Network (TNMN) at national level resulted in additional tasks in the design of the complex monitoring system.

15.5 Results and Discussion

From the data series of monitoring at three sampling sites (Őrtilos, Barcs and Drávaszabolcs), some trends in the water quality of the Hungarian Drava section can be revealed.

For both dissolved *oxygen* and oxygen saturation favorable results have been detected. Drava water was found ‘excellent’ on the basis of 90% duration from the 1990s (Dolgosné Kovács 2008). The values were not significantly influenced by the tributaries, their different origin, hydromorphology and discharge, reflecting the amount of organic matter in the water, oxygen concentrations were the highest in the 1970s, usually at Órtilos. Until the mid-1980s, based on chemical and biological oxygen demands, the water was only of ‘tolerable’ quality at all three sampling sites. From the 1990s, there was some improvement, but higher organic matter loads were found at Drávaszabolcs, due to the loads arriving with the Fekete-víz Stream and the lowest at Barcs. Apart from the beginning of the study period, the Drava had no direct untreated wastewater inflow from Hungarian territory. The amount of treated sewage was also minimal before its inflow was stopped. The tributaries usually had high organic matter contents which occasionally influenced the samples from the Drava at Barcs and Drávaszabolcs. From 2000, the oxygen balance of water was referred to Class III.

The parameters of *nitrogen* balance in the 1970s showed high pressure for ammonium and nitrogen mostly at Órtilos (Dolgosné Kovács 2008). Water quality from this respect was Class III or IV. Since the 1990s, more severe water pollution in the section of Drávaszabolcs was mainly due to the strongly contaminated Pécsi-víz Stream. Overall, the indicators of nitrogen balance often showed more favorable values for the Drava than for the tributaries.

The poorest *phosphorous* balance values were found at Drávaszabolcs, attributable to contaminants arriving with the Fekete-víz, and at Órtilos, where the upstream Croatian section was polluted at the beginning of the monitored period (Dolgosné Kovács 2008). Based on orthophosphate and phosphorus concentrations, from the mid-1990s water was mostly assessed as ‘good’ at sampling sites. In addition to the tributaries, nutrient balance was also affected by livestock ranches (mostly because of improper straw manure storage and liquid manure use on fields). From 2000 onwards, in terms of nutrient balance the water at the sampling sites was referred to class II or III.

The assessment of physico-chemical properties shows favorable water quality for most of the tributary streams (data extended to represent entire subbasins) of the Hungarian Drava catchment (Fig. 15.2). As far as the chemical status is concerned, ‘poor’ category was only recorded for the Pécsi-víz unit (Fig. 15.3). (It has to be noted that only 69% of the water bodies were assessed in the Drava catchment for the period 2009–2012, while extensive areas, mainly in Zala County, could not be evaluated.)

Microbiological contamination, mostly due to shortcomings in disinfection at municipal sewage treatment plants, was generally the most favorable at Órtilos and the most unfavorable in the Drávaszabolcs section (Dolgosné Kovács 2008). Outstanding values at Drávaszabolcs indicate fresh fecal contamination (probably

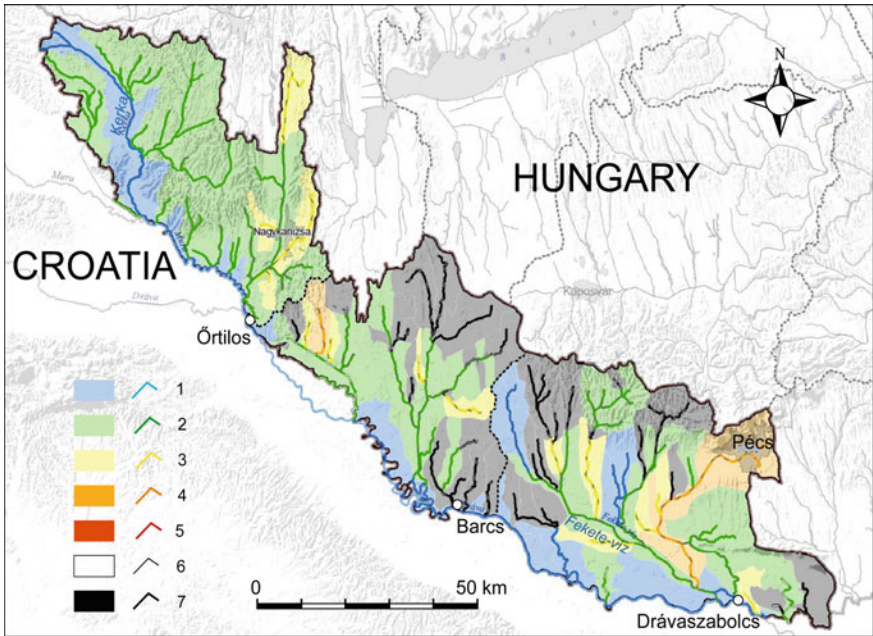


Fig. 15.2 Assessment of physico-chemical status for subbasins. *Source* STWMD (2015). 1, excellent; 2, good; 3, moderate; 4, poor; 5, very poor; 6, not assessed; 7, no data

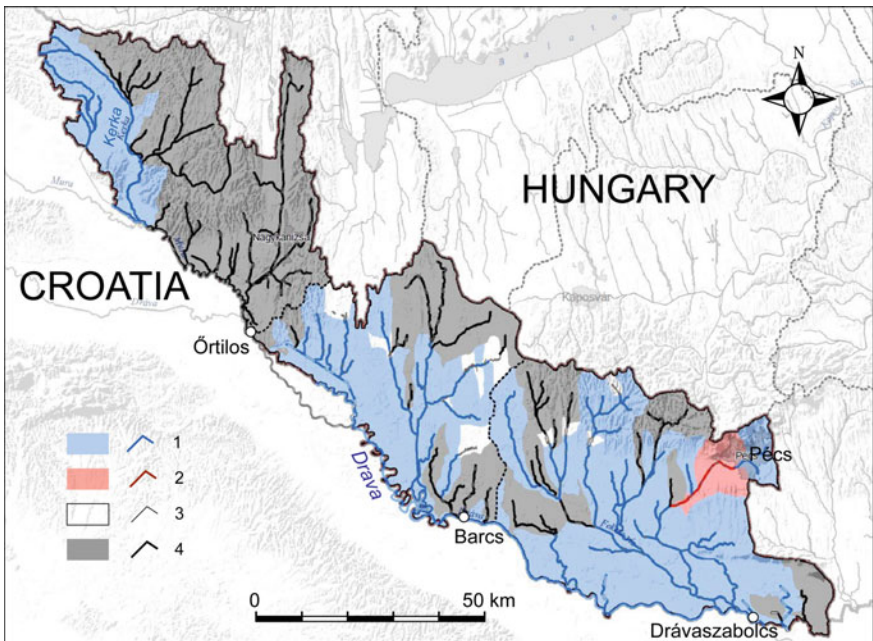


Fig. 15.3 Assessment of the chemical status for subbasins. *Source* STWMD (2015). 1, good; 2, poor; 3, not assessed; 4, no data

again through the Pécsi-víz). From 2000, the microbiological parameters at the sampling points were in Class III–V and Class II–III.

Based on 90% duration values, for *inorganic micro-pollutants* the Drava water was mostly assessed ‘excellent’ and in the case of aluminium ‘good’. Data from Barcs were generally the most favorable. Although somewhat higher values were measured at both Órtilos and Drávaszabolcs, the assessment stayed in the same class. Among *organic micro-pollutants*, crude oil and its products were classifiable in the study period. Until 1996, apart from a few years, the sampling sites were ‘highly contaminated’. At Órtilos pollutants came from outside study area, at Barcs the values are ascribed to hydrocarbon extraction, sediment dredging and renewed shipping (although at low intensity), while at Drávaszabolcs petrol products carried in the Drava by the Fekete-víz also contributed to the results. The values of other parameters show a favorable water quality without negative impacts from tributaries.

Even though the physico-chemical status was mostly ‘excellent’, the ecological assessment presents ‘excellent’ or ‘good’ values only over 6% of the catchment for the same period (Figs. 15.4 and 15.5).

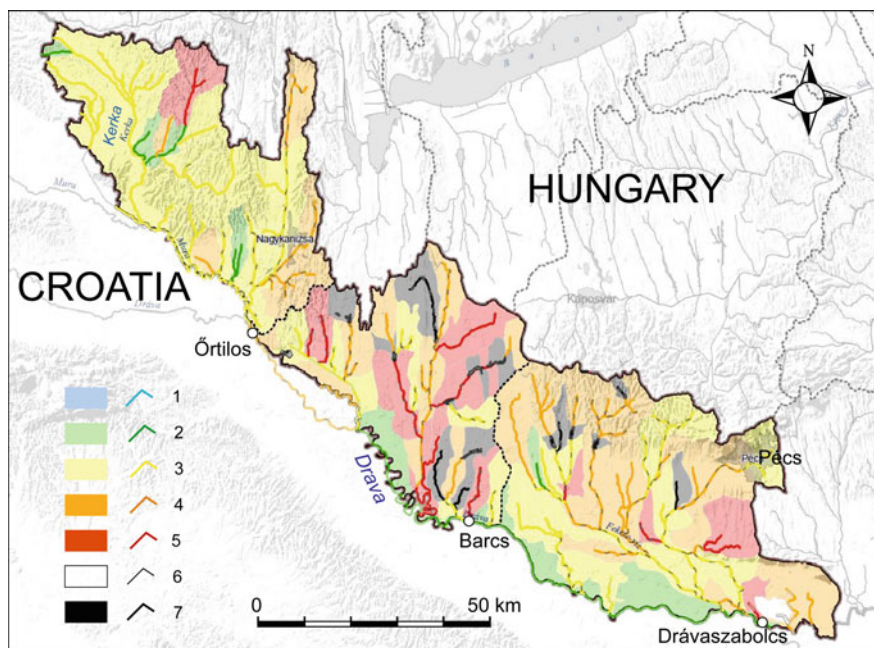


Fig. 15.4 Ecological assessment of surface waters in the Hungarian Drava catchment. For legend see Fig. 5.2. Source STWMD (2015)

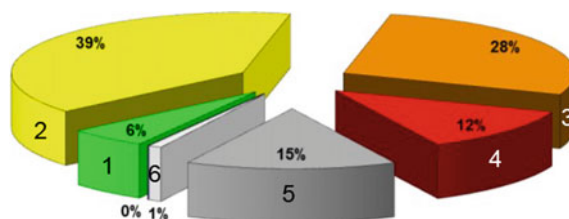


Fig. 15.5 Ecological status of subbasins. For the meaning of colours see Fig. 5.2

Table 15.6 Chemical status of lake Kisinc in 2014 (Tóth et al. 2015)

Monitoring site	Depth	Chemical and physico-chemical properties				
		dissolved oxygen	ammonium	nitrate	COD	phosphate
Kisinc oxbow lake	30 cm	poor	very good	very good	poor	good
	210 cm	poor	moderate	very good	poor	moderate

15.6 Case Study: Water Quality of an Oxbow Lake

After a rainy summer period in 2014, a water sampling campaign was organized at Lake Kisinc, the largest water body of the Cún-Szaporca oxbow (for description see Chap. 12). The aim of the investigation was to discover the daily periodicity in the concentration of chemical substances in the lake. Thus, every hour samples from –30 to –210 cm water depths (30 cm above the surface of lake sediments) were collected. The variable properties such as pH, redox potential, temperature, dissolved oxygen, were measured in the field. Other components like ammonium, nitrate, phosphorus forms (total and ortho-phosphorus) and COD were analyzed in the soil and water laboratory of the Institute of Geography, University of Pécs.

Evaluating the findings, the conclusion can be drawn that most of the chemical parameters do not follow the daily fluctuation of environmental parameters (with the exception of dissolved oxygen in the pondweed, next to the shore). Due the accumulation of organic matter in the sediment, the COD values are extremely high. We believe that after artificial water replenishment, which raised the water level by 1 m, COD values have increased (Table 15.6).

15.7 Conclusions

In the previous assessment systems, the locations, dates and frequency of water quality monitoring was not properly coordinated. Between 1980 and 1994, sampling sites were selected with the purpose of protecting the water quality of the main recipient, the Drava River. On tributaries sampling points were close to

confluences. Therefore, pressures (sources of pollution) upstream could not be precisely located. By the time the monitoring network was built, large-scale contaminations had already affected the rivers. Moreover, water quality modelling lacked hydromorphological parameters, including water discharge, and ecological indicators.

A novelty of the EU WFD is that it purports integrated water basin management in a complex hierarchical system, instead of focusing on individual water bodies. Thus, the water quality of minor streams acquires the same importance as that of big water bodies. This attitude requires a new approach to the allocation of sampling sites too. However, the efficiency and reliability of the new monitoring system can only be judged after the evaluation of 8–10 years of experience.

As far as the current situation is concerned, compared to major rivers in Hungary, like the Danube and the Tisza, our results confirm that at present the Hungarian Drava section is assessed as one of the cleanest water bodies. The reason for the relatively higher concentration of contaminants at the Drávaszabolcs sampling site is the polluting effect of the Fekete-víz stream, which is the recipient of sewage from Pécs through the Pécsi-víz Stream.

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