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# THE ROLE OF THE WATER QUALITY MONITORING NETWORK ON THE UPPER STRETCH OF THE DANUBE RIVER IN HUNGARY

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## ABSTRACT

After more than 25 years of continuous regular monitoring, it became known that the changes in water quality reflect the natural and geo-economic conditions of the Danube watershed. The scientific understanding of the present complicated relationships among the attributes of the water has been facilitated.

In this paper, the state of water quality in the Hungarian upper stretch of the Danube and its tributary waters is introduced. Special attention is paid to environmental factors influencing the productivity of the waters, such as:

- loading of external and internal organic material
- oxygen supply for the river
- elements of nitrogen and phosphorus contents and
- the quality and quantity characteristics of the primary production of micro vegetation, the basis of the food chain.

## INTRODUCTION

### The development of the water quality monitoring network

Individual analytical chemical measurements of surface water quality characteristics have been conducted in Hungary for more than 100 years. The first published water quality data related to the Danube is that of Balló (1875). Today, the results of Lajos Winkler's analytical work of water "Determination of Dissolved Oxygen in Water" are used all over the world.

At the turn of the century and in the first half of this century, such measurements were conducted only periodically and unsystematically. The intensive industrialisation - the increase in water demands and of water pollution - also caused a growth in the need for systematic water quality examinations. However, Hungarian water protection could not catch up to the standards which the Western countries had achieved earlier.

The comprehensive, systematic water quality examinations began in Hungary in 1954 in the Water Management Scientific Research Institute, where the first water quality laboratory was developed for physical, chemical and sapro-biological examinations. Later, the organization of the national water quality laboratory network began in the operation of the Water Conservancy Directorate in 1964.

Accordingly, the basic so-called centralized water quality network developed and has operated since 1968 on 113 rivers in the country (including the upper stretch of the Danube). The measurements include 32 physical, chemical, and biological variables with regular annual frequencies of 12, 26, and 52, respectively. The laboratory measurements were conducted according to internationally accepted methods. The measurement results were evaluated primarily from the standpoint of the most important water use.

In 1983, the number of sampling sites were reduced, the sphere of examined parameters were expanded corresponding to the general enviromental expectations and the information requirements necessary for the description of the hydro-ecological system. The scientifically-founded "integrated water quality requirement system," which simultaneously considers the demands for the quality of consumed water and the stability of the hydro-ecological system, was also introduced.

This water quality system was replaced in 1994 with the introduction of the new national norms, the objective of which are the determination of the state of the water quality from the ecological standpoint. At the 150 sampling sites designated for the nation's surface waters, 12 regional Environmental Protection Authority laboratories conduct water examinations for 80 physical, chemical, biological characteristics with an annual frequency of 12, 26 and 52 respectively.

The water quality data developing in the water quality monitoring network since 1968 is now recorded in a microcomputer data base which is accessible to the users and handled as a public data base. It is used to provide the water quality aspects of the monitoring of waterbird populations in the Danube River (Faragó, this volume).

## METHODS

The data considered are from the Water Quality Monitoring Network and the data of sampling sites of the branches of Danube. The sampling sites of national water quality examinations are:

- Danube: Rajka, 1848 river kilometer (rkm); Medvei bridge 1806 rkm; Komárom 1766 rkm; Dunaalmás 1751 rkm; Esztergom 1717 rkm.
- Tributaries: Mosoni Duna, Győr-Vének 2,4 rkm; Cuhai Bakonyér, Bőnyrétalap 7,0 rkm; Concó, Ács 2.8 rkm; Kühtreiber stream (Általér), Dunaalmás 0,5 rkm; Kenyérmezei stream, Tát-Esztergom bridge 1,4 rkm.

We are presenting data for COD, $DO_2$, N and P forms and chlorophyll-a. These chemical and biological parameters were measured according to Hungarian water quality standards.

## RESULTS AND DISCUSSION

The 2857 km reach of Danube in Hungary is of middle-reach character. The river becomes of middle-reach character approximately 800 km distance from the source, where more and more living organism find favourable conditions not only in the riverbank region, but in the slower flowing main channel as well. In the Danube the plants - primarily the algae in water - form the organic matters of their own bodies form inorganic nutrients dissolved in water with the use of photosynthesis. The quantity of plants are produced as the concentration of the inorganic nutrients and other limiting factors (light, temperature, current, etc.) make it possible.

**Organic matter pollution of Danube and its tributaries**

The organic matter content of the water of Danube which can be measured by chemical oxygen demand (COD) is formed partly by living organisms of microscopic size, partly by dead organic matter as well as floating matter of dead organisms and dissolved organic matter. The organic matter pollution of the Danube varies between 12,9-15,25 COD mg/l at the upper reach of 140 km, subject to the outer (allochton) and inner (autochton) organic matter loading. Due to the increment of the primary production as well as the direct sewage input at riverside, and the polluting material loading from the tributaries which are polluted at a greater extent than the Danube, significant increase of organic material of 18,5 per cent can be detected. **(Figure 1, Table 1)**.

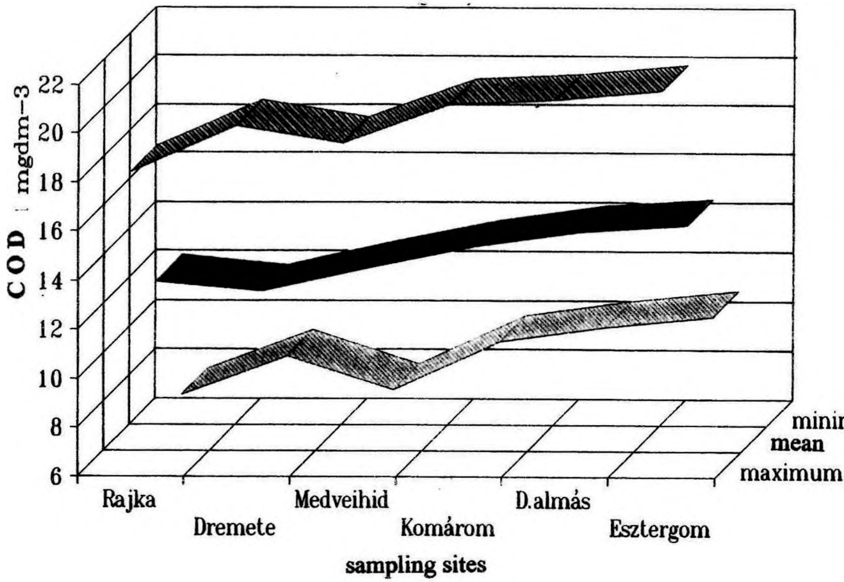


**Figure 1**: Annual, mean, maximum and minimum values of *chemical oxygen demand* (COD) at six sampling locations in the Danube River in Hungary in 1993.

**Table 1**: Selected features of water quality at six sampling locations in the Danube in 1993

| | river km | 1848 Rajka | 1825 Duna-remete | 1806 Medve | 1766 Komárom | 1751 Duna-almás | 1717 Esztergom |
|---|---|---|---|---|---|---|---|
| **COD mg/l** | min. | 7,2 | 8,8 | 7,4 | 9,4 | 10,0 | 10,4 |
| | mean | 12,9 | 12,55 | 13,47 | 14,32 | 14,95 | 15,25 |
| | max. | 18,4 | 20,3 | 19,6 | 21,2 | 21,4 | 21,8 |
| **DO2 mg/l** | min. | 5,84 | 6,16 | 4,61 | 6,25 | 8,16 | 5,97 |
| | mean | 9,40 | 9,32 | 9,36 | 10,31 | 10,27 | 10,45 |
| | max. | 12,48 | 12,72 | 13,16 | 13,20 | 13,60 | 14,24 |
| **Total N mg/l** | min. | 1,87 | 1,18 | 1,57 | 1,38 | 1,39 | 1,56 |
| | mean | 3,39 | 3,03 | 3,24 | 3,11 | 2,90 | 3,06 |
| | max. | 7,57 | 5,76 | 5,49 | 5,21 | 5,46 | 5,11 |
| **Total P mg/l** | min. | 0,06 | 0,09 | 0,09 | 0,09 | 0,09 | 0,09 |
| | mean | 0,16 | 0,16 | 0,16 | 0,16 | 0,15 | 0,18 |
| | max | 0,42 | 0,23 | 0,28 | 0,24 | 0,27 | 0,62 |
| **Chlorophyll-a mg.m-3** | min. | 1,02 | 1,02 | 1,36 | 1,36 | 2,38 | 1,70 |
| | mean | 25,07 | 21,03 | 27,35 | 31,64 | 42,49 | 41,28 |
| | max | 115,93 | 88,29 | 107,4 | 101,3 | 107,99 | 108,27 |
| **n/1993** | | 53 | 34 | 54 | 23 | 22 | 22 |

Among the tributaries Conco Brook which is loaded with agricultural pollutants is the most highly polluted. The water of Kenyérmezei Brook carries the treated sewage of pharmaceutical industry. The change in the organic material content at the mouth section of Általér (Kühtreiber Brook) is affected by the water-discharge of Öregtó in Tata and the treated city sewage. Organic matter content of the water of the Moson Danube is higher than those in the main Danube channel due to the affect of the untreated sewage in Győr (**Table 2**).

The oxygen supply of Danube is satisfactory. The producing and decomposing processes exercise strong influence on the dissolved oxygen content of the water, though the physical affects (temperature, surface diffusion) which are always the primary ones in the Danube. Therefore, the dissolved oxygen content is higher in the winter and lower in the summer. In spring time and early summer supersaturation can be detected more frequently due to the oxygen production of the algal mass. In winter time, oxygen saturation values of less than 75 per cent can be detected due to the oxygen consumption of the decomposing processes. Along the longitudinal section, the maximum and average values of the dissolved oxygen content are increasing, the reason there is the increase of the primary production in the river. The maximum value of dissolved oxygen concentration increased from 12,48 mg/l to

14,28 mg/l **(Figure 2,Table 1)**. The degree of oxygen supply of the polluted tributaries flowing into the Danube shows more extreme fluctuation. **(Table 2.)**

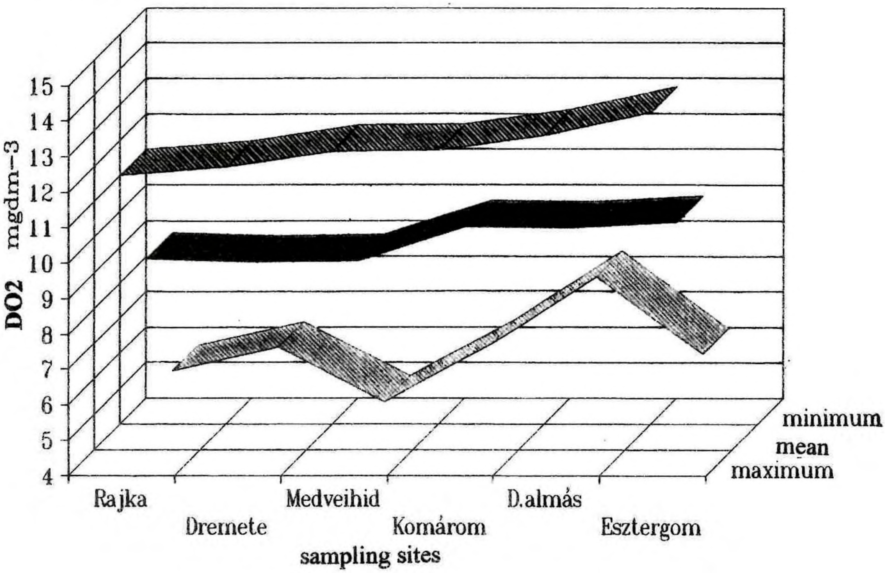


**Figure 2**: Annual, mean maximum and minimum values of *dissolved oxygen* ($DO_2$) at six sampling locations in the Danube River in Hungary in 1993.

**Aquatic plant nutrients**

The nutrients - compounds containing nitrogen and phosphorus - get into the waters through natural and artificial way. Their concentration depends significantly on the biological condition of the water flowing.

Considering the type of forms of nitrogen the Danube, it is featured by nitrate-nitrogen dominance with a contribution of more than 70 per cent. The content of organic nitrogen is about 20 per cent, while the content of ammonium-nitrogen is less than 10 per cent. The nitrite-nitrogen content can be neglected. Such proportion of forms of nitrogen promotes to the formation of alga. At the upper reach of the river the average contents of total nitrogen - 2,90-3,39 N mg/l - deviates from each other only slightly **(Figure 3, Table 1)**.

**Table 2:** Selected features of water quality at five tributaries entering the Danube river in 1993

| | river km | 2,4 Mosoni Danube | 7,0 Cuhai Bakonyér | 2,8 Concó | 0,5 Általér (Kühtreiber s.) | 1,4 Kenyérmezei stream |
|---|---|---|---|---|---|---|
| **COD** | min. | 16,0 | 16 | 23 | 24 | 45 |
| **mg/l** | mean | 25,3 | 24 | 46 | 50 | 184 |
| | max. | 51,5 | 66 | 139 | 33 | 478 |
| **DO2** | min. | 1,47 | 4,49 | 1,06 | 1,58 | 0,22 |
| **mg/l** | mean | 7,60 | 10,08 | 7,63 | 8,52 | 4,51 |
| | max. | 14,10 | 14,38 | 12,16 | 13,88 | 8,58 |
| **Total N** | min. | 1,25 | - | 2,68 | 2,88 | 17,40 |
| **mg/l** | mean | 3,36 | - | 10,40 | 6,13 | 30,49 |
| | max. | 8,32 | - | 46,80 | 12,90 | 48,50 |
| **Total P** | min. | 0,11 | 0,14 | 0,19 | 0,48 | 1,06 |
| **mg/l** | mean | 0,31 | 0,57 | 0,87 | 3,22 | 4,43 |
| | max | 0,91 | 1,72 | 3,55 | 8,74 | 9,84 |
| **Chlorophyll-a** | min. | 1,02 | 1,3 | 1,70 | 2,0 | 0,7 |
| **mg.m$^{-3}$** | mean | 45,66 | 8,6 | 49,0 | 44,8 | 3,6 |
| | max | 279,89 | 14,9 | 330,1 | 134,5 | 12,9 |
| **n/1993** | | 63 | 25 | 25 | 25 | 25 |

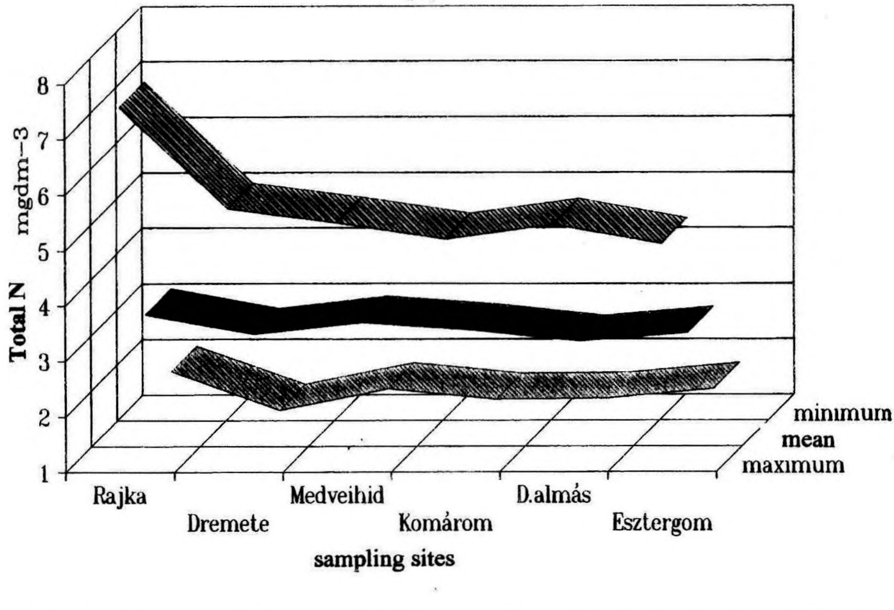


**Figure 3**: Annual, mean, maximum and minimum values of *total nitrogen* (Total N) at six sampling locations in the Danube River in Hungary in 1993.

The phosphorus the limiting nutrient resource for the water micro-vegetation are nearly identical in the river from the state border to Esztergom. During the past year the phosphorus loading coming from the cathcment area decreased significantly. However due to internal loading the phosphorus concentration in the water (max.: 0,24-0,62 P mg/l) is currently abundantly sufficient for maintaining the highly eutrophic condition of the river (**Figure 4, Table 1**).

The inflows of the tributaries contain sufficient nutrients to maintain high primary productivity of the waters, creating hypertrophic conditions (**Table 2**).

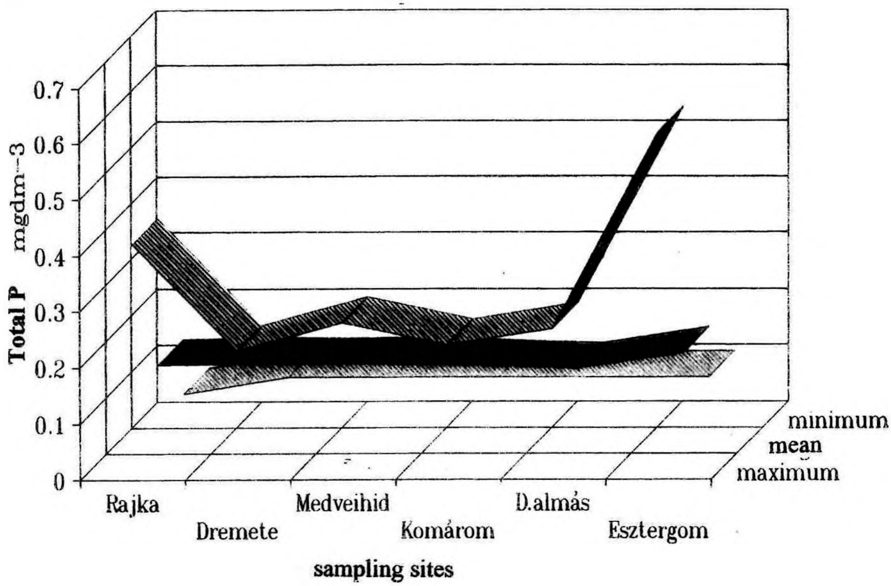


**Figure 4**: Annual, mean, maximum and minimum values of *total phosphorus* (Total P) at six sampling locations in the Danube River in Hungary in 1993.

**Formation of Algae in the Danube and its tributaries**

The concentrations of the inorganic nutrients in the Danaube does not limit the extent of algal formation in the river. However, the number of the restrictive factors such as the light conditions and the speed of the current can exert their decreasing effect on algal production.

Due to the natural regulating mechanism of the hydrometeorological factors, in the upper reach of the Danube in Hungary, the vegetative season lasts from the middle of February until early November. The first chlorophyll peak in spring, then in the low waters during summer and in the autumn followed the third maximum. This seasonal change which can be considered as regular, can be modified by water currents relating to the annual hydrometeorological condition (Bartalis, 1987).

The peak algal formation is in the spring, 88 - 115 chlorophyll-a $mg.m^{-3}$, - indicates hypertrophic condition of the river. The average concentration values of the chlorophyll-a are nearly doubled along the longitudinal section. **(Figure 5, Table 1)**. The trophic state of the right-side tributaries of the Danube exceeds that of the trophic state of the river except in the Cuhai Bakonyér and Kenyérmezei Brook. Their effect can be detected along the rivers bank at a longer-shoulder section located below the inflows of the waters of higher nutrient content **(Table 2)**.

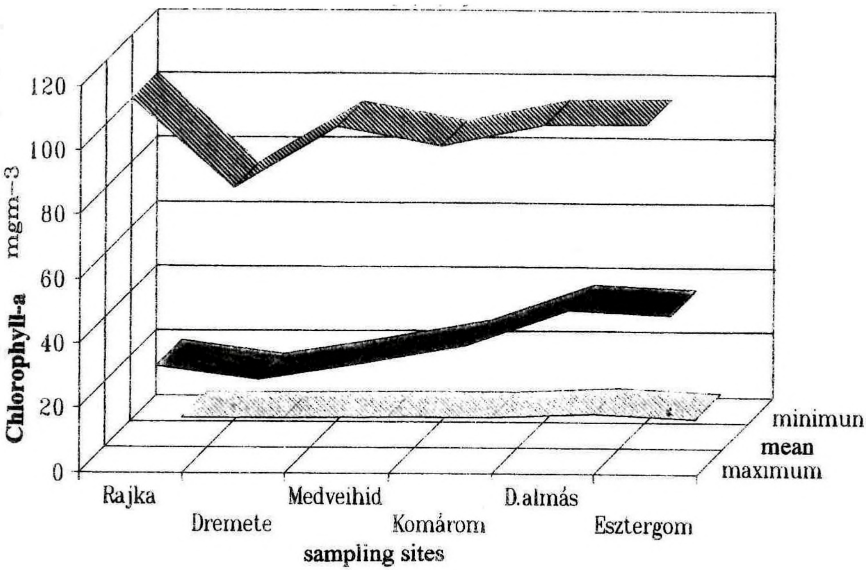


**Figure 5**: Annual, mean, maximum and minimum values of *chlorophyll-a* at six sampling locations in the Danube River in Hungary in 1993.

## The quality of water of the flood-plain branches

The flood-plain branches accompanying the main branch of the Danube create a dense water network of 125 km along the right-side bank of the river at the Szigetköz reach between 1852 and 1806 running km, while the branches between Gönyű and Dömös has been modified to a great extent. Their water supply, the exchange of the water always depend on the running of the water of the main branch. When it is rising, the branches are being filled with fresh Danube-water and the surplus flows back into the main bed. When it is falling, the water remaining in the flood-plain is converting into back-water, certain part of it is running off. When the worst happens, the flood-plain waters changed in quality, flow back to the main branch by a further transfusion.

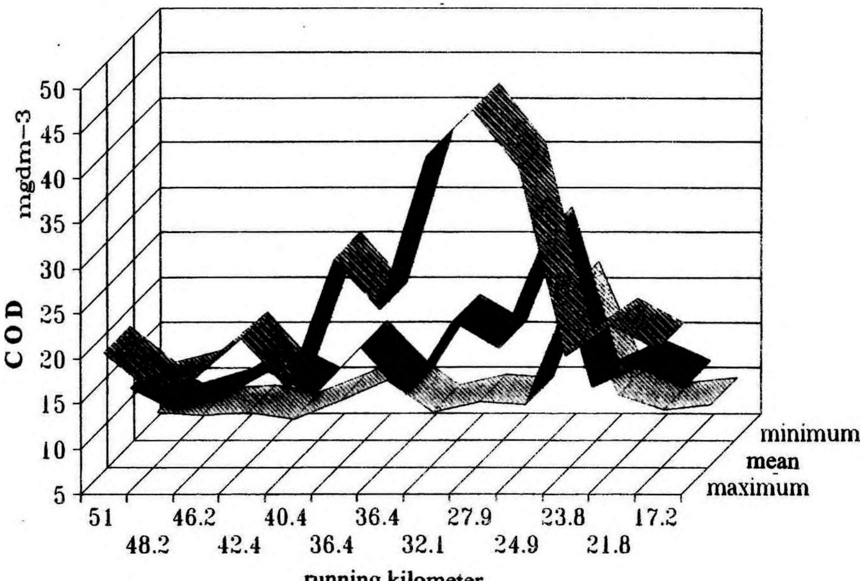


**Figure 6**: Annual, mean, maximum and minimum values of *chemical oxygen demand (* (COD) at 13 sampling locations in the flood-plain branches of the Danube (1852-1806 river km) in Hungary in 1993.

The inorganic and organic materials carried by the river will be formed through physical, chemical and biological processes as a result of the effects of different hydrological and morphological conditions. Among the nutrients coming with the Danube-water, the nitrate-nitrogen is used to a great extent and the average concentration of phosphate phosphorus is smaller than in the main branch. (Bartalis and Horváth, 1994). The high organic production in the water causes increase in the chemical oxygen demands (**Figure 6**).

## CONCLUSIONS

On the 140 km long section of the Danube examined, the load of organic pollutants increases by more than 10 % while the oxygen content of water remained near to saturated level. The nutrient concentration in the river is sufficient to maintain highly eutrophic conditions in water. From the five branches examined of Danube, the Kenyérmezei Brook is the most polluted one, but we couldn't show the impact of the stream on the water quality of Danube. The impact can only be shown locally along the short section on the right bank of the Danube.

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