Working Paper

System Approaches for the Analysis of Water Quality Management of the Sió, Kapos, Veszprémi-Séd, Malom, Nádor and Gaja River System (Hungary)

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WP-95-111
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Preface

In 1992 IIASA launched the Degraded River Basins in Central and Eastern Europe Project. The first phase of the project assessed the status of water quality in the region and identified the major challenges for improving water quality management. In the second phase, decision support systems were developed to assess water quality problems on a river basin scale and identify cost-effective means for improving water quality for the highly polluted rivers of the region. In this third phase, these decision support systems are being applied to evaluate alternative water quality management strategies in river basins which characterize the range of water quality management problems in the region. These case studies include the Nitra River in Slovakia, the Morava River in the Czech Republic, the Narew River in Poland and this study of the Sió River System in Hungary.

In the final phase of the project the knowledge gained from all of these studies will be synthesized into a comprehensive evaluation of water quality management so that new policies can be identified which are feasible, cost-effective and support sustainable progress towards better environmental quality for the people of Central and Eastern Europe.

ABSTRACT

The current challenge for water quality management in Central Europe and Eastern Europe is to identify feasible and cost-effective strategies for achieving sustainable progress towards improved water quality. This goal is set against a background of existing water quality standards which are strong but difficult to enforce, the changing role of the public sector after the fall of central planning, limited financial resources and the uncertainty and weak economic conditions of the transition. Within this context, successful water quality management requires strategies that are: (a) administratively enforceable; (b) strengthen and stabilize water quality management institutions; (c) financially feasible; (d) promote economic efficiency; and (e) fairly distribute costs over responsible parties.

The Sió, Kapos, Veszprémi-Séd, Malom, Nádor and Gaja River System epitomizes this need and confronts nearly all of the serious water management problems now facing Hungary. It is the home to the majority of Hungary's chemical industries receiving high wastewater loads from both industrial and municipal sources. The government seeks to clean up the river system, especially the Veszprémi-Séd River and Malom and Nádor Channels, but is concerned about the costs of the chemical industry and the economically stressed municipalities and their customers. Local water and environmental authorities face the controversial challenge of satisfying the various demands on the system while taking into account constraints on both quality and supply.

In this microcosm of Hungary and Central and Eastern Europe a water quality modeling and management tool developed by IIASA's Water Resources Project will be applied to help identify effective water quality management alternatives. This introductory Working Paper describes the nature of the water quality management problem, the policy setting and the management strategies which will be assessed.

Table of Contents

System Approaches for the Analysis of Water Quality Management of the Sió, Kapos, Veszprémi-Séd, Malom, Nádor and Gaja River System (Hungary).

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1. INTRODUCTION AND OBJECTIVES

The current challenge for water quality management in Central Europe and Eastern Europe is to identify feasible and cost-effective strategies for achieving sustainable progress towards improved water quality. This goal is set against a background of existing water quality standards which are strong but difficult to enforce, the changing role of the public sector after the fall of central planning, limited financial resources and the uncertainty and weak economic conditions associated with the transition. Within this context, successful water quality management requires strategies that are: (a) administratively enforceable; (b) strengthen and stabilize water quality management institutions; (c) financially feasible; (d) promote economic efficiency; and (e) fairly distribute costs over responsible parties.

The Sió, Kapos, Veszprémi-Séd, Malom, Nádor and Gaja River System, henceforth referred to as the Sió System[6], epitomizes this need and confronts nearly all of the serious water management problems now facing Hungary. It is the home to the majority of Hungary's chemical industries, receiving high wastewater loads from both industrial and municipal sources. Agricultural non-point source pollution negatively influences water quality in a part of the basin. Moreover, these pollution problems are exacerbated by the system's relatively low flows and demands for freshwater from farms for irrigation and fishponds for aquaculture.

The Hungarian government seeks to clean up the river system, especially the Veszprémi-Séd River and Malom and Nádor Channels, but is concerned about imposing additional costs on the

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[6] This system is composed of the regulated Sió Channel which flows as a natural water course in its lower reaches, the Kapos River, theVeszprémi-Séd River, the Malom and Nádor Channels and Gaja Creek, which flow into the Sió Channel.

chemical industry and economically stressed municipalities and their customers. Local water and environmental authorities face the controversial challenge of satisfying the various demands on the system while taking into account constraints on both quality and supply.

It is in this microcosm of Hungary and Central and Eastern Europe that a water quality modeling and management tool developed by IIASA's Water Resources Project will be applied to help identify effective water quality management alternatives. Towards this end, this study has the following objectives:

- to synthesize the existing knowledge on the water resource situation in the basin and to prepare a data base of water quality and water use information;
- to develop efficient management strategies for handling the joint quantity-quality problem for a case study of the Veszprémi-Séd River and Malom and Nádor Channel System; and
- to evaluate the cost implications of alternative effluent, ambient and mixed effluent-ambient water quality standards with an emphasis on identifying the most cost-effective strategies for this case study.

This work on the Sió System, and in particular on the Veszprémi-Séd River and Malom and Nádor Channel System should serve as a model for Hungary as it moves towards developing feasible, cost-effective and enforceable water quality management policies. It will provide Hungarian water management experts with an approach for evaluating the tradeoffs associated with different water quality standards which can be applied in the future to other river basins.

The next section outlines the key features of the current water resources situation in the watershed and identifies the critical water quality problems. In addition, Section 2 also identifies the Veszprémi-Séd River and Malom and Nádor Channel System as an attractive case study for analyzing alternative water quality standards in Hungary and for identifying cost-effective strategies for water quality improvement. Section 3 describes the water quality management strategies that will be evaluated for the Veszprémi-Séd River and Malom and Nádor Channel System case study. Section 4 describes the decision support system developed by IIASA to evaluate these strategies. Section 5 discusses the institutional context of water quality management in Hungary and identifies critical policy issues. Finally, Section 6 summarizes the study and describes the intended outputs.

2. BACKGROUND

2.1. Natural Characteristics of the Sió System

The Sió System is located west of Budapest and the Danube River and east, south-east of Lake Balaton with boundary coordinates 45° 50' and 47° 32'N, and 17° 30' and 19° 03' E. The Sió Channel is the only outlet of Lake Balaton, and begins at Siófok, Hungary. The Sió Channel joins the Danube River at 1497,1 Danube River km as shown in Figure 2.1. The basin covers 8 953 km^2 or 9,6% of the total territory of Hungary. The Sió System is comprised of three major sub-basins, the Kapos River Basin, the combined watershed of the Veszprémi-Séd River and

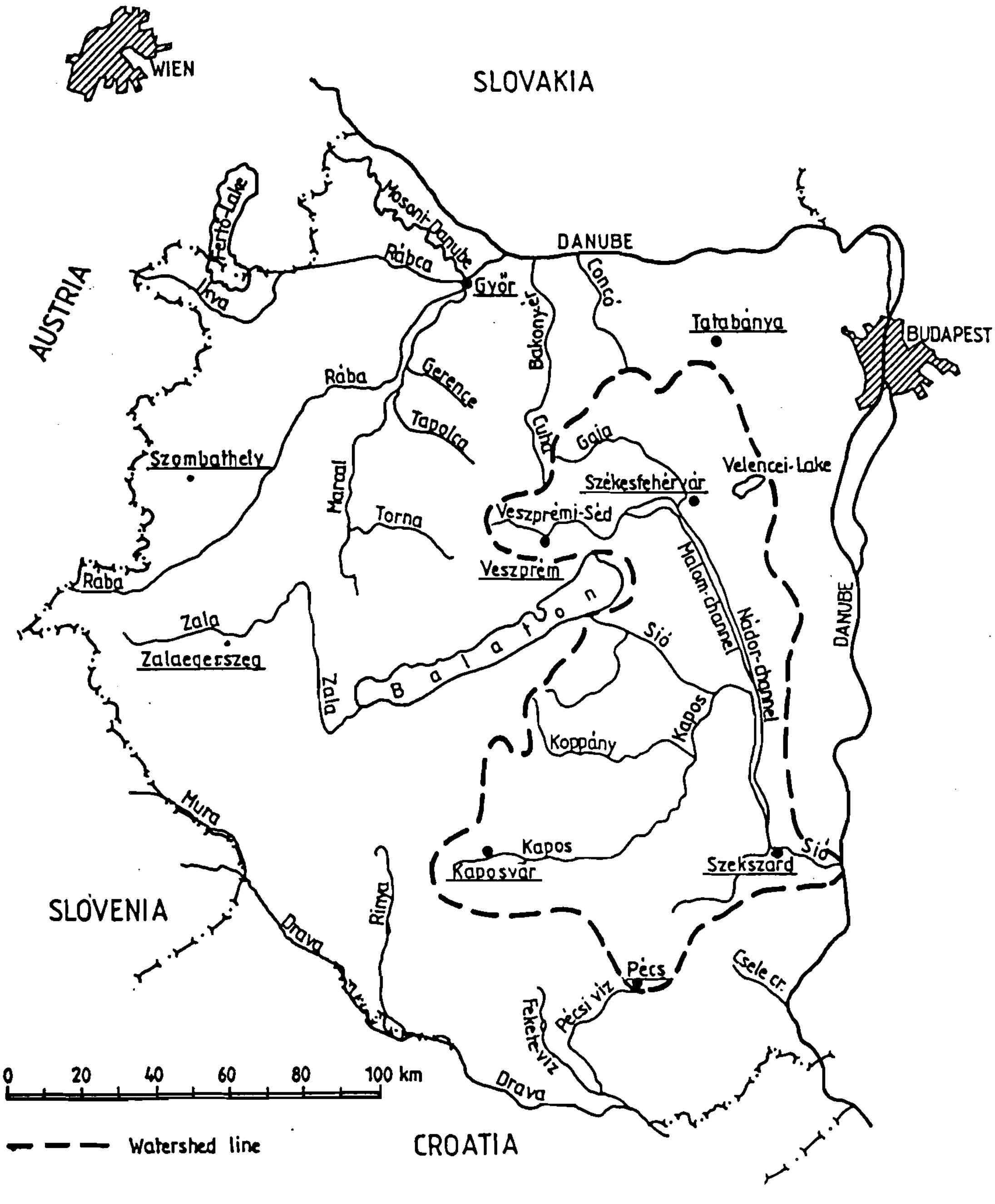


Figure 2.1 Map of river networks in the Sió System.

Malom and Nádor Channels, and the direct drainage area of the Sió Channel itself. The length of the Sió Channel from the ship-lock at Lake Balaton to the floodgate at the Danube River is 122,8 km.

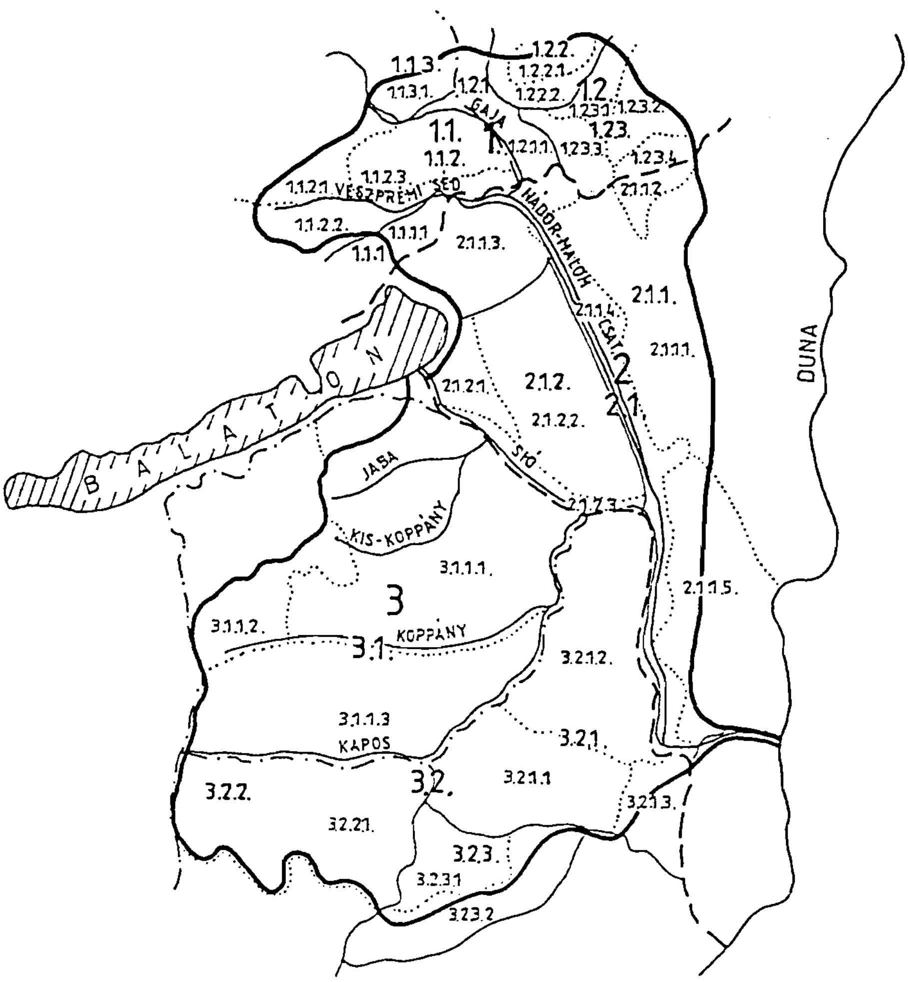
The Kapos River, 111,4 km in length, is a western tributary of the Sió Channel. The Veszprémi-Séd River and its continuation in the Malom and Nádor Channels create the longest water course within the entire Sió System, it is 167 km in length (see, Figure 2.1). The Malom and Nádor Channels flow nearly parallel to each other until they join at Őrspuszta. The flow regime of these channels is no longer natural, because they have been highly regulated watercourses for several decades.

Geographical conditions. Three major geographic areas can be distinguished in the system, as shown in Figure 2.2. The territory west of the Sió Channel is part of the Transdanubian Hills, which has two characteristic regions, namely the Outer Somogy region, a hilly area north of the Kapos River, and the Mecsek Mountains and Tolnai-Baranyai Hills region, south of the Kapos River. These western territories form 52% of the total area of the watershed. The northern part of the Sió System is covered by two regions of the Transdanubian Mid-Mountains called the Bakony Mountains and the Vértes-Velencei Mountains regions, which constitute 20% of the basin. The area located east of the Sió Channel up to the foothills of Transdanubian Mid-Mountains is called the Mezőföld region, which is a characteristically flat area extending over 28% of the watershed.

Geological conditions. The geological conditions of the entire system are determined by the fact that it is formed and extended on the basic rocks of the Danube River Basin and the pre-mountains of the Central-Carpathians. The Bakony Mountains were formed from metamorphic Paleozoic magmatic and sedimentary rocks, white and gray limestones, cherty limestone, dolomite, marl, red sandstone and anhydride. The Mezőföld region is comprised of fluvial, aeolian and flood plain sand, mud, loess and loessic deposits. These are also characteristic to the Outer Somogy region and the Tolnai-Baranyai Hills as well, with some additional mosaics of argillaceous marl, lignite, and gravel. The Mecsek Mountains, the most southern part of the watershed, are formed from magmatized granite, mica-schits in the east, and red nodular and white nodular limestone, dolomite, marl, and red sandstone in the middle and west.

The Bakony and Mecsek Mountains are karstic areas and their karstic nature greatly affects the subsurface level and chemical composition of the groundwater. In other regions the average groundwater level varies between 1 and 2 m, close to river beds, and between 3 and 4 m, in the plain areas. The chemical composition of groundwater in the watershed, excluding the Bakony and Mecsek Mountains, is characteristically alkaline.

Climate and hydrological conditions. The climate in the northern part of the watershed is characteristic to the Transdanubian Mountains. The annual average air temperature varies between 8,5 and 10,0 °C. Approximately 550 to 600 mm/year precipitation is typical, but at higher elevations in the Bakony Mountains precipitation can exceed 700 mm/year. In the Mezőföld region, the southern plain region of the Veszprémi-Séd River and the Malom and



1. Transdanubian Mid-Mountains

1.1. Bakony Region

1.1.1. Balatoni-Upland
1.1.1.1. Vilonyai-Mountains
1.1.2. North-Bakony
1.1.2.1. Old-Bakony
1.1.2.2. Veszprémi-Devecseri-Trench
1.1.2.3. East-Bakony
1.1.3. Bakony Foothill
1.1.3.1. Súri-Bakony Foothill

1.2. Vértes and Velencei Mountains

1.2.1. Vértesalji Hills
1.2.1.1. Móri Trench
1.2.2. Vértes Mountains
1.2.2.1. Vértes Plateau
1.2.2.2. Outer Vértes
1.2.3. Velencei Mountains and its surroundings
1.2.3.1. Zámoly Basin
1.2.3.2. Sörédi Plateau
1.2.3.3. Lovasberényi Plateau
1.2.3.4. Velencei Mountains

2. Plain

2.1. Mezőföld

2.1.1. Duna-Sárvíz Region
2.1.1.1. Mid-Mezőföld
2.1.1.2. Velence Basin
2.1.1.3. Sárrét
2.1.1.4. Sárvíz Valley
2.1.1.5. South-Mezőföld
2.1.2. West-Mezőföld
2.1.2.1. Enying Plateau
2.1.2.2. Káló́z-Igar Loss Plateau
2.1.2.3. Sió Valley

3. Transdanubian Hills

3.1. Outer Somogy

3.1.1. Outer Somogy
3.1.1.1. East Outer Somogy
3.1.1.2. West Outer Somogy
3.1.1.3. South Outer Somogy

3.2.Mecsek, Tolnai-Baranyai Hills

3.2.1. Tolnai Hills
3.2.1.1. Völgység
3.2.1.2. Tolnai Plateau
3.2.1.3. Szekszárd Hills
3.2.2. Zselic
3.2.2.1. North Zselic
3.2.3. Mecsek Region
3.2.3.1. Baranyai Plateau
3.2.3.2. Mecsek Mountains

Figure 2.2. Morphological regions of the Sió System

Nádor Channels Basin, the average air temperature is between 9,5 and 10,5 °C and the precipitation is between 550 and 600 mm/year. The summer in this region is long, moderately hot, and relatively dry. The long-term average air temperature varies between 10 and 10,2 °C in the Outer Somogy region, while the corresponding precipitation varies between 650 and 700 mm/year. The most southern region, the Mecsek Mountains and Tolnai-Baranyai Hills region, has the highest yearly average precipitation varying between 700 and 800 mm/year. However, the average air temperature is not significantly lower than in other parts of the watershed.

The availability of water during the spring period is determined mostly by the snow cover occurring in the winter. The average length of the permanent snow cover in the watershed is between 35 and 45 days. Table 2.1 presents the long term average values of permanent snow cover days for each region within the Sió System.

Table 2.1. Permanent snow cover days in the regions of the Sió System.

	1.1. Bakony Mountains Region	1.2. Vértes and Velencei Mountains Region	2.1. Mezőföld Region	3.1. Outer Somogy Region	3.2. Mecsek Mountains and Tolnai-Baranyai Hills Region
Permanent snow cover [days]	40 - 45	35 - 45	35 - 40	30 - 40	35 - 45

The characteristic water budget and surface runoff values for the major regions of the basin are given in Table 2.2. The Bakony Mountain region and Mecsek Mountains and Tolnai-Baranyai Hills region have some surplus based on a long term average. However, this surplus cannot counterbalance the deficit of the other three regions. The water management control activities are important for compensating for this water budget deficit, especially in the lower reaches of the Malom and Nádor Channels. Section 2.3 discusses more details of the water resources management issues of the watershed, and characteristic flow values of significant water courses in the Sió System are summarized in Appendix 1.

Table 2.2. Characteristic water budget and surface runoff values of the Sió System.

Runoff characteristics	1.1. Bakony Mountains Region	1.2. Vértes and Velencei Mountains Region	2.1. Mezőföld Region	3.1. Outer Somogy Region	3.2. Mecsek Mountains and Tolnai-Baranyai Hills Region
Specific runoff [$l/s.km^2$]	3 - 5	2 - 2,5	1 - 2	1 - 3	1,5 - 4
Runoff coefficient [%]	15 - 30	11 - 16	6 - 10	7 - 11	10 - 20
Water budget deficit [mm/y]	-	40 - 100	50 - 120	40 -50	-
Water budget surplus [mm/y]	50 - 100	-	-	-	20 - 50

Flow in the Sió Channel is dominated by the Kapos River. Above the confluence with the Kapos River the discharge of the Sió Channel is almost negligible most of the time of the year. There are high flows in the upper reaches of the channel only when water is released from Lake Balaton to control the lake water level. The history of record also shows that 1991 was a dry year especially in the Veszprémi-Séd River and Malom and Nádor Channel System. The flow values for these channels are highly influenced by water management actions and water abstractions. More details regarding flow distributions are discussed in Section 2.3.

Soil conditions. The soil types within the watershed vary according to region. The soils in the Bakony Mountains are dominantly of rendzina types. The Mezőföld region is a mixture of soils, where lowland chernoziem, meadow chernoziem and calcareous chernoziem soils cover most of the region, except close to river beds where meadow soils are typical. In the Outer Somogy region and the Tolnai-Baranyai Hills calcareous chernoziem is characteristic at lower altitudes, while at higher altitudes brown forest soils are dominant.

The soils in the Mezőföld and Outer Somogy regions and the eastern part of the Tolnai-Baranyai Hills have good infiltration rates, permeability, and hydraulic conductivity. Field capacity and water retention are also good. In the western half of the Tolnai-Baranyai Hills and the northern foothills of the Mecsek Mountains the soils have moderate infiltration rates, permeability and hydraulic conductivity, and their field capacity and water retention are high. The soil moisture regime is an equilibrium type in the Mezőföld region. Heavy downward flow is characteristic to the Mecsek and Vértes Mountains. Heavy surface runoff is common in the Outer Somogy region and in the Tolnai-Baranyai Hills. In the Bakony Mountain region the soil moisture regime of a forest type is dominant.

Land use. The current land use, and consequently the vegetation cover, of the watershed is highly affected by anthropogenic actions. Table 2.3 shows that 72% of the entire watershed area is used for agricultural production (i.e., crop land, orchards, wine-growing areas, meadow, and pasture), 20,7% is forested, 1,4% is open surface water, 0,9% is uncultivated areas, and 2,7% is settlements. Table 2.4 summarizes the number and estimated area of different lakes, ponds, and reservoirs in this system, which significantly affect the water resources management of the basin.

2.2. Anthropogenic Influences on the Sió System

The Sió System is the most complex water resources system in Hungary. Industrial and agricultural activities are both significant. These characteristic features are reflected in the settlement network. Major cities are located near the divide line of the watershed where industries are concentrated, while villages are dominant in the middle of the basin, where agriculture production is dominant.

Population. The population density in the Sió System is 96,2 capita/km^2, which is lower than the national average. The population is concentrated mainly in 24 cities. In the Bakony Mountains region Veszprém, Várpalota and Székesfehérvár are the dominant cities. Smaller cities are located in the Mezőföld region, namely Enying, Gárdony, Mór and Sárbogárd. There

Table 2.3. Land use in the Sió System.

Region	Unit	Total area	Crop land	Or-chard	Wine-growing	Meadow and pasture	Forest	Open water surface	Uncul-tivated	Settle-ments
1.1. Bakony Mountains Region	km² %	1 075 100	287 26,7	16,5 1,5	9,5 0,9	225 20,9	483 44,9	7 0,7	4 0,4	43 4,0
1.2. Vértes and Velencei Mountains Region	km² %	710 100	411 57,9	5 0,7	22 3,1	45 6,3	187 26,3	5 0,7	6 0,9	29 4,1
2.1. Mezőföld Region	km² %	2 500 100	1960 78,4	19 0,7	42 1,7	132 5,2	125 5,0	79,5 3,2	17,5 0,7	125 5,0
3.1. Outer Somogy Region	km² %	2 550 100	1 855 72,7	22 0,9	65 2,6	44 1,7	372 14,6	30 1,2	34 1,3	128 5,2
3.2. Mecsek Mountains and Tol-nai-Baranyai Hills Region	km² %	2 118 100	1 170 55,2	9 0,4	59 2,8	55 2,6	693 32,7	5,5 0,2	20,5 1,0	106 5,0
Total area	km² %	8 953 100	5 683 63,5	71,5 0,8	197,5 2,2	501 5,6	1 860 20,7	127 1,4	82 0,9	431 4,8

Table 2.4. Open, non-flowing water surface areas in the Sió System.

Type	Unit	1.1. Bakony Mountain Region	1.2. Vértes and Velencei Mountains Region	2.1. Mezőföld Region[1]	3.1. Outer Somogy Region + 3.2. Mecsek Mountains and Tolnai-Baranyai Hills Region	Total
Natural lake	number area [ha]	5 6,8	5 23,5	40 171,7	5 13,0	55 215,0
Fishpond	number area [ha]	7 239,0	1 54,0	20 1 504,5	6 419,6	34 2 217,1
Reservoir	number area [ha]	-	5 814,1	16 551,2	25 803,5	46 2 168,8
Artificial lakes	number area [ha]	-	-	16	47 617,0	63 942,0

1 Excluding Lake Velencei

are three major cities in the Outer Somogy region, Siófok at the head of the Sió Channel, and Kaposvár and Dombóvár in the upper reaches of the Kapos River. Pécs and Komló are the largest cities in the southern part of the Sió System.

There are more than 300 villages in the watershed, most of them based on farming. The majority of the settlements are served from public water supply systems which serve 97% of the watershed population. Sewer systems serve only 50 to 55% of the population, mostly in larger settlements.

Industry. The dominant industrial activities are in the northern (i.e., near Veszprém, Várpalota, Székesfehérvár) and southern (i.e., near Kaposvár, Komló, Pécs) regions. In the northern region there are important metallurgy industries, thermal power plants, coal and bauxite mines, chemical factories, heavy machinery plants, transport equipment plants, telecommunication industries, precision instruments industries, wood, paper, and printing industries, and pharmaceutical industries. Food processing, textiles, clothing, and handicraft industries dominate the central region. The characteristic industries of the southern region are coal mines, foundries, forging mills, heavy engineering equipment factories, brick production plants, roofing-tile plants, heat-resistant products industries, wood, paper, and printing industries, leather, fur, and footwear industries, handicrafts, and food processing industries.

As a consequence of this intensive industrial activity there are more than 35 major industrial point sources within the system. In addition to the large numbers of industrial sources there are 25 municipal type point sources which also exceed the effluent standard limits for at least one pollutant.

Agriculture. Agriculture plays a dominant role in the economy of the region. The Sió region is one of the most fertile and productive in Hungary. The agricultural soils of the area are ranked among the highest quality according to a land assessment carried out in the early 1980's. Dominant crops are maize, wheat, sugar beets, sunflowers and in the southern region, grapes. The highest average yields in Hungary are produced from this region. Maize, wheat, sugar beet, and sunflower yields exceed 7.6, 5.6, 2.7, and 30 t/ha, respectively. To produce these high yields, fertilizer has been heavily used in the entire watershed area. At the peak usage level, the application rate of nitrogen fertilizers exceeded 350 to 400 kg/ha. This dramatically high rate has recently dropped by at least 50% because of the economic crisis which has heavily affected agriculture since 1990.

Large scale farming systems, i.e., state farms and cooperatives, were dominant until the early 1990's, when the economic and social transition to a market economy started and extensive privatization began. A new stable agricultural plan has not yet been established, so the recent production level and agricultural chemical application rate may be estimated at only 70 to 85% of the peak production achieved during 1980's.

2.3. Water Resources Management Issues in the Sió System

The Sió Channel has inadequate carrying capacity along the 30 km middle reach of the channel. The current carrying capacity of this reach is 50 m^3/s. When the release from Lake Balaton coincides with high flows in the Kapos River and its tributaries, the carrying capacity of this reach is not sufficient to convey the combined flows of the Sió Channel and the Kapos River. To accommodate the high flow period, the carrying capacity of the Sió Channel should be increased to 80 m^3/s over the entire length of the channel.

Between the origin of the Sió Channel at Lake Balaton and its junction with the Kapos River the water flow in the channel is minimal and the water quality is determined by wastewater effluents most of the year. Below the confluence of the Sió Channel and the Kapos River, the water quality of the Sió Channel is dominated by the quality of the Kapos River. On the Kapos River there is currently no stressing daily management problem. The results of two comprehensive longitudinal water quality measurements carried out in 1992 revealed that in the upper half of the Kapos River the reduction of the emission loads from point sources would increase water quality (VITUKI, 1993). In the lower half of the Kapos River non-point source pollution must be controlled to achieve significant water quality improvement.

The water quality of the Veszprémi-Séd River and Malom and Nádor Channel System has been decreasing since the 1950's. The Veszprémi-Séd River branches into the Malom and Nádor Channels downstream of the city of Királyszentistván although currently the entire flow from the Veszprémi-Séd River is diverted into the Malom Channel. This system provides water for agriculture and fishponds and assimilates waste from 14 point sources, nine industrial plants and five municipal wastewater treatment plants. Extensive industrial pollution and the growing municipal wastewater treatment plant effluents have significantly reduced the water quality in the watershed.

In the Nádor Channel and its tributary, Gaja Creek, twelve major point sources release partially treated wastewater. Therefore water in the Nádor Channel is unsuitable for irrigation and fishpond use in the stretch of the channel between the cities of Királyszentistván and Csór.

Until recently there was no water quality problem in the Malom Channel, which is the major supply source for fishponds. Most of the time observed water quality satisfied Class I standard limit values for most parameters. There were only some cases when the channel was classified as Class II. In April 1993, decreasing water availability and increasing pollution loads from two major point sources caused fish-kills in fishponds in the middle and lower reaches of the Malom Channel. The definite cause of the fish-kills has not been determined, but some evidence shows that the high instream ammonia concentrations (e.g., 28-30 mg/l ammonia) and concurrent high pH values could have been the cause of the fish-kills. Monitoring data from the national environmental protection program and data for dedicated profile measurements are discussed, along with some preliminary results of more detailed analyses of the fish-kill problem, in Appendix 2.

In addition to the water quality problem, there are more and more frequent water shortages in this system, particularly in the Malom Channel. On the Veszprémi-Séd River and Malom and Nádor Channel System 27,05 x 10^6 m^3/y of water is permitted for agricultural and fishpond use by the local District Water Directorate. A majority of this water is supplied through the Malom Channel to users. However, during the last few years experience has shown that available water resources in the Malom Channel are between 9 and 10 x 10^6 m^3/y, or only 33 to 37% of the permitted quantity. Table 2.5 presents monthly available, demanded, and allocated amounts of water for the Nádor and Malom Channels in 1993.

Table 2.5. Available, demanded, and allocated amount of water in 1993.

	Malom Channel				Nádor Channel		
	Available	Demanded	Deficit	Allocated	Available	Demanded	Allocated
	1000 m^3				1000 m^3		
January	988	100	-	747	10 006	-	-
February	907	100	-	703	11 116	-	-
March	1 130	1 640	510	545	11 691	500	500
April	1 065	1 640	575	434	11 029	1 050	1 896
May	820	480	-	526	10 325	150	1 122
June	692	1 080	388	564	7 683	700	746
July	571	1 190	620	1 894	8 056	820	822
August	348	811	463	1 419	5 678	800	1 749
September	436	250	-	1 093	7 866	150	319
October	862	190	-	-	11 530	690	690
November	938	340	-	300	9 396	1 500	1 500
December	1 226	240	-	300	10 700	-	-
Total	9 982	8 061	2 556	8 525	115 076	6 360	9 344

Along the Malom and Nádor Channels several water transfer structures exist, consisting of sluices, gates, open connection channels, and diversion structures. Table 2.6. shows the location and characteristic parameters of these hydraulic structures. There are three major transfer channels between the Malom and Nádor Channels at Ősi, Sárszentmihály, and Szabadbattyán. In addition, two major reservoirs are used to control flood events or to store water in this basin at Sárszentmihály and Soponya. By the early 1980's this system was one of the most artificially regulated and controlled water management regions of Hungary. These structures may be useful in satisfying the growing demand for water in the Malom and Nádor Channels, however, they are rarely used now to maintain water supplies in the region.

The Gaja Creek flows into the Nádor Channel near the city of Csór and is comprised of mine water pumped from bauxite mines located in the upper part of the creek. Available water from the Gaja Creek depends on demands for water for the Lake Velencei watershed, for the city of Székesfehérvár, and for industrial use. It is also predicted that within five to seven years mine

Table 2.6. Location of hydraulic structures in the Veszprémi-Séd River and Malom and Nádor Channels.

River name	Hydraulic structures controlling water level				
	River km	Location	Type of the structure	Threshold level	Level of wear
				m.B.f.	m.B.f.
Malom Channel	71+580	in river bed	divider	148.30	
Malom Channel	66+170	left bank	gate	131.90	
Malom Channel	54+683	left bank	spillway	111.30	
Malom Channel	45+884	left bank	spillway		108.41
Malom Channel	44+005	in river bed	sluice	105.70	
Malom Channel	38+867	left bank	spillway		106.40
Malom Channel	33+163	left bank	spillway	103.71	104.35
Malom Channel	33+160	in river bed	dam	102.60	
Malom Channel	26+915	in river bed	dam	102.70	
Malom Channel	22+900	in river bed	dam	100.12	
Malom Channel	13+593	left bank	spillway		99.38
Malom Channel	6+899	in river bed	dam	97.22	
Malom Channel	1+295	right bank	spillway		98.70
Malom Channel	1+285	in river bed	dam	96.92	
Malom Channel	0+000	in river bed	flood gate	96.30	
Veszprémi-Séd	36+625	in river bed	sluice		
Nádor Channel	111+400	in river bed	dam	109.08	
Nádor Channel	101+508	in river bed	dam	101.20	
Nádor Channel	96+450	in river bed	dam	101.23	
Nádor Channel	85+064	in river bed	dam	99.32	
Nádor Channel	79+987	in river bed	dam	98.04	
Nádor Channel	56+407	in river bed	dam	94.15	

water pumping in the upper Gaja Creek will be reduced considerably, which immediately raises questions of how to maintain both water supplies and water quality in the Malom and Nádor Channels under reduced flows.

2.4. The Veszprémi-Séd River and Malom and Nádor Channel System Case Study

In this work, the Veszprémi-Séd River and Malom and Nádor Channel System was chosen as an illustrative case study for analyzing alternative water quality management approaches and water quality objectives for Hungary. The water quality and water supply problems in the system are severe, and the point source discharges, and therefore the management alternatives, are well defined. This case study is used to demonstrate an approach for determining the costs of different ambient and effluent water quality standards. The focus of the case study is on identifying water quality management strategies for achieving an acceptable level of water quality for fishery uses and on estimating the cost to industries and municipalities under such strategies. The cost of achieving water quality for fishery use may then be compared with the goal of fish production. The approach taken is to apply DESERT, a decision support tool developed in the Water Project at IIASA, in order to simulate and to optimise the system.

3. ANALYSIS OF THE VESZPRÉMI-SÉD RIVER AND MALOM AND NÁDOR CHANNEL SYSTEM

For the Veszprémi-Séd River and Malom and Nádor Channel System, the fishpond water demands occur in March, July, and August, so it is necessary to meet ambient water quality standards for fishery use at these times. Since July and August are similar in terms of water quality conditions and impacts, it may be possible to analyse the system by investigating the more critical of these two months, in addition to March.

The analysis in Appendix 2 shows that the historical fish-kills in the region may have been caused by ammonia toxicity. Analyses of the history of record of the water quality monitoring data, for the years 1989-1993, show that Hungarian ambient water quality standards for fishery use are violated for ammonia, nitrite, and phosphate in the months of March, July, and August, for biochemical oxygen demand (BOD) in the month of March, and for dissolved oxygen (DO) in the months of July and August. Therefore, ammonia is identified as the primary pollutant for this system. It may also be important to investigate water quality management programs for this system for controlling: 1) nitrite in March, July, and August; 2) BOD in March; and 3) DO in July and August. Since ammonia management programs may affect nitrate emissions and there are European Community (Environment for Europe, 1993) ambient nitrate standards for fishery use, nitrate concentrations may also need to be investigated. Finally, since there is no apparent justification for the existence of the phosphate standard for fisheries use, other than the prevention of eutrophication, it may not be necessary to investigate phosphate management programs.

The specific tasks to be undertaken for this case study include:

(1) An analysis of alternative waste load allocations for the Veszprémi-Séd River and Malom and Nádor Channel System for the control of ammonia, and possibly for the control of other constituents, such as BOD and DO. The results of this work may provide insight into the costs of achieving the standards for these pollutants, and could be useful in analysing the appropriateness of a given standard level; and

(2) An analysis of Task 1 under different flow regimes for the Gaja Creek.

The waste load allocations to be analysed include the following approaches:

Individual Effluent Limits. The ambient water quality standard is set for a river, or for a section of the river, and the Regional Environmental Inspectorate stipulates stricter effluent limit values for those polluters that have a significant effect on the ambient water quality of the river. This process is legally based in the current regulation. The Regional Environmental Inspectorate may also set a time limit during which the polluters must carry out the necessary steps to comply with the new limit.

Uniform Effluent Limits. The effluent limits on water quality are set so that the ambient water quality standard is met, and each discharger is required to achieve the same level of effluent water quality.

Least Cost Effluent Limits. The effluent limits on water quality for the dischargers are set so that the ambient water quality standard is achieved at least cost.

Each of these alternative waste load allocations may be analysed for a range of ambient water quality standards. In order to meet the various effluent water quality levels, dischargers in the region may apply several approaches for reducing pollutant loadings. They may:

- build a new water treatment;
- upgrade any existing waste water treatment technology;
- extend the wastewater treatment capacity if the current capacity is overloaded;
- change production line technologies, if it is possible;
- divert raw waste water to another waste water treatment plant, if it is possible and economic;

  or
- select a combination of the approaches mentioned above.

For this case study, the Hungarian and European Community ambient standards for ammonia, unionised ammonia, BOD, and DO concentrations for fishery use and the United States Environmental Protection Agency (USEPA) ambient standard for unionised ammonia concentration for fishery use will be investigated. These water quality standards are to be maintained in both channels, assuming no transfer between the channels. In the Malom Channel the standards are to be maintained at the location of the first fishery water intake. In the Nádor Channel the standards are to be maintained just upstream of the location of the third canal joining the two channels. In addition, to analyse the effect of reducing the flow in the Gaja Creek, the waste load allocation for these standards will be investigated under the case where the Gaja Creek flow is reduced from 0.875 to 0.53 and 0.0 m^3/sec, as suggested by the Regional Environmental Inspectorate.

4. DECISION SUPPORT SYSTEM: DESERT

In order to identify the emission levels that achieve the ambient water quality standard under the waste load allocation alternatives described in Section 3, two analytical steps are required. The first step is to develop a simulation model of the relationship between effluent loads and ambient water quality. The second step is to develop an optimization model of the waste load allocation, or waste management decision, that incorporates the costs of waste treatment in the model objective. To perform these tasks, IIASA has developed an advanced decision support system for water quality management, DESERT, which is described in this section.

Decision support in emission control in general, and in water quality management in particular, involves a sequence of analytical steps. It begins with analysis of the current situation and with the identification of short-term and long-term pollution-related problems. For this purpose, both regular monitoring data and special environmental assessment programs should be used.

After the nature of the pollution problem is determined, it is necessary to relate the ambient pollution in the river to the effluents, such as the emissions from municipalities and industrial dischargers. For this purpose, a simulation model of water quality is used, which includes parameter estimation, verification, and preferably uncertainty analysis (Masliev and Somlyódy, 1994). With such models, insight into the current situation is gained and it is possible to analyze changes in ambient quality due to changes in emission. The simulation model output may then be used as input into the waste load allocation, or water quality management, optimization model.

The DESERT integrated software for decision support in water quality management in a river basin, developed by the IIASA Water Resources Project, will be applied in this study (Ivanov et al., 1995). It incorporates a water quality simulation model with a water quality management optimization model. It allows for management of multiple sets of data, the simulation of hydraulics and water quality in a branched river system, the optimization of a set of pollution control alternatives based on the performance of a cost-related objective function, and the evaluation of uncertainty. Additionally, there is a possibility of on-line model formulation, which allows for the specification of equations for water quality processes. The layout of the software is shown in Figure 4.1.

The DESERT software is written in C++ in an object-oriented fashion, which simplifies maintenance of the code and reduces the probability of programming errors. The core of the software is the interpreter, which processes model descriptions and commands from the user or from an external command file. The interactive nature of the model provides a simple and efficient way to define relationships and coefficients for water quality processes and reactions. The transport equations and hydraulics equations are built into the system and can be selected from a menu of several possible options. The interpreter allows the user to specify any additional reaction functions for the system being analyzed.

The data management unit uses a database engine compatible with xBase relational databases, such as FoxPro and dBase. Data display is performed with the help of an external spreadsheet software package, such as Microsoft Excel. Simulation results are transferred to the external spreadsheet or plotting package via Object Linking and Embedding, OLE, libraries, which are part of the Microsoft Windows 3.1 Operating System.

The calibration unit is particularly important in water quality management, since in general all the uncertainty associated with the modeling process may be treated as parameter uncertainty.

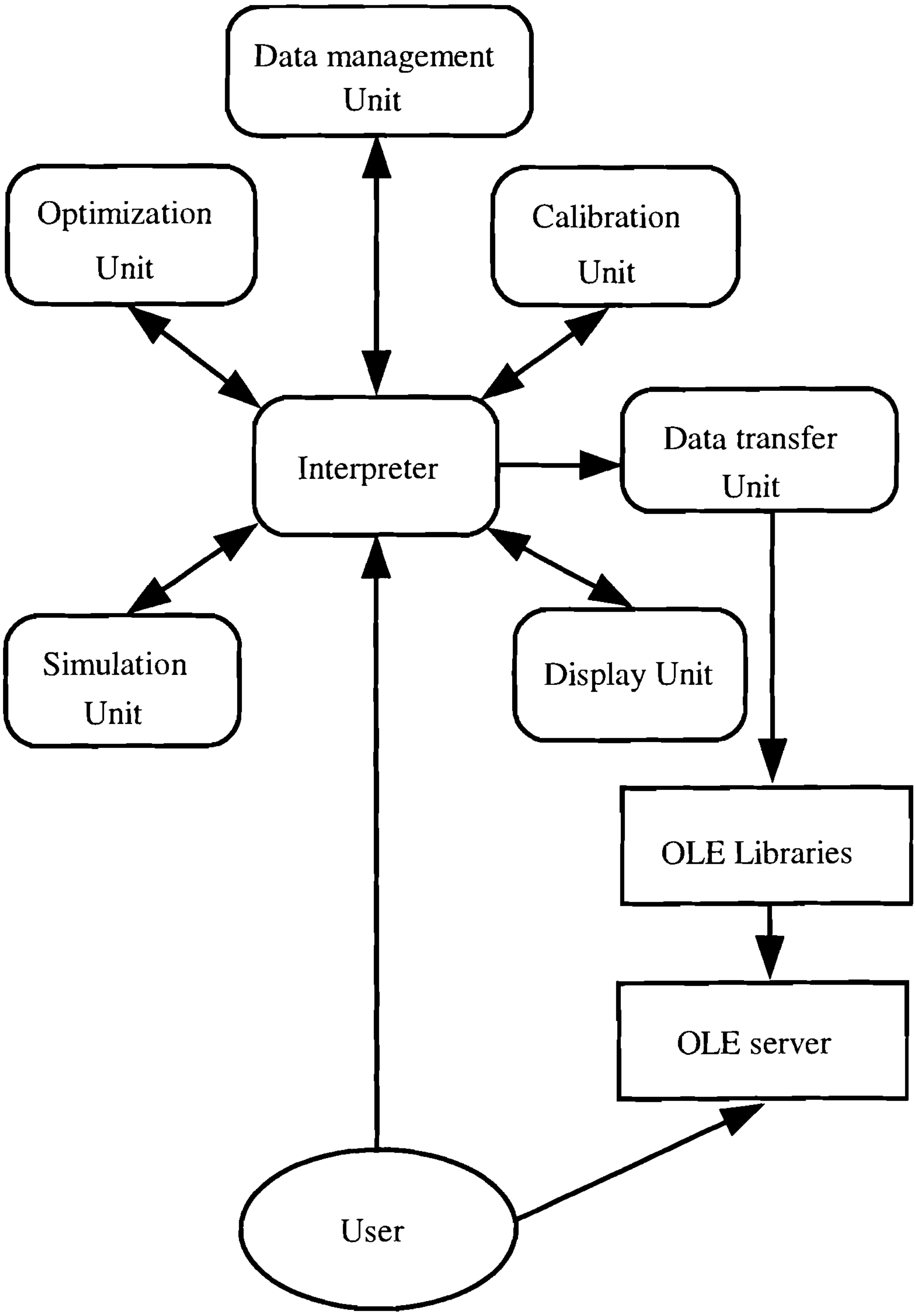


Figure 4.1. Outline of the DESERT 1.0 software.

The Hornberger-Spear-Young behavior definition method (Hornberger et al., 1980) for calibration is implemented in the software.

As a rule, a management problem can be presented as a search for a suitable regional wastewater treatment policy. There are many techniques that can be applied to identify the waste load allocation strategy. In DESERT the dynamic programming (DP) technique is used (Bellman, 1957). The advantages of the DP method are that: (a) DP is generic, the solution algorithm does not depend on the complexity of model, linearity or non-linearity, or the number of state variables; and (b) DP decomposes a problem into a sequence of decisions, or subproblems. In the case of water quality management in a river reach, the subproblem is the treatment decision at each water quality control point along the river.

The main drawback of the DP technique is the rapid increase in memory requirements as the number of state variables increases. This is referred to as the "curse of dimensionality." The virtual memory handling technique of the Microsoft Windows 3.1 Operating System partially solves this problem, but at the expense of computational speed.

5. POLICY ISSUES

Water quality management in Hungary is shaped by the institutions and policies developed to control the development, use and quality of water resources. This section describes the institutions charged with managing water and water quality and the existing policies for controlling water pollution. It concludes by attempting to identify the major challenges and opportunities for strengthening the system of water quality management.

5.1. Institutional Background

Hungary first created a national agency for integrated water resources in 1958 when the National Water Directorate (Országos Vízügyi Főigazgatóság) was established. Soon afterward twelve District Water Directorates were created to administer the policies of the national directorate at the regional level. Recognizing the importance of water management, the government in 1964 upgraded the Directorate to the ministerial level and the National Water Authority (Országos Vízügyi Hivatal) was created. This authority became a powerful institution with broad authority over water management including water supply, irrigation, water quality, flood control, navigation, and hydropower development.

Historically, responsibility for pollution related health hazards was the charge of the National Institute for Public Health and its regional public health inspectorates. Responsibility for water supply protection rested with the National Water Directorate. In 1977 a new National Agency for Environmental Protection and Nature Conservation was established, together with seven regional inspectorates. This agency, however, had limited authority and most important environmental decisions and supervising authorities were delegated to other ministries (Lehoczki, 1993).

In 1987 responsibility for water management and environmental protection were brought together in the new Ministry of Environment and Water Management (Környezetvédelmi és Vízügyi Minisztérium). The objective of integrating water and environmental protection was to strengthen and concentrate environmental administration. At the same time the seven Environmental Inspectorates were integrated into the twelve District Water Directorates and given the name of environmental and water authorities. Following integration, water management remained the dominant interest of the new ministry (Lehoczki, 1993).

In 1990 the new government once again reorganized water and environmental management. Water management was shifted to the Ministry of Transport, Telecommunication and Water Management (Közlekedési, Hírközlési és Vízügyi Minisztérium). Environmental protection was combined with regional planning to create a new Ministry for Environment and Regional Planning (Környezetvédelmi és Területfejlesztési Minisztérium). Administration and enforcement which had been combined at the regional level in 1987 was once again separated and put under their separate ministries. At the same time two new agencies were created to supervise the activities of the twelve District Water Directorates and the now twelve Regional Environmental Inspectorates; they are the National Water Authority and the Main Environmental Inspectorate (Lehoczki, 1993).

The new Ministry for Environmental and Regional Planning (Környezetvédelmi és Területfejlesztési Minisztérium) has primary authority for coordinating and implementing Hungary's environmental protection laws. Its general authority covers:

- developing the overall environmental strategy;
- analyzing and evaluating the state of the environment;
- managing an appropriate monitoring system and information network;
- developing the system and methodology for environmental impact assessment; and
- encouraging environmentally friendly practices (Lehoczki, 1993).

In the area of water quality and quantity it has the authority to:

- define the water qualification system;
- define environmental conditions and requirements for interventions related to water resources and enforcing them;
- define and enforce the environmental aspects of monitoring, data collection, and processing;
- define harmful levels of water pollution and the permissible level of pollutants;
- develop regulations for water protection and enforce them;
- define environment related tasks in preventing and reducing damages from accidental water pollution; and
- encourage environmentally safe water management (Lehoczki, 1993).

Primary responsibility for the actual administration of environmental standards and regulations rests with the twelve Regional Environmental Inspectorates under the supervision of the Main Inspectorate for Environmental Protection. These inspectorates monitor and collect information on pollution and environmental quality as well as set and collect fines for violating standards (Lehoczki, 1993).

Whereas the primary responsibility of the Ministry for Environment and Regional Policy is for the protection of water resources, the responsibility of the Ministry of Transport, Telecommunication and Water Management (KHVM) is to administer the utilization of water resources. Because KHVM and its District Water Directorates direct the development of water resources and control their use, their operations significantly affect water quality.

5.2. Financial Resources

Hungary has eight different national programs for subsidizing investment in municipal waste water treatment and sewage collection. In 1992 these programs transferred 17.2 billion HUF from the national treasury to water supply, sewage system and sewage treatment activities carried out by municipalities, local authorities and local "water civil works associations" (World Bank, 1993).

The largest of these programs is the "targeted grants" program administered by the Interior Ministry which distributed 10.8 billion HUF to the water sector in 1992. Until recently this program would match 60% of the cost of sewage treatment plant construction. Municipalities were entitled to receive support from this program as long as they could demonstrate technical feasibility and the availability of counterpart funds. The conditions are so attractive to municipalities that applications for grants have rapidly exceeded available resources so that requests must be carried over to the next year, perhaps longer. Some priority is given to requests from "sensitive" areas. The program has had the unfortunate effect of delaying investment in wastewater treatment as municipalities find it cheaper to wait for money from the central government than to raise the funds themselves (World Bank, 1993). In response to these problems the Ministry has tightened up eligibility requirements and the whole program is now under review (Lehoczki, 1995).

The next largest program is the Water Fund under the Ministry of Transport, Telecommunications and Water Management. This fund is supported by revenue from water abstraction fees collected by the District Water Directorates. The Water Fund finances the activities of these Directorates as well as providing subsidies for investments in municipal water and wastewater works. Abstraction fees generated approximately 3.0 billion HUF in revenue in 1994 (Lehoczki, 1995)

In an attempt to address the country's most pressing municipal wastewater treatment problems, the Ministry of Transport, Telecommunications and Water Management has initiated the "21 Cities Program." The 21 cities targeted in this program include Budapest, the 17 other county seats and 3 other cities. Budapest will receive first priority, but unfortunately, current funds are insufficient to meet the cost of meeting the capital's requirements, much less the other cities. The World Bank is currently funding a small preparatory project related to this program.

In 1992 the Central Environmental Protection Fund granted 0.5 billion HUF for wastewater treatment. By 1994 support for water quality protection had grown to 11.4 billion HUF (Donáth, 1995). The Fund can contribute up to 60% of investment in wastewater treatment in the form of grants and interest free loans. Currently the Fund is supported from an array of environmental charges, including fines on wastewater, allocations from the state budget and the European Union's PHARE program (Donáth, 1995). The importance of environmental charges as a source of revenue is expected to grow as fines are replaced by effluent taxes under the new environmental law (World Bank, 1993).

The Regional Development Fund, whose primary purpose is to help generate employment through infrastructure investment in depressed areas, may also provide support for wastewater treatment. These funds can also be combined with support from other previously mentioned government programs. Support to the water sector totaled 2 billion HUF in 1992.

The Supplementary Grant program for water and sewerage provides financial support to municipalities where the cost of water and/or wastewater service exceeds a nationally defined cap, revised annually. Envisioned as a temporary program to help bridge the difficulties of economic transition, the program has channeled 1.2 billion HUF into the water sector.

The "addressed grants" program is also indirectly related to the economic transition. This program provides 100% funding for projects initiated prior to decentralization and provided 1.2 billion HUF in 1992.

An additional source of funding to the sector is OTP Bank, the national savings bank. OTP administers a program offering subsidized credit to local "water civil works associations" for investment in expansions of water and sewage service. Interest on OTP loans for such investments are about a third of the market rate. OTP is the main source of funds for network investments.

5.3. Environmental Regulation

5.3.1. Water Quality Standards

Hungary's current system of water quality standards and surface water quality classification was adopted on January 1, 1994 (MSZ 12749, 1993). The system establishes five surface water quality classes and specific standards for fifty-three characteristics in five broad categories: oxygen household, nitrogen and phosphorus budget compounds, microbiological characteristics, micro and toxic pollutants, overall toxicity, radioactive elements and other characteristics.

All Hungarian surface waters are classified into one of five classes:

Class I	- Excellent	(Kíváló)
Class II	- Good	(Jó)
Class III	- Tolerable	(Tűrhető)
Class IV	- Polluted	(Szennyezett)
Class V	- Highly Polluted	(Erősen szennyezett)

For the five classes there are standards for each of the fifty-three characteristics. Other characteristics are also measured but are not yet covered by standards. These include turbidity, calcium and chloride and others. The specific standards for all characteristics are given in Appendix 3.

Water quality is monitored through a network of one hundred and fifty monitoring stations on lakes and rivers. Samples are taken at regular intervals ranging amongst stations from once a week to once every two months. The majority of stations are sampled on a bi-weekly basis. There are nine sampling stations currently in operation in the Sió River System.

5.3.2. The Fine System

The primary mechanism used to enforce compliance with the above water quality standards are fines levied on pollution discharge in excess of effluent standards. The system was introduced in 1984 and currently covers 19 "polluting substances" and 13 "toxic substances". In 1994 fine levels were doubled to account for inflation in the intervening 20 years but, even with this adjustment, it is less costly for industry to pay the fine than to control pollution. The Ministry for Environment and Regional Planning acknowledges that the current system leaves them without an adequate tool to enforce compliance to water quality standards (Klarer, 1994).

Responsibility for enforcing standards rests with the twelve Regional Environmental Inspectorates which set and collect fines. The formula for setting fines is based on a number of factors: the pollutant, quantity and concentration of discharge, number of days during which the standard was exceeded, character of receiving water, dilution capacity of the receiving water, the plant's previous pollution record, a factor to penalize severe polluters and "a factor relating to other water management considerations at the site." In practice the formula leaves much to the discretion of both the inspector and the regional inspectorate. Procedures for monitoring effluents are such that it is fairly easy for dischargers to dilute samples used by the inspectorate to calculate the fines (Klarer, 1994).

Fines collected in 1993 amounted to 156.2 million HUF and in 1992, 236.0 millon HUF. These revenues are shared between the municipalities and the Central Environment Protection Fund (CEPF) with 30% going to municipalities and 70% going to the CEPF. Whereas the funds received by the Central Environmental Fund are earmarked for water quality improvement, the funds distributed to the municipalities can be used for any purpose. The current system provides no financial incentive for regional inspectorates to enforce standards and levy fines. Moreover, financially troubled industries often do not pay the fines that have been imposed (Klarer, 1994).

5.4. Evaluation: Issues and Opportunities

Several conclusions can be drawn from this overview of the current institutional arrangement for water resources protection and management in Hungary:

(1) Water quality protection and water supply management have historically been separate, then linked, and now once again separate. The current institutional arrangement is not necessarily more stable than those previous. Both Ministries make and enforce decisions which impact both the quality and availability of water resources. Any attempt to influence water quality management in Hungary must include the participation of both Ministries.

(2) The 1990 decree which separated water management from environmental protection does not clearly demarcate the responsibilities of the two ministries and their associated regional agencies. A plan is currently under consideration to integrate the responsibilities of the Regional Environmental Inspectorates and the District Water Directorates based on the French model of river basin authorities (Lehoczki, 1995).

(3) Funds are transferred from the national government to municipalities through a variety of uncoordinated programs. The funding priorities of these programs are not determined by water quality considerations. Clever municipal governments can obtain funding from more than one national program, if they are willing to wait. Upgrading municipal sewage treatment is stalled while local governments wait for government funds. The current level of funding is inadequate to achieve significant progress towards improved water quality.

(4) The current situation of unenforcably stringent standards is a failure. It fails to acheive water quality objectives, it fails to raise revenues for environmental protection, it fails to build the credibility of the Regional Environmental Inspectorates whose responsibility it is to enforce the law.

In addition to these institutional issues, there are three additional political and economic factors that will influence policy development:

(5) In the spring of 1995 Parliament passed a new environmental law. While it is now up to the responsible ministries to develop accompanying regulations to implement the law, new policies are expected to be more consistent with the "Polluter-pays-principle" and move enforcement strongly toward a system of effluent taxes and away from the current system of non-compliance fines. However, the new law also embraces BAT as the primary means of achieving Hungary's environmental quality objectives.

(6) In 1993 polluted water from the Veszprémi-Séd River and Malom Channel was responsible for widely publicized fish-kills on fish farms fed from the river. As a result the Ministry of Environment and Regional Planning is under pressure to do something about water quality. While the Ministry would like to upgrade the classification of the river from industrial water use to agricultural water use and apply the related discharge standards, there are also under pressure from the chemical industry and the Ministry for Industry to do nothing which will adversely impact industry in the basin.

(7) The economic transition induces uncertainty about the future of industry in the watershed and its associated effluent discharges as well as the ability of firms to finance a stronger pollution efforts. Privatization has made it more difficult to obtain reliable data on the status of individual firms.

6. SUMMARY AND RESEARCH OUTPUTS

The illustrative case study of the Veszprémi-Séd River and Malom and Nádor Channel System will be used to demonstrate the approach for identifying alternative waste load allocations developed in the Water Project at IIASA. This case study will provide a "pilot case" for Hungary which can be used to investigate alternative water quality management approaches and to develop water quality objectives and standards. In the introduction to this paper a successful water quality management strategies was defined as one that is: (a) administratively enforceable; (b) strengthen and stabilize water quality management institutions; (c) financially feasible; (d) promote economic efficiency; and (e) fairly distribute costs over responsible parties.

. How can this work contribute to this objective?

First, enforceability is the most critical operational issue. Defining "optimal" or "efficient" standard levels, charge rates, fines or technologies is irrelevant if these are not enforced. The aim must be to build credibility into the administration of water quality standards. There are four necessary conditions for a credible program: (a) the level of standards, effluent charges or fines (whatever the choice) must be realistic; (b) it must be simple in application; (c) it must create incentives within the enforcing institution to enforce; and (d) it must be perceived as being "fair". The approach demonstrated in the Veszprémi-Séd River and Malom and Nádor Channel System case study may be used to evaluate the cost of different water quality standards and the efficacy of alternative waste management approaches.

Second, this research can help strengthen water quality management by supply tools and analysis to help responsible authorities at all levels to better understand the relationship between management actions and their consequences in terms of both water quality and the economic effects of these actions. Improving analytical capabilities at the regional level will, in addition, help develop credible enforcement institutions.

Third, integrated analysis of water quality management at a river basin scale can contribute to stabilizing the current institutional arrangement for water quality management by demonstrating how actions of the District Water Directorates and the Regional Environmental Inspectorates individually affect water quality and the management activities of the other agency. This understanding could potentially help identify a more efficient delineation of responsibility between the two responsible agencies.

Finally, identifying the Least Cost Effluent Limits waste load allocation for achieving a specified set of water quality objectives is critical for realizing efficient use of limited resources.

While the Least Cost Effluent Limits solution may not necessarily be adopted, it should be identified as a bench mark against which other alternatives can be measured. It will be equally important to distinguish the factors which most significantly affect costs.

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REFERENCES

Bellman, R.E. (1957) *Dynamic Programming*. Princeton University Press, Princeton, New Jersey.

Donáth, B. (1995) "The Use of Foreign Financial Assistance in Hungary." in G. Klaassen and M. Smith, eds., Financing Environmental Quality in Central and Eastern Europe: An Assessment of International Support, Conference Papers Report, International Institute for Applied Systems Analysis (IIASA).

Environment for Europe (1993). Environmental Action Programme for Central and Eastern Europe. Submitted to the Ministerial Conference in Lucerne, Switzerland, 28-30 April, 1993, Annex 9.

Hornberger, G.M. and Spear, R.C. (1980) "Eutrophication in Peel Inlet, I. Problem-defining behavior and a mathematical model for the phosphorus scenario." *Water Resources Research*, 14, 29-42.

Ivanov, P, I. Masliev, M. Kularathna, A. Kuzmin, and L. Somlyódy (1995) DESERT: Decision support system for evaluating river basin startegies. International Institute for Applied Systems Analysis (IIASA), Working paper WP-95-23.

Klarer, J., ed. (1994) Use of economic instruments in environmental policy in Central and Eastern Europe. Regional Environmental Center, Budapest.

Lehoczki, Zs. (1993) Environmental Administration in Hungary, Task IIIc: Analysis of Institutional implications of harmonization, Hungary.

Lehoczki, Zs. (1995) Senior advisor to the Ministry of Finance for the Harvard Institute for International Development, personal communication, August 1995.

Masliev, I. and Somlyódy, L. (1994) Uncertainty analysis and parameter estimation for a class of river dissolved oxygen models. International Institute for Applied Systems Analysis (IIASA), Working paper WP-94-9.

MSZ 12749 (1993) Magyar Szabvány MSZ 12749. Felszíni vizek minősége, jellemzők és minősítés. Október. (Hungarian Standard 12749: Quality of surface water, quality characteristics and classification. In Hungarian.)

Smith, M.G. (1994) The state of the art in economic instruments and institutions for water quality management. International Institute for Applied Systems Analysis (IIASA) WP-94-55.

VITUKI (1993) Felszíni vizek területi vízminőségszabályozásának fejlesztése. (Development of regional water quality and control for surface waters.) Water Resources Research

Center, VITUKI, Fehér, J., ed., Research Report No. 713/3/2245, Budapest, Hungary. (In Hungarian.)

World Bank (1993) Financing water and sewerage investment in Hungary: Discussion note - September 1993.

APPENDIX 1. CHARACTERISTIC FLOW VALUES OF SIGNIFICANT WATER COURSES IN THE SIÓ SYSTEM.

Table A1.1 Characteristic flow values of significant water courses in the Sió System.

No.	Name of the recipient	Gauge location	Distance from mouth [km]	Length of recipient [km]	Size of the watershed total / to the gauge [ha]	1981-90 KQ [m³/s]	1981-90 KKQ [m³/s]	1981-90 KÖQ [m³/s]	1981-90 KNQ [m³/s]	1981-90 NQ [m³/s]	1991 KQ [m³/s]	1991 KÖQ [m³/s]	1991 NQ [m³/s]	Comment
1	Veszprémi Séd River	Söly	20.50	55.50	513 / 403	0.120	0.261	0.812	6.940	10.800	0.100	0.379	3.900	
2	Gaja Creek	Bodajk	26.70	60.00	339 / 260	0.132	0.228	0.738	6.950	13.500	0.086	0.456	3.700	
3	Nádor Channel	Sárszentmihály	95.80	111.40	3449 / 1391	0.070	0.794	3.403	11.698	19.000	1.390	2.510	5.420	
4	Nádor Channel	Cece	46.70	111.40	3449 / 300	0.250	0.763	4.457	9.464	11.100	0.580	3.080	8.100	
5	Dinnyés-Kajtori Channel	Aba	19.10	25.50	923 / 923	0.045	0.601	0.496	1.847	2.150	-	-	-	1985-87
6	Lake Velencei	Agárd	-	-	495 / 495	-	-	-	-	-	-	-	-	No Q measurement
7	Császárvíz River	K_rakáspuszta	8.87	29.50	381 / 334	0.000	0.028	0.211	1.686	2.990	0.015	0.165	1.490	
8	Vereb-Pázmándi-víz River	Kápolnásnyék	0.70	13.50	114 / 114	0.000	0.005	0.039	1.002	5.300	0.001	0.017	0.426	
9	Sió Channel	Siófok	121.80	122.80	8953 / 0	-	-	-	-	-	-	-	-	No Q measurement
10	Sió Channel	Simontornya	76.70	122.80	8953 / 3750	1.220	2.390	16.300	58.800	74.700	2.110	6.480	36.000	
11	Sió Channel	Szekszárd	18.60	122.80	8953 / 8950	-	-	-	-	-	-	-	-	No Q measurement
12	Kis-Koppány River	Ádánd	1.00	39.00	262 / 262	0.004	0.065	0.528	9.260	14.510	-	-	-	1981-87
13	Koppány River	Törökkoppány	36.90	56.50	745 / 260	0.020	0.111	0.592	4.439	9.040	0.102	0.649	10.700	
14	Koppány River	Tamási	14.50	56.50	745 / 656	0.080	0.228	1.052	5.439	8.470	0.169	0.797	3.780	
15	Kapos River	Kaposvár	90.90	111.40	3750 / 327	-	-	-	-	-	-	-	-	No Q measurement
16	Kapos River	Dombóvár	60.70	111.40	3750 / 1707	0.860	1.204	4.550	25.020	43.400	-	-	-	1980-85
17	Kapos River	Kurd	44.00	111.40	3750 / 2119	0.600	1.170	4.370	29.400	52.800	0.250	3.610	23.200	From 1987
18	Kapos River	Pincehely	7.90	111.40	3750 / 3210	1.140	1.855	6.298	37.150	71.500	1.220	4.910	28.000	From 1984
19	Deseda Creek	Somogyaszaló	13.88	31.00	167 / 49	0.000	0.010	0.127	4.123	13.632	0.015	0.065	0.453	1986-89
20	Deseda Creek	Toponár	3.80	31.00	167 / 155	0.000	0.034	1.369	4.068	5.650	-	-	-	1981-87
21	Surján Creek	Szentbalázs	4.60	20.00	113 / 100	0.000	0.026	0.249	4.160	12.280	0.005	0.099	3.190	
22	Baranya Creek	Csikóstőttős	3.20	36.00	462 / 451	0.018	0.176	1.293	24.130	62.900	0.171	0.807	8.330	
23	Völgységi Creek	Magyaregregy	45.10	53.00	554 / 34	0.000	0.003	0.073	2.795	8.016	0.008	0.069	10.300	1986-89
24	Völgységi Creek	Bonyhád	20.30	53.00	554 / 228	0.017	0.101	0.459	7.383	14.500	0.086	0.351	10.400	

Legend: KQ = low flow, KKQ = mean low flow, KÖQ = mean flow, KNQ = mean high flow, NQ = high flow.

APPENDIX 2. ANALYSIS OF THE POSSIBLE CAUSE OF FISH-KILLS IN THE APRIL 1993 IN MALOM AND NÁDOR CHANNELS

A2.1 Background and History of the Problem

The Veszprémi-Séd River and Malom and Nádor Channel System is used as a water supply source for several of fishponds located in the region. Water use is relatively heavy, as much as half of the water from the channels may be diverted to the fishponds at times. In April 1993, fishpond owners near Úrhida reported massive fish-kills in which more than 2 tons of fish were lost. It is assumed that the problem was caused by inadequate water quality in the Malom Channel, from which water was taken for the fishponds.

The Malom Channel receives water from the Veszprémi-Séd River, which is polluted by both an industrial and municipal point source. The city of Veszprém, located on the Veszprémi-Séd River upstream of the Malom Channel, has a municipal wastewater treatment plant with a design capacity of 16000 m3/d, and is operating close to design capacity. The wastewater treatment plant effluent contains high concentrations of ammonia nitrogen, i.e., as much as 30 mg/l, which can be toxic for fish. The Veszprémi-Séd River also receives wastewater from the Bakony Works chemical plant. A release of oxygen-demanding substances such as BOD and ammonia from either of these sources could cause anoxia in the water and may also be a cause of fish-kills. The aim of the analysis presented here is to identify, on the basis of existing data, the most likely cause of the event, as well as the water quality management problem in the Veszprémi-Séd River and Malom Channel.

A.2.2 Monitoring Data and Analysis

The water in the Malom Channel is subject to regular monitoring both by the Regional Environmental Inspectorate and by the District Water Directorate. The latter performs analyses of much fewer constituents, mostly to determine suitability of channel water for use by fishponds.

Figure A2.1 shows DO concentrations based on monitoring data for the Veszprémi-Séd River below the city of Veszprém, and Figure A2.2 presents the DO concentrations in the Malom Channel close to the intake for the fishponds at Úrhida. The DO concentration is plotted, in mg/l, for different dates between 1 January 1988 and 28 September 1993. It can be seen that DO is at times very low, presenting danger for the aquatic environment. However, the anoxic periods mostly arise in summer, and the aforementioned accident occurred in early spring, when the DO concentration was relatively high. Consequently, the probability of anoxia as the cause of the accident is not very high.

Figure A2.3 shows unionized ammonia concentrations for the Veszprémi-Séd River below the city of Veszprém, and Figure A2.5 presents the unionized ammonia concentrations in the Malom Channel close to the intake for the fishponds at Úrhida. Unionized ammonia is very toxic for fish and other aquatic life. As shown in Figure A2.3, the concentration of unionized ammonia was extremely high in the Malom Channel during the accident in April 1993. The level of fish toxicity for unionized ammonia is 400 mg/m^3 according to the USEPA recommendations. It is very likely that the unionized ammonia concentration is the cause of the fish accident. Figure A2.5 shows that this highly contaminated water most likely originated from the city of Veszprém, because after the municipal emission, but prior to any industrial emissions, the unionized ammonia is very high.

Figure A2.4 shows ammonia concentrations for the Veszprémi-Séd River below the city of Veszprém, and Figure A2.6 presents the ammonia concentrations in the Malom Channel at Úrhida. close to the intake for the fishponds. The unionized ammonia concentration is determined mostly by two factors: total ammonia and pH. Figures A2.4 and A2.6 show that the total ammonia is high nearly permanently in the Veszprémi-Séd River, but it is much lower in the Malom Channel during summer periods, when the aquatic vegetation is growing in the channel. Aquatic vegetation is probably a sink for the dissolved mineral nitrogen. It absorbs most of the ammonia from the water during the vegetation period. Consequently, it is not surprising that the accident occurred in early spring, when the aquatic vegetation did not yet develop and the concentration of ammonia in the channel water was still high.

Also, pH is influencing the chemical equilibrium between unionized and ionized ammonia in the water. Figure A2.6 shows that pH is fluctuating randomly, but that the water on average is basic, which is a precondition for high concentrations of unionized ammonia relative to ammonia. Therefore, it may be presumed that the spring accident was caused by a combination of three factors. These are: (1) the high ammonia concentration originated from the municipal source of the city of Veszprém, (2) the basic characteristics of water, coming from the karstic region, and (3) the absence of vegetation in the channel during the spring. As long as all of these three factors are present, repetition of similar accidents may be possible.

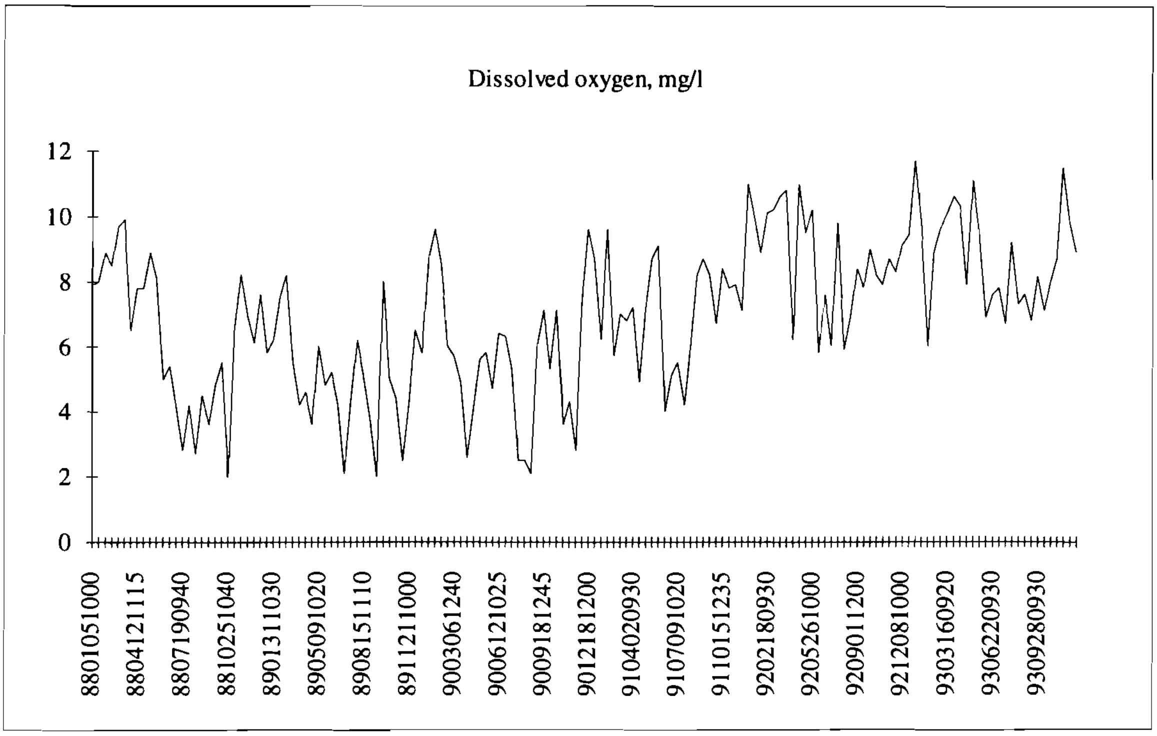

Figure A2.1 Dissolved oxygen concentration in the Veszprémi-Séd River near the city of Veszprém.

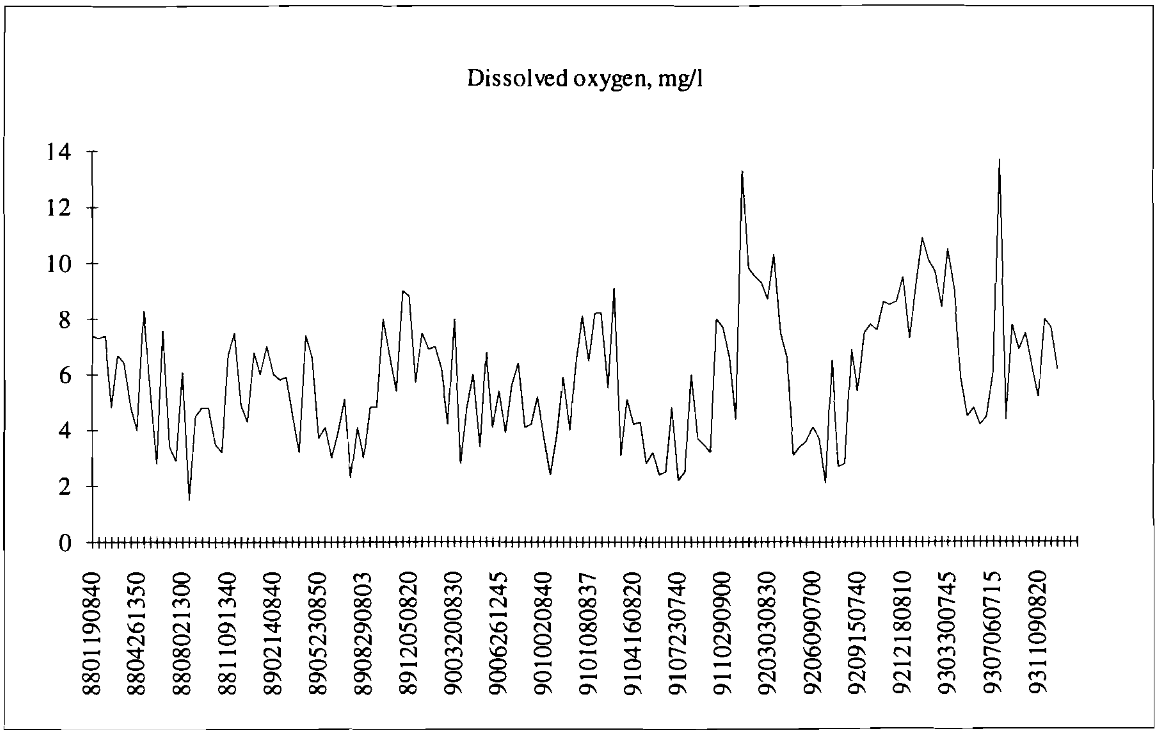

Figure A2.2 Dissolved oxygen concentration in the Malom Channel at Úrhida.

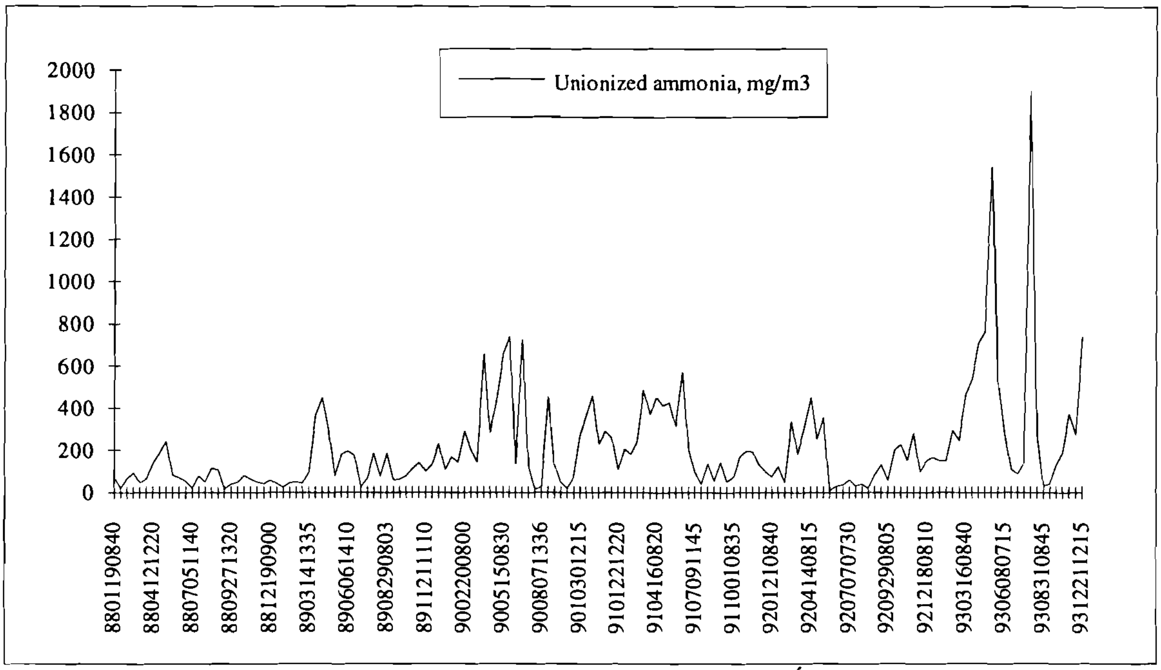

Figure A2.3 Unionised ammonia concentration in the Malom Channel at Úrhida.

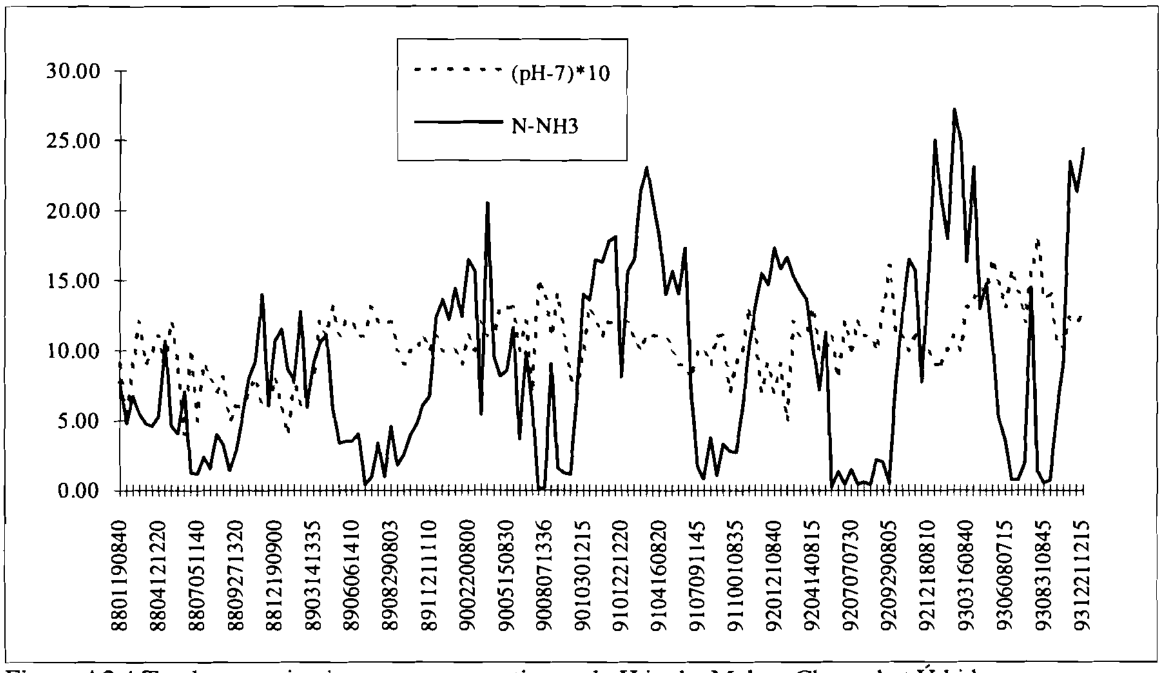

Figure A2.4 Total ammonia nitrogen concentration and pH in the Malom Channel at Úrhida.

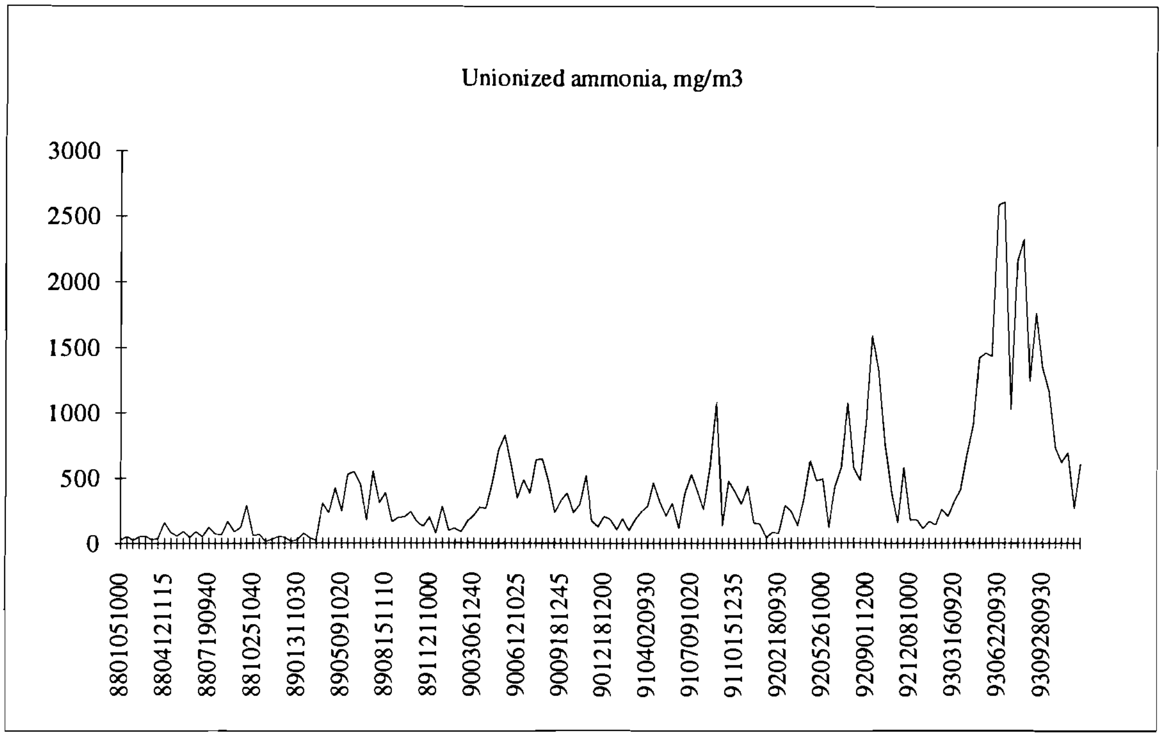

Figure A2.5 Unionised ammonia concentration in the Veszprémi-Séd River near the city of Veszprém.

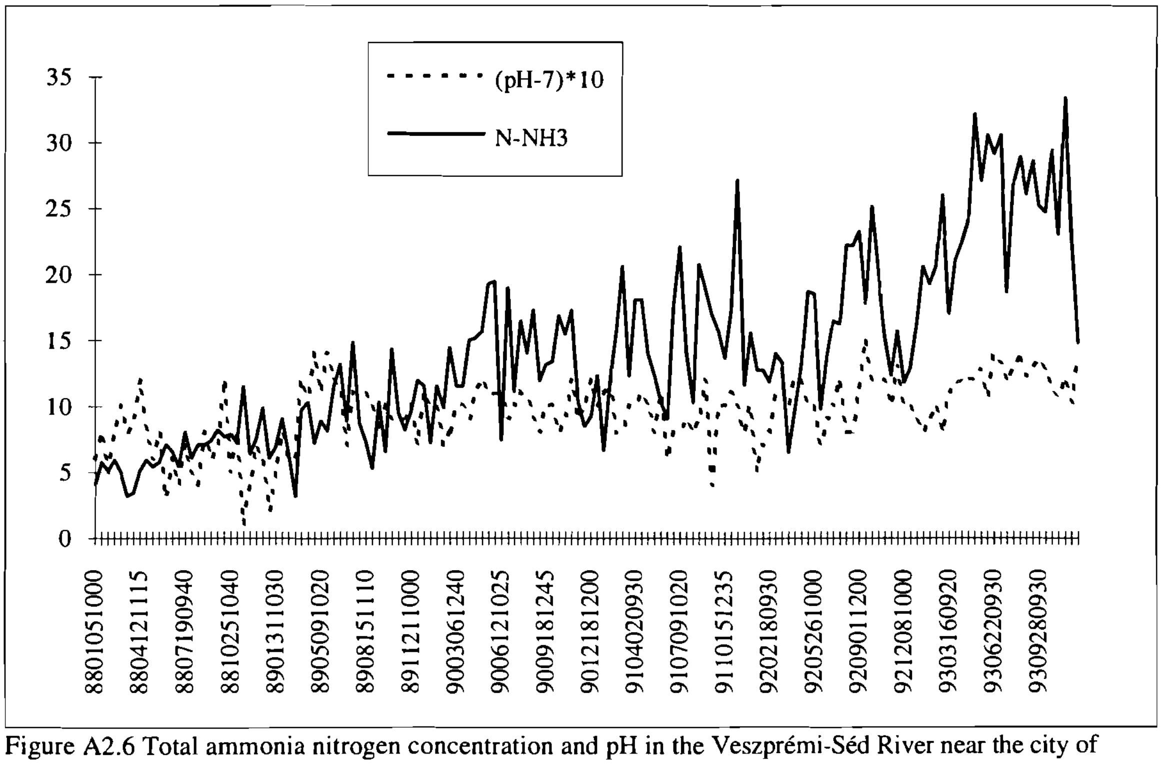

Figure A2.6 Total ammonia nitrogen concentration and pH in the Veszprémi-Séd River near the city of Veszprém.

APPENDIX 3. HUNGARIAN SURFACE WATER QUALITY STANDARDS AND CLASSES AND EMISSION STANDARDS FOR INDUSTRIAL AND MUNICIPAL EFFLUENTS

Table A3.1 Surface water quality standards and classes (Hungary).

Water quality characteristics	Unit	Limit values for water quality classes: I. Excellent	II. Good	III. Tolerable	IV. Polluted	V. Highly Polluted	Hungarian Standards	Comments
A. Oxygen regime								
Dissolved oxygen (DO)	mg/l	7	6	4	3	< 3	MSZ ISO 5813	
	%		70-80	50-70	20-50	<20		
		80-100	100-120	120-150	150-200	>200		
Biochemical oxygen demand (BOD)	mg/l	4	6	10	15	>15	MSZ 12750-22	
Chemical oxygen demand (COD_{mn})	mg/l	5	8	15	20	>20	MSZ 12750-21	
Chemical oxygen demand (COD_{cr})	mg/l	12	22	40	60	>60	MSZ 12750-21	
Total organic carbon (TOC)	mg/l	3	5	10	20	>20	1)	
Saprobic index (Sap)	-	1,8	2,3	2,8	3,3	>3,3		
B. Nutrients								
Ammonium (NH_4-N)	mg/l	0,2	0,5	1,0	2,0	> 2,0	MSZ ISO 7150-1	
Nitrite (NO_2-N)	mg/l	0,01	0,03	0,1	0,3	> 0,3	MSZ 448-12	
Nitrate (NO_3-N)	mg/l	1	5	10	25	> 25	MSZ 12750-18	
Organic nitrogen	mg/l						MSZ 12750-20	
Total nitrogen (T-N)	µg/l	100	200	400	1000	> 1000	MSZ 260-20	For rivers entering lakes or reservoirs.
Total phosphorus (T-P)	µg/l	40	100	200	500	> 500	MSZ 260-20	Other cases.
Orthophosphate (PO_4-P)	µg/l	50	100	200	500	> 500	MSZ 12750-17	For rivers entering lakes or reservoirs.
Orthophosphate (PO_4-P)	µg/l	20	50	100	250	> 250	MSZ 12750-17	Other cases.
Chlorophyll-a (Chl-a)	µg/l	10	25	75	250	> 250	MSZ ISO 10260	
C. Microbiological								
Coliforms (CF)	-	1	10	100	1000	> 1000	MSZ ISO 9308-1	
Fecal coliforms (FC)	-	0,2	1	10	100	> 100	MSZ ISO 9308-2	
Fecal streptococci (FS)	-	0,2	1	10	100	> 100	MSZ 448-44 MSZ ISO 8199	
Salmonella	-	non detectable	non detectable	2)	detectable	detectable	MSZ 448-44	
Total bacterial number at 37 °C							MSZ ISO 6222	
Total bacterial number at 22 °C							MSZ ISO 6222	

Table A3.1 Surface water quality standards and classes (Hungary), continued.

Water quality characteristics	Unit	Limit values					Hungarian Standards	Comments
		I. Excellent	II. Good	III. Tolerable	IV. Polluted	V. Highly Polluted		
		for water quality classes						
D. Micropollutants and toxicity								
D1. Inorganic micropollutants								
Aluminum (Al)	µg/l	20	50	200	500	> 500	MSZ 12750-52	
Arsenic (As)	µg/l	10	20	50	100	> 100	MSZ 12750-11	
Bor. (B)	µg/l	100	200	500	1000	> 1000	MSZ 10889-2	
Cyanide CN)	µg/l	10	20	50	100	> 100	MSZ 260-30	
Zinc (Zn)	µg/l	50	75	100	300	> 300	MSZ 12750-8	
Mercury (Hg)	µg/l	0,1	0,2	0,5	1	> 1	MSZ 12750-12	
Cadmium (Cd)	µg/l	0,5	1	2	5	> 5	MSZ 12750-7	
Chromium (Cr)	µg/l	10	20	50	100	> 100	MSZ 260-32	
Chromium-VI (Cr-VI)	µg/l	5	10	20	50	> 50	MSZ 260-32	
Nickel (Ni)	µg/l	15	30	50	200	> 200	MSZ 260-34	
Lead (Pb)	µg/l	5	20	50	100	> 100	MSZ 12750-33	
Copper (Cu)		5	10	50	100	> 100	MSZ 12750-10	
D2. Organic Micropollutants	µg/l							
Phenols (Ph-ind)		2	5	10	20	> 20	MSZ 1484-1	
Surfactants (MBAS)	µg/l							
- anionactive detergents	µg/l	100	200	300	500	> 500	MSZ 12750-24	
- non-ionic detergents								
Oils (Oil)	µg/l							
- crude oil and oil products		20	50	100	250	> 250	MSZ 12750-23 3)	
- pholycyclic aromatic hydrocarbons	µg/l							
- Benzo(a) pyrene (PAH)		0,005	0,007	0,01	0,05	> 0,05	MSZ 448-45	
Volatile chlorinated hydrocarbons	µg/l							
- Chloroform (Cl-CH)	µg/l	5	10	30	100	> 100	MSZ 448-50	
- Carbon tetrachloride	µg/l	1	2	3	10	> 10	MSZ 448-51	
- Trichloroethylene	µg/l	3	5	10	50	> 50	MSZ 448-51	
- Tetrachloroethylene		3	5	10	50	> 50	MSZ 448-51	

Table A3.1 Surface water quality standards and classes (Hungary), continued.

Water quality characteristics	Unit	Limit values					Hungarian Standards	Comments
		I. Excellent	II. Good	III. Tolerable	IV. Polluted	V. Highly Polluted		
		for water quality classes						
D. Micropollutants and toxicity, continued								
Pesticides								
- Lindane	µg/l	0,1	0,2	0,5	2	> 2	MSZ 448-42	
- Malation	µg/l	0,1	0,2	0,5	2	> 2	MSZ 448-40	
- 2-,4-D	µg/l	0,5	1	2	5	> 5	MSZ 12750-27	
- MCPA	µg/l	0,2	0,3	0,5	2	> 2	MSZ 12750-27	
- Atrazine	µg/l	0,5	1	2	5	> 5	MSZ 12750-28	
- PCBs	µg/l	0,01	0,05	0,2	2	> 2		
- Pentachlorophenol (PCP)		2	5	10	20	> 20		
D3. Toxicity								
(Daphnia test, static fish test , etc.)		non toxic	non toxic	frequent, non toxic	toxic	toxic in dilution		
D4. Radioactivity								
Gross beta	Bq/l	0,17	0,35	0,55	1,1	> 1,1	MI 19376	
Cesium-137 (Cs-137)	Bq/l	0,011	0,10	0,22	0,44	> 0,44	MI 19376	
Strontium-90 (Sr-90)	Bq/l	0,003	0,01	0,055	0,11	>0,11	MSZ 19392	
Tritium (H-3)	Bq/l	8,3	50	165	330	>330	MSZ 19387	
E. Other characteristics				6,0-6,5	5,5-6,0	< 5,5	MSZ 448-22	
pH		6,5-8,0	8,0-8,5	8,5-9,0	9,0-9,5	> 9,5		
Conductivity (EC)	µS/cm	500	700	1000	2000	> 2000	MSZ 448-32	Only for rivers, and creeks.
Iron (Fe)	mg/l	0,1	0,2	0,5	1	> 1	MSZ 12750-34	
Manganese (Mn)	mg/l	0,05	0,1	0,1	0,5	> 0,5	MSZ 12750-5	
							MSZ 1484-2	

1 Under elaboration.

2 If only in 1/3 of the samples.

Table A3.2 National emission standards for industrial and municipal effluents into recipient water bodies (Hungary)

Serial no.	Kind of pollutant	Aerial limit value categories (mg/l)					
		I.	II.	III.	IV.	V.	VI.
I.	Polluting substances						
1.	Dichromate oxygen consumption	50	75	100	100	150	75
2.	Oil and grease[1]	2	5	10	10	10	10
3.	Organic solvents (non dilutable in water)	0,05	0,05	0,05	0,05	0,05	0,05
4.	pH[2]	6,5	6,5	5	6	5	6
5.	Total salts - of natural origin -of technical origin	 1000 1000	 1000 1000	 2000 2000	 1000 1000	 - -	 2000 2000
6.	Sodium equivalent[3]	45	45	45	45	-	45
7.	Phenols	0,1	0,1	3	3	3	3
8.	Total suspended solids	100	100	200	200	500	200
9.	Tar	0,1	0,1	2	2	2	1
10.	Ammonia-ammonium ion[4]	2	5	30	10	30	10
11.	Total iron	10	10	20	20	20	20
12.	Total manganese	2	2	5	5	5	5
13.	ANA detergents	2	2	5	5	5	5
14.	Sulfides	0,01	0,01	2	2	5	2
15.	Active chloride	2	2	2	2	2	2
16.	Fluorides	2	2	10	5	10	10
17.	Total phosphorus[5]	1,8	2	2	2	-	2
18.	Nitrate[5]	40	50	80	80	-	80
19.	Coliform count[6] (i/cm^3)	10	10	10	10	10	10
II.	Toxic substances						
20.	Easily releasable cyanides	0,1	0,2	0,2	0,2	0,2	0,2
21.	Total cyanides	2	10	10	10	10	10
22.	Total copper	0,5	1	2	2	2	2
23.	Total lead	0,05	0,1	0,2	0,2	0,2	0,2
24.	Total chromium	0,2	0,5	1	1	1	1
25.	Chromium VI	0,1	0,3	0,5	0,5	0,5	0,5
26.	Total arsenic	0,05	0,05	0,1	0,1	0,1	0,1
27.	Total cadmium	0,005	0,01	0,005	0,05	0,05	0,05
28.	Total mercury	0,001	0,005	0,01	0,01	0,01	0,01
29.	Total nickel	0,5	0,5	1	1	1	1
30.	Total zinc	1	2	5	5	5	5
31.	Total silver	0,01	0,05	0,1	0,1	0,1	0,1
32.	Toxicity	dilution required for LD 50%					

1 Three-fold increased limit value for grease and oil of animal or vegetable origin (organic solvent extract).
2 In terms of the respective HCL of NaOH quantities.
3 The quantity of sodium in kg above the amount required to balance 45 equivalent % of the calcium, magnesium, and potassium content of the water.
4 Total ammonium and ammonia, expressed as N in mg/l.
5 For categories I and II it is to be applied in all cases, while for categories III, IV, and VI it should be applied only to waste waters discharged to standing water bodies.
6 n < 4.

Table A3.3 National standards for industrial connections into public sewers (Hungary)

Serial no.	Kind of pollutant	Aerial limit value categories (mg/l)					
		I.	II.	III.	IV.	V.	VI.
I.	Polluting substances						
1.	Dichromate oxygen consumption	1000	1000	1200	1200	1500	1000
2.	Organic solvent extract (oil-grease)	40	40	50	50	60	20
3.	Phenols	5	5	10	10	10	10
4.	Tar	1	2	5	5	5	5
5.	ANA detergents	20	20	50	50	80	50
6.	pH	<6,5 or > 10,0					
7.	Sulfide	0,1	1	1	1	1	1
8.	Sulfate	400	400	400	400	400	400
9.	$N(NH_3-NH_4)$	100	100	150	150	150	150
10.	Active chlorine	10	10	30	30	50	30
11.	Total salts - of natural origin -of technical origin	 1500 1500	 1500 1500	 2500 2500	 2500 2500	 3000 3000	 2500 2500
12.	Total fluoride	20	20	50	50	50	50
13.	Total iron	10	10	20	20	20	20
14.	Settleable matter, 10 min	100	100	150	150	150	150
II.	Toxic substances						
15.	Easily releasable cyanides	0,05	0,05	0,1	0,1	0,1	0,1
16.	Total cyanides	0,5	0,5	1	1	1	1
17.	Total copper	1	1	2	2	2	2
18.	Total lead	0,2	0,2	0,4	0,4	0,4	0,4
19.	Total chromium	0,5	0,5	1	1	1	1
20.	Chromium VI	0,2	0,2	0,5	0,5	0,5	0,5
21.	Total arsenic	0,1	0,1	0,2	0,2	0,2	0,2
22.	Total cadmium	0,1	0,02	0,1	0,1	0,1	0,1
23.	Total mercury	0,005	0,01	0,05	0,05	0,05	0,05
24.	Total nickel	0,5	0,5	1	1	1	1
25.	Total stannum	0,3	0,3	0,5	0,5	0,5	0,5
26.	Total zinc	2	5	10	10	10	10
27.	Total silver	0,1	0,1	0,2	0,2	0,2	0,2
28.	Organic solvents	0,05	0,05	0,1	0,1	0,1	0,1
29.	Carbondisulfide	0,05	0,05	0,1	0,1	0,1	0,1
30.	Benzol	0,05	0,05	0,1	0,1	0,1	0,1
32.	Toxicity	dilution required for LD 50%					