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# WATER QUALITY MANAGEMENT OPTIONS FOR A DOWNSTREAM TRANSBOUNDARY RIVER BASIN – THE SAJÓ RIVER CASE STUDY

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## ABSTRACT

Water quality management has been a priority in Hungary in the past decades. Focus was especially upon improving water supply and stimulating economic development.

On 1st January 1996 new Law on General Regulations for Environmental Protection (No. 53/1995) and the Act on Water Management (No. 57/1995) came into force. These laws are framework laws providing objectives to the development of the legal instrumentation of environmental and water protection. These new regulations should reflect the transitional nature of Hungary and should stimulate and facilitate the use of the most cost-effective and efficient forms of water quality management. Furthermore the regulations should aim at harmonization with EC directives.

To support the elaboration of the new regulations case studies were carried out in the frame of a EU PHARE financed project to give answers to several water quality management and economic questions, such as (a) the way in which water quality objectives can be set when dealing with transboundary loads and vulnerable groundwater resources; (b) how to address industries in sanitation; (c) how to formulate collection and treatment requirements in the case of a very sensitive surface water originating in a river basin with predominantly non-vulnerable groundwater resources; (d) the cost effective sanitation strategy; (e) the determination of permissible loads by using water quality models; and (f) how to allocate this load among pollution sources. The paper is gives an overview of the case study with the discussion of the conclusions. 

KEYWORDS

Water management; water quality; surface waters; modeling; transboundary river basin.

## INTRODUCTION

Water quality management has been a priority in Hungary in the past decades. Focus was especially upon improving water supply and stimulating economic development. Hence a large utility gap exists between the coverage of water supply and sewerage and consequently a large amount of waste water is discharged into lost-wells or often not properly functioning septic tanks or discharged without treatment into surface waters. The present system of standards, legal rules and financing is however not geared towards the stimulation of the most cost-effective solutions and the limited funds are consequently not always well spend.

The Sajó River Basin case study (considering only the Hungarian part of the basin) is a special example to a highly industrialized area with a significant transboundary river basin character (DHV Water BV, 1997). Consequently, this river basin was selected for case study for the above listed objectives. The current paper introduces shortly the study area, gives an overview of the applied methodology and discusses the conclusions drawn.

## STUDY AREA

The Hungarian part of the Sajó Valley is located in Borsod–Abaúj–Zemplén county, in the north-eastern region of Hungary (Fig. 1). It stretches from the border with Slovakia across Borsod–Abaúj–Zemplén county from north-west to south-east. The total watershed area of the Sajó River is 12 708 km$^2$ from which 3200 km$^2$ is located in Slovakia. The total population of the Sajó watershed is approximately 350 000. Miskolc, the third largest Hungarian city with population of 185 000 is situated at the downstream part of the river stretch.

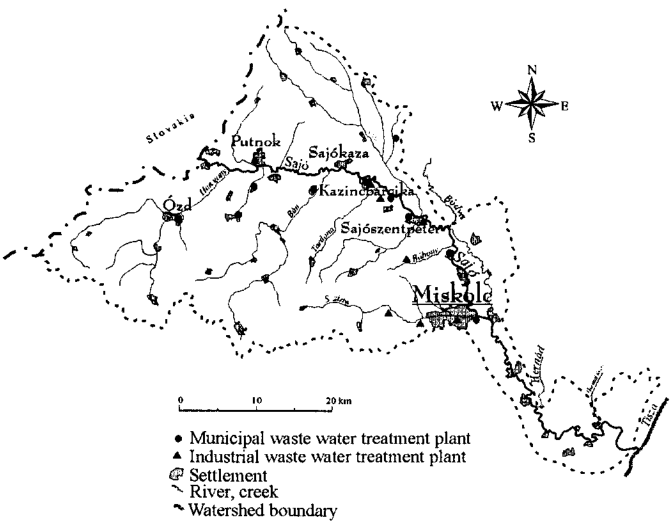


Figure 1. The Sajó River Basin.

The Sajó Valley is one of the most industrialized territories in Hungary. The significant sectors are: lignite mining, smelting, engineering industry, machine factory, chemical industry, food industry. Nowadays, a considerable number of industrial enterprises or within these, specific technologically independent production units lost their economic viability under present market economic conditions. The result of these changes is, for the time being, that industrial water pollution has considerably decreased. However, it is anticipated that the level of industrial production in 2000 will reach again the level of 1990 (before the socio-economic changes started).

Agricultural land at the close vicinity of Sajó River is relatively scarce. Near to the cities the typical agricultural sectors are vegetable and fruit gardens and animal husbandry. In the basin agricultural pollution is mainly of non-point pollution type. Note that the Hernád river—a tributary of Sajó river—was considered as point source in this study, thus characteristic of Hernád watershed are not discussed.

Both the municipal and the industrial water consumption have decreased during the 1990s. The reasons are: the decreasing population, the increasing drinking water price, and the economical recession with decreasing industrial production (Fig. 2). The municipal water consumption will also decrease in the future, because of inflation and price advance. The industrial water use will increase, according to the economical forecast, but the increase will not be significant.

There are 17 main municipal wastewater treatment plants on the Hungarian part of the Sajó watershed. Miskolc City municipal wastewater treatment plant is the overwhelming dominant municipal pollution load to the surface waters of the watershed. This wastewater treatment plant represents about 80% of the daily municipal load to the Sajó, while the other 16 are responsible only for about 20%. Downstream to Miskolc the water quality of the Sajó river is significantly affected by the load coming from Miskolc MWWTP. The sewerage ratio on the Sajó watershed not too high. In case of towns the ratio is 60-90%, while at smaller settlements between 0-30%. The amount of collected wastewater (municipal and industrial) has decreased during the investigated period, because of decrease in municipal and industrial water consumption (Fig 2).

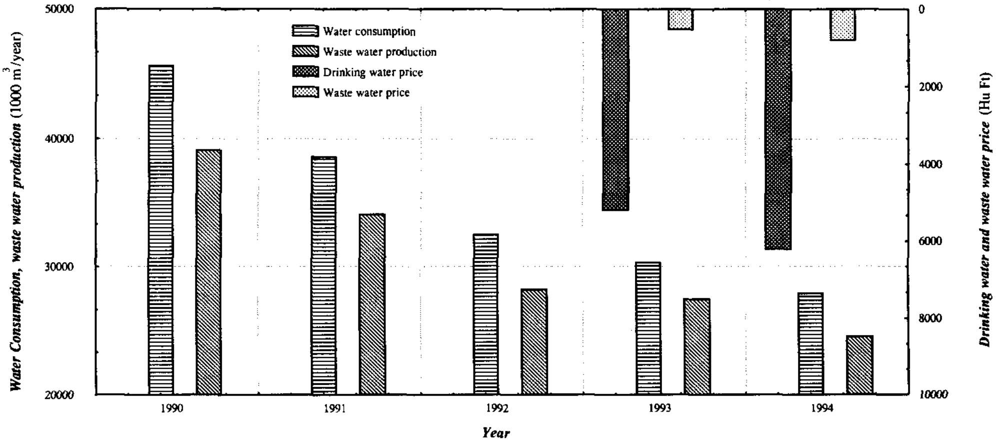


Figure 2. Water consumption and wastewater production on the Hungarian part of Sajó Basin.

The industrial development probably will not reach significant level in the future. Therefore it is not foreseen, that the water consumption and waste water production reach the level of the eighties. The quantity of industrial wastewater remains the same as at present, because of the increasing costs, and usage of advanced production technology.

## WATER QUALITY

The Sajó River was the most polluted river of Hungary until 1990. The situation has changed in 1991 drastically, because a major paper factory in Slovakia was closed down, and the Hungarian industries decreased the production also due to the economic recession. The result of these activities was a significant water quality improvement, not only at the border section, but along the Hungarian part of the river, as well (Fig. 3). Figure 3 shows the effect of the paper factory on $BOD_5$ concentration at the border section. After the factory was closed down the biochemical oxygen demand of the incoming water body drastically decreased (with more than two water quality classes).

The nutrient household components such as ammonia, nitrite, nitrate and orthophosphate show also a decreasing tendency during the examined period. Probably this situation will not change more in the next future. It can be stated that the water quality at the border section satisfies the II. water quality criteria (Hungarian standard) and the situation will probably be the same in the future.

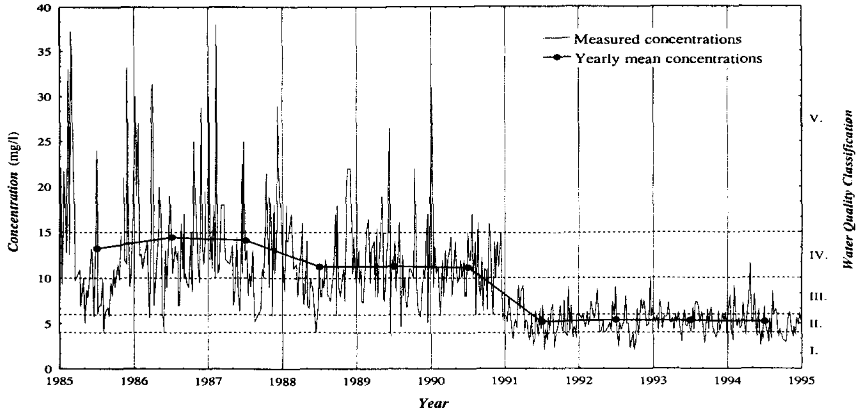


Figure 3. Measured $BOD_5$ concentration for Sajó River at Sajópüspöki (123.5 rkm).

## APPROACHES

Four regulation alternatives were identified which were considered during the water quality modeling and cost estimation procedures. The alternatives were: i) present national approach, ii) revised national approach, iii) partial river basin approach and iv) full river basin approach. Table 1 summarizes the objectives and sanitation targets of the applied approaches. The question to be raised is to what extent boundary conditions should be formulated at the national level, since naturally targets for the Tisza River (the recipient of Sajó River) would fail to be reached if the Sajó discharges high load of pollutants. Different approaches could be followed. At the national level one may demand:

a) compliance with minimum treatment and collection requirements which will function as national standards;
b) compliance with pollution reduction targets for the Sajó River to be set within the context of an international treaty with Slovakia;
c) compliance with pollution reduction targets for the Sajó formulated in the context of a national framework, e.g. in order to meet objectives for the downstream stretches of the Tisza River;
d) compliance with a general minimum level of ambient water quality to be set for rivers, such as the Sajó River.

Compliance with part a) is always required. Options b) and c) could not be detailed in the presence of this study since they involve negotiation and political compromise. However option d) a general level of ambient water quality may be proposed. However, option d) may not be met easily and/or immediately as long as there is a high level of transboundary pollution, hence its compliance may have to be linked with option b). In case of Sajó River the differences in sanitation strategies between the revised national and both river basin approaches are small. In principle, all these approaches might cope with setting interim targets depending upon the development of transboundary pollution. In the revised national approach a subsidiary law that will back-up the Environmental Inspectorate would be sufficient for setting specific, meaning looser, effluent standards for smaller settlements and perhaps also for the larger settlements on the short term.

## MODELLING SCENARIOS

With the help of DESERT software (Ivanov et. al, 1996), wastewater load allocation alternatives for the river were determined with conditions achieving ambient water quality standards for fishery, industry and drinking water uses and low flow augmentation taking into account of the different alternative regulation approaches. To complement wastewater treatment for achieving water quality standards under Uniform Effluent Limits (UEL) and Non-Uniform Effluent Limits (NUEL) strategy conditions were applied. The water quality model was prepared for oxygen and nutrient household parameters, considering those components which have effect on one parameters (Galambos, 1996; Fehér, 1993; Fehér, 1995).

Table 1. Regulation approaches used in scenario analysis

| Approach | Objectives | Sanitation targets |
|---|---|---|
| Present National | Two area categories (II. and III.) within the basin. No area categories for groundwater. | No specific targets for collection rates. Adopted are: <2000 PE closed septic tanks and treatment according to area category (mechanical treatment with chemical precipitation) |
| Revised National | Representing drinking water, including vulnerable groundwater resources, fishery, industry. | <2000 PE on vulnerable groundwater and zones that meet the requirements of the EC nitrate directive closed septic tanks and/or collection resources combined with minimal treatment;<br><2000 PE on non-vulnerable groundwater open septic tanks and minimal treatment;<br>>2000 PE collection and mechanical treatment with chemical precipitation for smaller (<100.000 PE) and biological treatment for larger towns (>100.000 PE). |
| Partial river basin | Vulnerable and non-vulnerable groundwater are categories. | <2000 PE on vulnerable groundwater and zones that meet the requirements of the EC nitrate directive closed septic tanks and/or collection resources combined with minimal treatment;<br><2000 PE on non-vulnerable groundwater open septic tanks and minimal treatment;<br>>2000 PE collection and treatment according to permissible loads but complaint with EC directives. |
| Full river basin | Vulnerable and non-vulnerable groundwater categories. | <2000 PE on vulnerable groundwater and zones that meet the requirements of the EC nitrate directive collection and minimal treatment;<br><2000 PE on non-vulnerable groundwater open septic tanks and minimal treatment;<br>>2000 PE collection and mechanical treatment according to permissible loads but compliant with EC directives Best Management Practices on vulnerable groundwater zones and those that meet the requirements of EC nitrate directive. |

Uniform Effluent Limits strategy implies that the concentration of effluent has to be the same in case of all wastewater treatment plant. The uniform effluent concentration limits for ammonia were set to 30, 20, 10, 5 mg/l, respectively. The uniform effluent concentration limits for $BOI_5$ were 252, 108, 14 mg/l, respectively. Three types of water use objectives were distinguished along the Sajó river:

- Drinking water use at Sajólád (from 40+000 rkm to 30+000 rkm)
- Fishery water use effective from Sajószentpéter to the mouth of the river (from 75+000 rkm to 0+000 rkm)
- Industrial withdrawals at 120+800 rkm, 85+200 rkm, 56+000 rkm, respectively.

Non-Uniform Effluent Limits strategy implies that the concentration of effluent is not the same for all waste water treatment plants. Seven major types of scenarios were distinguished during the optimization procedure. These are as follows:

- Drinking water use on the basis of EU directives
- Drinking water use on the basis of Hungarian directives
- Fishery water use on the basis of EU directives
- Fishery water use on the basis of Hungarian directives
- water quality class on the basis of Hungarian classification
- water quality class on the basis of Hungarian classification
- Industrial water use

Each scenario had several sub-scenarios for cost optimization:

1. charge based on quantity of $BOD_5$ (5, 10, 20, 100 HUF/kg, resp.)
2. charge based on quantity of nitrogen (5, 10, 20, 100 HUF/kg, resp.)
3. charge based on quantity of phosphorous (80, 200, 500 HUF/kg, resp.)
4. charge based on quantity of $BOD_5$, N and P discharged. The quantity of pollutants is aggregated with the help of Hazard Unit (HU) calculation, when the unit charge was (100, 200, 1500, 2000 HUF/HU, resp.) (1 US$ = 241 HUF)
5. reduced investment cost by 30%.
6. reduced investment cost by 50%.

Table 2. Total annual incremental cost needed at major WWTPs in case of different water use objectives.

| WWTP | Uniform | Effluent | Limit strategy | Fishery (H) | | | Fishery (EU) | | | Wq class II. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Code Number | *Treatment Technology* | ICDIFF [kUS$] | *Total annual incremental cost* [kUS$] | *Treatment technology* | ICDIFF [kUS$] | *Total annual incremental cost* [kUS$] | *Treatment Technology* | ICDIFF [kUS$] | *Total annual incremental cost* [kUS$] | *Treatment Technology* | ICDIFF [kUS$] | *Total annual incremental cost* [kUS$] |
| *T4816* | BT | | 643 | BT+NR | 560 | 776 | BT+NR | 560 | 776 | BT+NR | 560 | 776 |
| *T4822* | BT | | 12 | MT | | 8 | MT | | 8 | MT | | 8 |
| *T4826* | BT | | 129 | BT | | 129 | BT | | 129 | BT | | 129 |
| *T4831* | BT | | 191 | BT | | 191 | BT | | 191 | BT | | 191 |
| *T4834* | BT | | 21 | MT | | 8 | MT | | 8 | MT | | 8 |
| *T4839* | BT | | 54 | BT | | 54 | BT | | 54 | BT | | 54 |
| *I4801* | BT | 747 | 373 | BT | 747 | 373 | BT | 747 | 373 | BT | 747 | 373 |
| *I4806* | BT | 490 | 112 | MT+CP | | 62 | MT | | 25 | MT | | 25 |
| *I4811* | BT | 332 | 70 | BT | 332 | 70 | MT | | 12 | MT | | 12 |
| *I4821* | BT | | 203 | BT | | 203 | BT | | 203 | BT | | 203 |
| *I4830* | BT | 191 | 46 | MT+AD | 50 | 21 | MT | | 16 | MT | | 16 |
| *I4832* | BT | 760 | 207 | MT+CP | 99 | 91 | MT+CP | 99 | 91 | MT+CP | 99 | 91 |
| In situation 2005 | | | | | | | | | | | | |
| *T4816* | BT | | 668 | BT+NR | | 805 | BT+NR | | 805 | BT+NR | | 805 |
| *T4822* | BT | | 12 | MT | | 8 | MT | | 8 | MT | | 8 |
| *T4826* | BT | | 129 | BT | | 129 | BT | | 129 | BT | | 129 |
| *T4831* | BT | | 357 | BT | | 359 | BT | | 357 | BT | | 357 |
| *T4834* | BT | | 25 | MT | | 12 | MT | | 12 | MT | | 12 |
| *T4839* | BT | | 67 | BT | | 67 | BT | | 67 | BT | | 67 |
| *I4801* | BT | | 373 | MT | | 137 | MT | | 137 | MT | | 137 |
| *I4806* | BT | | 141 | MT | | 29 | MT | | 29 | MT | | 29 |
| *I4811* | BT | | 70 | MT | | 12 | MT | | 12 | MT | | 12 |
| *I4821* | BT | | 241 | BT+NR | | 257 | BT+NR | | 257 | BT+NR | | 257 |
| *I4830* | BT | | 54 | MT | | 16 | MT | | 16 | MT | | 16 |
| *I4832* | BT | | 207 | BT | | 207 | BT | | 207 | BT | | 207 |

*T4816-* Miskolc WWTP
*T4822-* Borsod Dressing Works
*T4826-* Ózd WWTP
*T4831-* Kazincbarcika WWTP
*T4834-* Putnok WWTP
*T4839-* Sajószentpéter WWTP
*I4801-* North-Hungarian Chem. Works
*I4806-* LKM metallurgy
*I4811-* Diósgyőr Paper Factory
*I4821-* BORSODCHEM
*I4830-* D4D Wire Works
*I4832-* Borsod Coal Separator

MT Mechanical treatment
MT+CP Mech. treat. with chemical precip.
MT+AD Mech. treat. with agricultural disp.
BT Biological treatment
BT+NR Biological treat. with nitrogen removal

The objective function to be minimized was equal to the sum of the total annual cost for all treatment plants. The total annual cost of each plant is given by the sum of the operation, maintenance and replacement costs and the investment cost, which is transferred to an annual base by multiplying it with capital recovery factor.

Cost of alternatives

Table 2 summarizes different additional cost elements of the alternatives considered. We included incremental total investment costs (ICDIFF) compared to the existing situation and incremental total annual cost for four model runs.

The cost table shows that there are some possible cost savings if the uniform technology requirement was relaxed. There is substantial investment cost saving particularly for the Fishery EU and Water Quality Class II requirements compared to the uniform technology requirement. It is worth to note that the cost savings originate from industrial polluters where there is no need for secondary treatment installation. There is some overall cost increase in the municipal sector, as well. However, the incremental investment cost figures are not too high because additional canalization is not assumed and there is already biological treatment for all municipal sources considered.

*Implications for fee (tariff) changes*
Due to the nature of restructuring inside the municipal sector the additional waste water fee is small. In fact, at two small municipalities there could be lower fee since lower level of treatment would be the cost effective to achieve given water quality objectives. Since fee increase is rather small, the affordability is not a real issue for the model analysis. In reality, it is more of a question how to get households connected to the sewage system already built. The level of fee required for full cost recovery of the present level of canalization and treatment is likely above the affordability level in smaller municipalities.

*Cost effectiveness*
Comparing alternatives, the uniform technology requirement is not a cost efficient option. In that alternative small plants engage into biological treatment and incur high unit cost while the improvement in their effluent quality has barely detectable impact on river water quality. Model runs show that it is more cost efficient to increase treatment in big municipal sources and allow industrial sources to treat less. We must note, this conclusion is relevant only for traditional pollutants and industrial sources would still need to tackle their toxic substance emissions.

*Waste water (effluent) charges*
In this case study the charge levels are somewhat different since here we had chance to analyze the incentive impact of the charges and not only of the revenue raising potential. Results show that incentive impact appears at a high level of charges. Charges based on one single pollutant has a "biased" incentive effect while the hazard unit based charge has more balanced impact. The hazard unit based charge is more suited for water quality regulation purposes.

Charge revenue becomes fairly high at high unit charge levels but it does not increase proportionately since the pollution reduction incentive is becoming strong. The municipal sources, like the city of Miskolc, bear a large part of the financial transfer burden. In general, effluent charges based on traditional pollutants generate high financial transfer payment obligations for the municipalities. Such additional burden appears as a additional cost element to be covered through increased waste water fees.

## CONCLUSIONS

The following conclusions were drawn:

- If the transboundary load and effluent load in the Hungarian stretch increase than the drinking water requirement seem to be unattainable especially at the lower stretch due to Miskolc WWTP.
- The water quality for fishery is attainable with present and predicted future loads. The II. water quality class is attainable in the present and next future. The water quality for industrial use is attainable at present and in the future.

- Parameters of I. water quality class are too strict, this state is unattainable.
- The NUEL strategy is more cost-effective than the UEL strategy from an economical point of view. Every waste-water treatment plant has a different reaction to charge changing. The examined treatment plants can be divided into three groups: low load, medium load and high load. The high load treatment plans are not sensitive to small change in loads generated by charge change.
- With present transboundary pollution, the Sajó water quality would be worse than the proposed value even if no water would be discharged on the Hungarian stretch. In other words, the water quality problem of the Sajó can only be solved if the water quality at the border section is better than at present.
- It supports the assumption that when EC minimum requirements are to be met by the urban pollution sources and the industries have to comply with a set of strict heavy metals emission standards, that cost optimization may only be limited to medium-sized rivers with a specific ecological function and that the resulting permissible load calculation would only decided if P and N removal would be necessary above that already dictated by the EC urban waste water directive.

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