SUSTAINABILITY ASSESSMENT OF A SPECIAL WATER MANAGEMENT PRACTICE IN A HUNGARIAN RIVERBASE

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Abstract

The purpose of the study is to assess the sustainability of the current water management practice of thermal water usage for bathing. The methodological approach is material flow analysis since it allows to achieve results without regular or online measurements. The current river base management plan recorded the quality status of certain reaches of river Kösely and its tributaries - the receiving water bodies of the used thermal waters - regarding salt content as good and moderate. The ecological status is recorded as moderate and weak, respectively. Since the Water Framework Directive prescribes to achieve the goal of good ecological status, water management measures must be implemented to meet this objective. Since there is no BAT for salt removal from used thermal waters, the possibility to reduce salt loads remain the only feasible measure. The purpose of the study in the frame of a PhD study was to assess with calculations the yearly variations of water and salt flow in river Kösely and its tributaries in order to assess the sustainability of the practice of thermal water management in the river catchment. The result of the calculations is a flow scheme provided with numerical data of yearly water- and salt flow and a subsequent calculation of necessary rate of reduction of usage and discharge of thermal water.

Key words: *salt content, BAT for salt removal, material flow analysis, reduce salt loads, salt flow*

1. INTRODUCTION

This study is a case study of the sustainability aspects of a special water management practice which is however not extraordinary in Hungary. This globally special practice is the usage of natural thermal water for bathing purposes and the discharge of the used thermal water afterwards without treatment either in a sewer system or in a recipient. Consequently the thermal water enters the sewage treatment plant or it is collected in a pond for the vegetation period of the year and discharged into the recipient water body later on. Hungary is rich in thermal waters containing minerals in high concentrations which make them suitable for curing. Most of them are nominated as curing waters which is relevant form water quality management aspects since different standards are applied on them. That is, a double standard is applied for the same water depending on the name of the activity. Being a unique resource it is a national interest to exploit it but the sustainability aspects are not considered strictly. Finding sustainable means of exploitation of thermal waters would mean benefits on the long run. The sustainability aspects did not even exist when thermal baths began to operate, neither did we assess environmental impacts of projects. However the exploitation rate of thermal water resources is growing without really concerning about sustainability aspects.

Since Hungary is the member of the EU, the Water Framework Directive (WFD) prescribes that management activities should aim to achieve the goals of the directive within river basin districts that is why it is inevitable to investigate the possibilities of better water management practices. The investigation is meant to prove that there are other driving forces beyond this obligation.

In our paper we explore to use Material Flow Analysis (MFA) for salts as a tool to analyze the resource effectiveness of current water management measures within a water district in view of sustainability. Material flow analysis (MFA) offers a simple tool for water quality control without requiring regular measurements. The method is additionally justified by the fact that salt is a conservative pollutant and the amount of thermal water is approximately constant compared to the river discharge.

As far as policymaking is concerned, the tool of MFA enhances early recognition of problems and priority setting in - due to the challenge of adaptation to climate change, for example - forthcoming decision making and strategy planning processes (Hendriks, C., et.al 2000). The overall goal is to harmonize the social needs of thermal water utilization with water management planning (Figure 1)

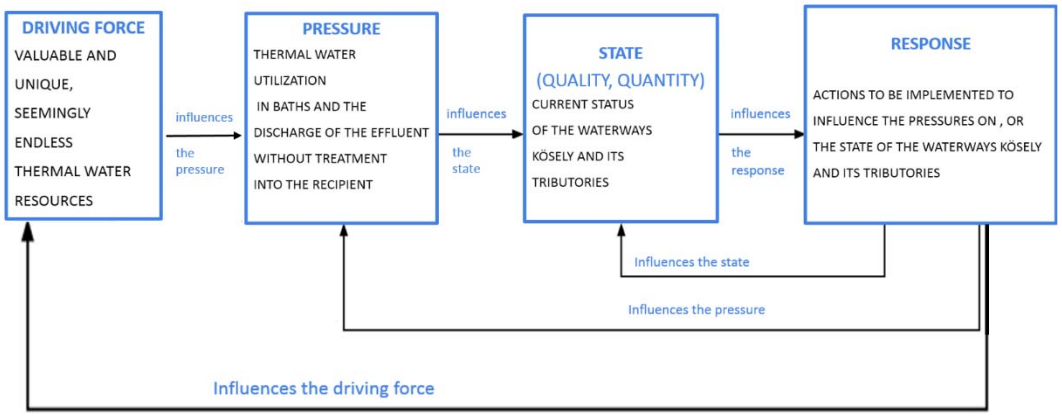


Figure 1. Driving forces and pressures of current water management practice

2. THE STUDY AREA

Salt flow is generated by the direct effluent from three thermal baths in the Kösely river catchment (Figure 2).

	direct length, km	cumulative length, km	direct catchment area, km²	cumulative catchment area, km²
TÓCÓ	25	25	131	131
KONDOROS	30	30	234	234
KÖSELY	60,9	85,9	702	1067

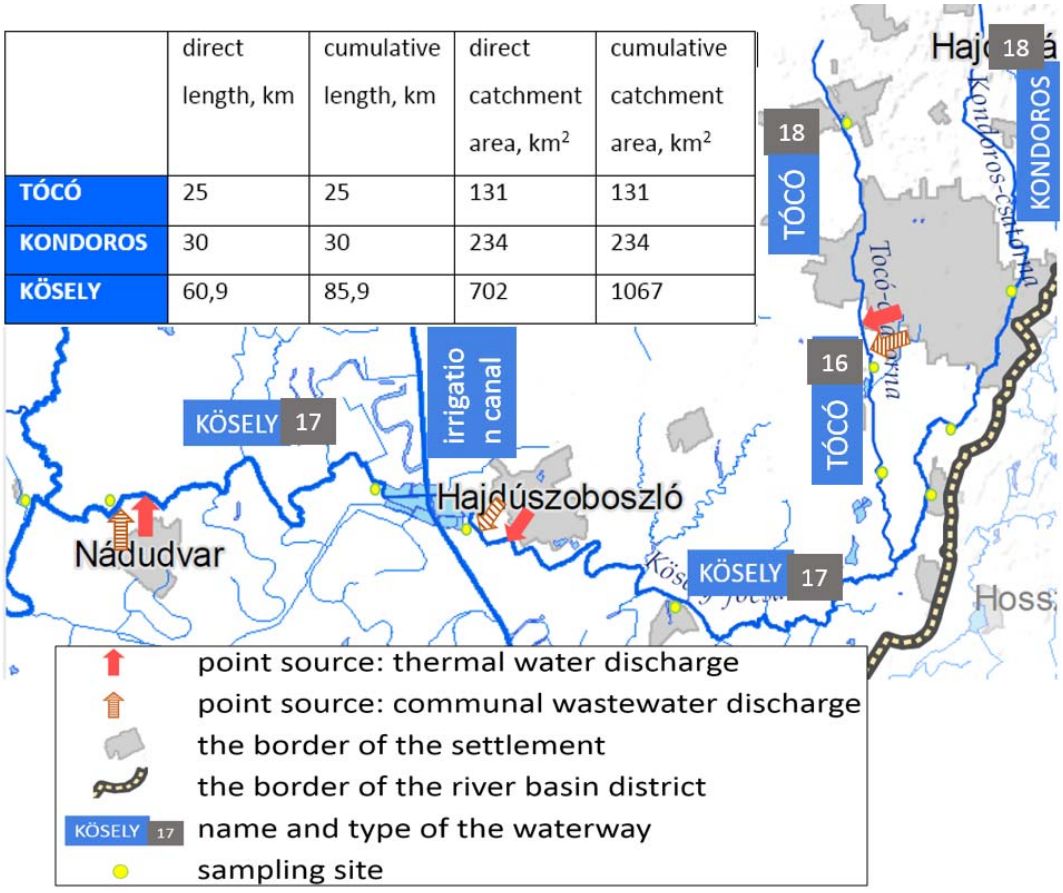


Figure 2. The study area and the point sources of thermal water

According to the current practice in Hungary the used thermal water is discharged into the sewage system in Debrecen and collected in a pond in Hajdúszoboszló. At the end of the process the same recipient water body called Kösely and its tributaries are loaded with all the dissolved solids (Figure 3). The salt content of the thermal water is not reduced in either cases. The storage in ponds provide reduction of temperature and certain reduction of suspended solids and BOD. Wastewater treatment plants can also reduce the quantity of suspended solids and BOD.

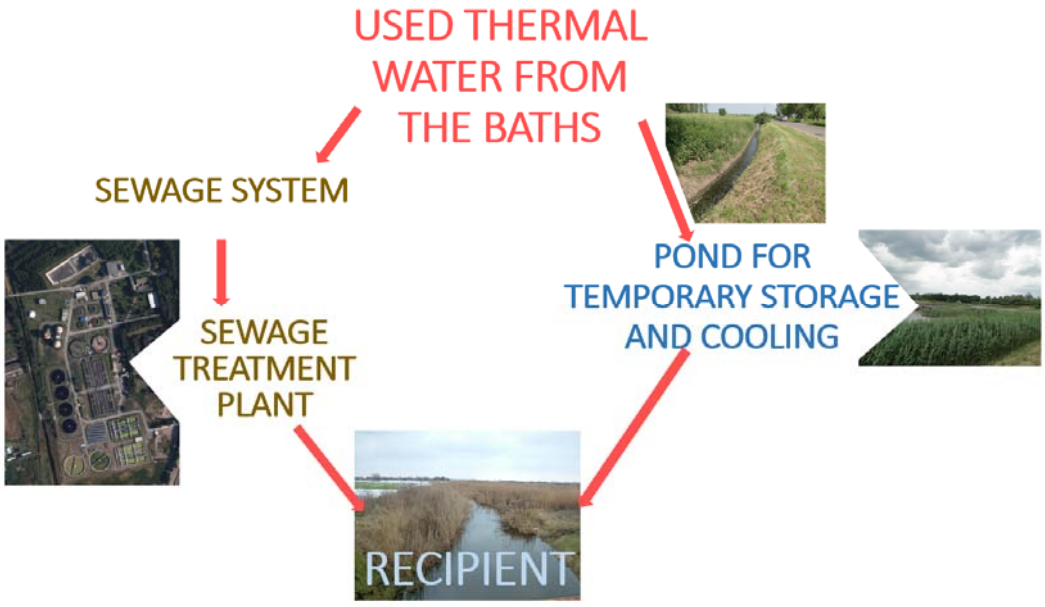


Figure 3. Two pathways of used thermal waters according to the currently widespread management practices in Hungary

3. METHOD

3.1. Primary data collection

3.1.1. Hydrologic data

- The design river discharge data was provided by the water authority for seven reaches of Kösely along with the area of sub catchments and the length of the reaches. These are the maximum probable flow rates or from other viewpoint it is the channel capacity.
- Discharge per square km of basin area is q = 25 mm/year (Zsuffa, 1975), so the volume of annual runoff from the catchment is
- $V = A \cdot q = 1000 \cdot 1061{,}4\ km^2 \cdot 25\ mm/year = 26\ 535\ 000\ [m^3]$
- We could use an artificial gauged statistics - the river is artificial since the flow is influenced at several points and it is impossible to separate the natural flow regime from the anthropogenic influences. The gauge is close to the estuary at Nádudvar.
- The mean flow is one of the most commonly used statistics in hydrology and water resources planning. It was estimated from a 10-year-long record of Nádudvar gouge data by summing all daily discharges and dividing by the number of days in the record.
- Peak flow: 17,1 m^3 /s
- Mean flow: 6,16 m^3 /s
- Lowest flow: 3,03 m^3 /s

- Ecosystems are most vulnerable during low flow periods because of a reduction in dissolved oxygen, a deterioration in water quality due to reduced effluent dilution. The ninety percentile exceedance flow is used to assess the availability of water for the dilution of certain effluents which is the flow exceeded for ninety per cent of the time. It was defined from the flow duration curve by ranking all daily discharges and finding the discharge exceeded by ninety per cent of all values (Figure 4).

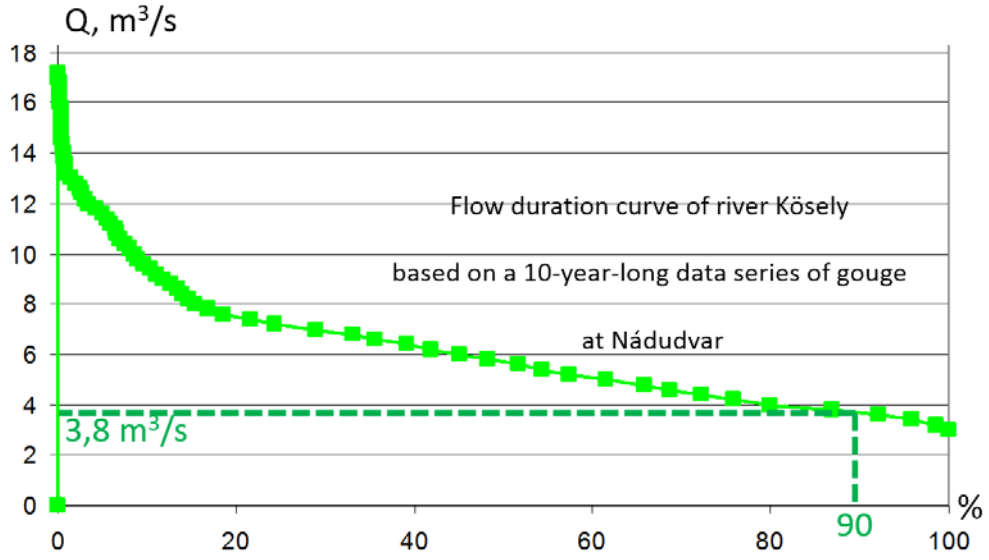


Figure 4. Flow duration curve of river Kösely based on 10-year-long data series of gouge at Nádudvar; Q_{90} = 3,8 m^3 /s

3.1.2. Quality data

3.1.2.1. RBMP status assessment

According to the ecological status assessments of investigated surface water bodies in the national river base management plan (HunRBMP, 2016) both the physico-chemical quality and the ecological status are bad and moderate on the reaches loaded with used thermal waters (Figure 5). The ecological balance is maintained by prevention of pollution so the exceedances in pollution means that there is no balance.

The physico-chemical quality of the irrigation canal carrying the water of river Tisza is high. Also, the water flow types are given in the OVGT, these are 16, 17, and 18 for the investigated waterways.

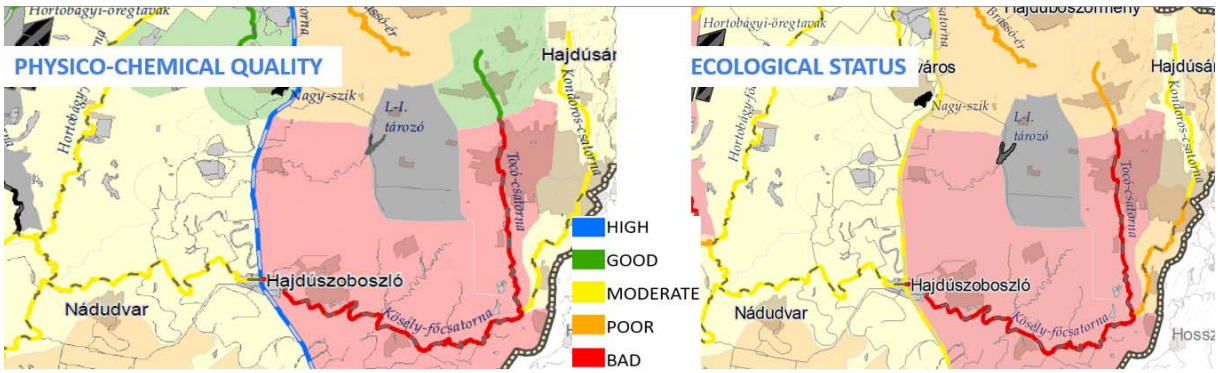


Figure 5. The physico-chemical quality and the ecological status of water bodies in the study area, (HUN RBMP, 2016)

3.1.2.2. Salinity of the water ways in the catchment – own measurements

Salinity of the water ways in the catchment at eleven sampling sites on river Kösely, Tócó and Kondoros was measured on twenty-eight occasions in a one year-long period in 2008. (Hancz, 2010). According to these measurements

- the averages of measured EC values at every sampling site exceeded the limit value for EC regarding the requirements against irrigation water
- the smallest among the averages of measured EC values at every sampling site was 801 µS/cm, a bit above the limit value for EC regarding the requirements against irrigation water, which is 780 µS/cm

3.1.2.3. Abstracted thermal water quality data

Salt content of abstracted thermal waters in the study area are available expressed in Electric Conductivity, but in order to develop he material flow diagram these data are converted into TDS values (Table 1).

	EC [µS/cm]	TDS [g / m^3]
Debrecen	7417	5433
Hajdúszoboszló	2800	1554
Nádudvar	3210	2039

Table 1. Salt content expressed in TDS (Total Dissolved Solids) and Electric Conductivity

3.1.3. Thermal water abstraction data

Volume of abstracted thermal waters in three towns on the investigated catchment in year 2008 are presented in Table 2, Figure 6. The source of the data is the Water Authority. According to the study of VITUKI (2005) and OVGT (2016) the thermal water aquifers - having low renewal rate - below the catchment are overexploited such as several others in the country. The ongoing investigations may bring new and more detailed results.

	DEBRECEN	HAJDÚSZOBOSZLÓ	NÁDUDVAR	
ANNUAL VOLUME OF ABSTRACTED THERMAL WATER, m^3	616 416	1 747 620	127 833	∑ 2 491 869

Table 2. Volume of abstracted thermal waters in the investigated catchment in year 2008.

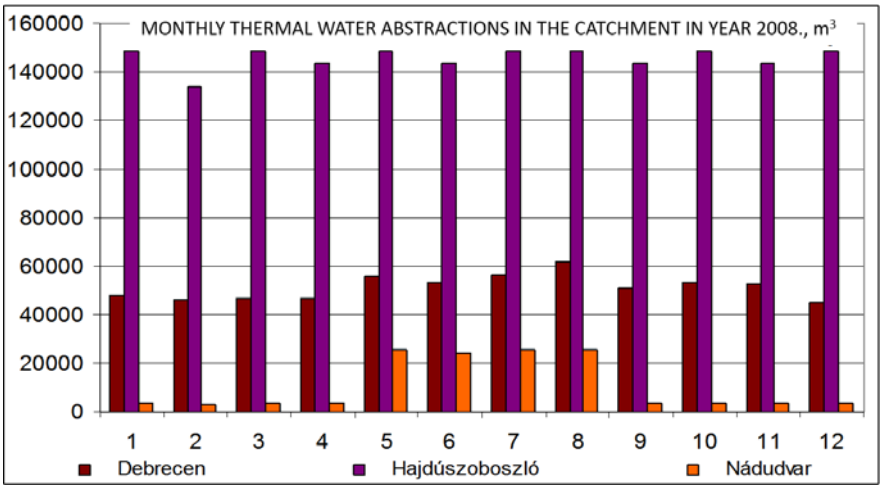


Figure 6. Monthly thermal water abstractions in the catchment in year 2008., m^3

4. RELEVANT ENVIRONMENTAL STANDARDS REGARDING SALT CONTENT

4.1. Limit values for salt content in irrigation waters

Standards regarding salt content in waters are meant to ensure that using it for irrigation will not cause accumulation of salts in the soil. It remains an essential issue since demand for irrigation water is growing in Hungary. According to VÁRALLYAI et al., (1936) the salt content of irrigated soils are not expected to grow if the TDS in the irrigation water remain below 500 mg/l (EC <780 µS/cm).

4.2. Limit values for water pollutants in surface waters

Adverse impacts of salts in surface waters beyond a limit are already known (Hancz, 2004)

The Commission establishes environmental quality standards in Decree No. 10 of 2010 (VIII. 18) VM so as to limit the concentrations of certain chemical substances that pose a significant risk to the environment or to human health in surface waters in the European Union environmental Quality Standard is

< 1200 µS/cm for water flow type 16, 17 – Tócó below thermal water discharge and Kösely.

< 1000 µS/cm for water flow type 18 - Tócó above thermal water discharge and Kondoros.

4.3. Technology-based effluent limitations

Technology-based effluent limitations (Table 3) are applied for effluents of baths of balneology and thermal bath purposes in case of discharging into a recipient. The Commission establishes effluent quality standards in Decree No. 28 of 2004 (XII. 25) KvVM of the Ministry of Environmental Protection and Water Management concerning emission standards of water-pollutant substances so as to control polluting activities.

effluent VARIABLE	**UNIT**	energetic usage	**balneology**	**thermal bath**
total salt content	**mg/l**	3000	**5000**	**2000**
temperature	°C	30	**30**	**30**

Table 3. Technology based effluent standards to be applied for discharging into a recipient (Decree No. 28 of 2004 (XII. 25) KvVM)

4.4. Non-technology-based effluent limitations

Non-technology-based effluent limitations (Table 4) are applied for effluents containing salts of any technology having no technology based effluent standards in case of discharging into a recipient.

effluent VARIABLE	UNIT	not intermittent recipient	intermittent recipient
total salt content	mg/l	-	2000
temperature	°C	technology based effluent standards accepted	

Table 4. Non - technology based effluent standards to be applied for discharging into a recipient (Decree No. 28 of 2004 (XII. 25) KvVM)

4.5. Effluent standards to be applied for discharging into the sewage system

Conservative pollutants found in wastewater are not changed while passing through the treatment processes in a conventional wastewater treatment plant. This type of pollutant may be removed by the treatment processes and retained in the plant's sludges or it may leave in the plant effluent.

Salts are not conventional pollutants typical of municipal sewage and for which municipal secondary treatment plants are typically designed. That is why the possible adverse impacts are investigated and reported in the literature. These reports about the effects that salinity has on the performance of microorganisms in biological processes treating wastewater are contradicting. (Mostafa et.al,2006).

Effluent standards to be applied for discharging into the sewage system (Table 5) are applied for effluents containing salts of any technology having no technology based effluent standards in case of discharging into a sewage system.

effluent VARIABLE	UNIT	not intermittent recipient	intermittent recipient
total salt content	mg/l	2500	2500
temperature	°C	40	40

Table 5. Non - technology based effluent standards to be applied for discharging into a sewage system (Decree No. 28 of 2004 (XII. 25) KvVM)

5. CALCULATIONS

5.1. Runoff calculations

The Q_{90} = 3,8 m^3 /s discharge is divided among the 7 reaches of the river channel, based on the influencing factors like the areas of the sub-catchments, the design-flow of excess-water discharge on the reaches and the ten years-long series of rain data (Table 6).

	KÖSELY		TÓCÓ		KONDOROS	
	BELOW	ABOVE	BELOW	ABOVE	LOWER REACH	UPPER REACH
	HAJDÚSZOBOSZLÓ DISCHARGE		DEBRECEN DISCHARGE			
AREA OF THE CATCHMENT, km^2	241,04	453,8	97,42	88,61	39,3	133,84
VOLUME OF ANNUAL RUNOFF, m^3/y	6026000	11345000	2435500	2215250	9825000	334600
CUMULATIVE VOLUME OF RUNOFF, m^3/y	26350250	20324250	4650750	2215250	4328500	3346000

Table 6. Estimated runoff volumes for seven reaches in the catchment

5.2. Calculation of salt flows

	DEBRECEN	HAJDÚSZOBOSZLÓ	NÁDUDVAR	∑
ANNUAL VOLUME OF ABSTRACTED THERMAL WATER, m^3	616416	1747620	127833	2491869
WEIGHTED EC, µS/cm	7418	2973	3210	
WEIGHTED TDS, g/m^3	5433	1554	2039	
VOLUME OF SALT FLOW, t/y	40,19	32,59	3,13	75,9

Table 7. Salt flows deriving from the three discharges in t/y

In spite of the fact that the highest volume of thermal water is abstracted in Hajdúszoboszló, the greatest salt mass is flowing from Debrecen (Figure 7), (Table 7). It also indicates that measures could be most effectively implemented in Debrecen.

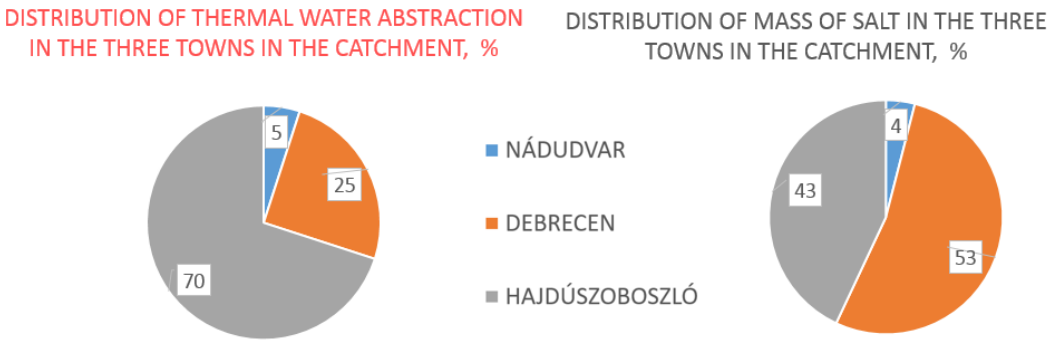


Figure 7. Distribution of thermal water abstaractions and respective salt masses in the river Kösely catchment

A more accurate assumption of the origin of salt is provided in Figure 8 introducing the processed data of salt content in different types of wastewater. It is evident that the saltload connected to sewage can be explained with the practice of discharging thermal waters into the sewage system however sewage itself contains TDS of about 100-200 g/m^3 (Uvidia et.al,2013).

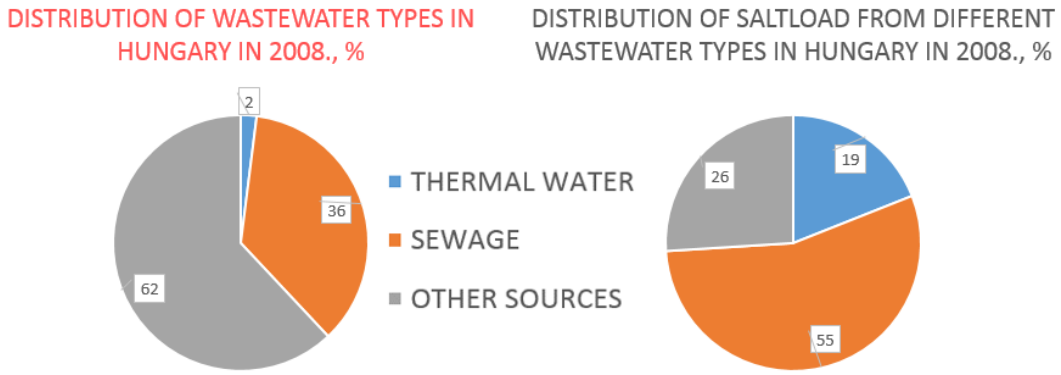


Figure 8. Distribution of wastewater types and respective salt contents in Hungary (processed data from HUN RBMP, 2016)

5.3. Salt and water flow diagram

There is an anthropogenic and a natural flow of salts. Natural salt flow is calculated on the basis of background concentrations of salt in the water of river Tócó above thermal water discharging. Salinity of Tócó above the discharge was measured on twenty-eight occasions in a one year-long sampling period. The average which can be considered as background concentration was 1050 µS/cm (Hancz, 2010). Figure 9 summarizes all the water and salt flows. In- and outflows are balanced since there is no significant stock of either materials.

1050 µS/cm ≈ 1050 · 0,5 mg/l = 525 mg/l = 525 g/m^3

The natural salt flow is therefore 525 g/m^3 · 26350 m^3 = 13, 833 t

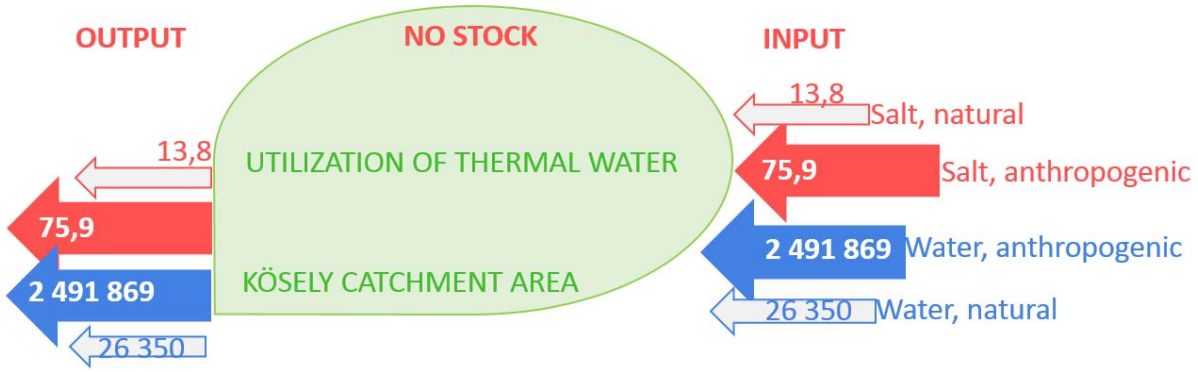


Figure 9. Anthropogenic and natural annual salt and water flow in the catchment of river Kösely in tons for the year 2008.

6. SUSTAINABILITY ASSESSMENT

Assessment of how the current water management practice meets sustainability criteria is carried out in this chapter based on the results so far. Meeting the following five criteria (OECD, 2000) of sustainable water management would prove that it is sustainable.

6.1. Anthropogenic salt flow must not exceed the natural salt flow

The ratio of the anthropogenic and the natural salt flow is 75,9/ 13,833 = 5,5 which means that the anthropogenic salt flow is more than five times bigger than the natural flow. This criterion is not met.

6.2. Anthropogenic processes and their impacts should be reversible

It needs no investigation to declare that the process of anthropogenic salt flow is irreversible. This criterion is not met.

6.3. Anthropogenic loads must not exceed the natural assimilation capacity of the recipients

Quality data (3.1.2.1., 3.1.2.2.) indicates that the desired water quality (4.2.) is not met in the catchment below thermal water discharges which proves that this criterion is not met.

6.4. Unrenewable natural resources are not overexploited

The thermal water aquifers - having a very low renewal rate - below the catchment are overexploited (3.1.3.) so this criterion is not met.

6.5. Stocks of toxic or otherwise harmful materials are not accumulated in the environmental elements.

This criterion is supposed to be met but it needs investigations. Salts being soluble and conservative pollutants are not expected to settle in the sediment or accumulate in another pathway.

7. FINDINGS AND INTERPRETATION

The objective of the paper was to assess the sustainability of the current practice of thermal water management in the catchment of river Kösely. According to five criteria it is not sustainable.

The ratio of the anthropogenic salt flow significantly exceeds the natural one although we have not considered wintertime deicing salt use.

The processes and their impacts are not reversible since the salt flows cannot be reversed even with technical measurements.

Anthropogenic loads exceed the salt-assimilation capacity of the water bodies which is proven by the quality assessed in the RBMP and by own measurements introduced elsewhere. Furthermore, the year of investigation was two per cents rainier than an average year, that is, the measured values of electric conductivity would probably be higher in drier years. Dilution may decline in the future if green infrastructure measures will be implemented to cope with extreme storm water events.

Also, the extent of temporary rivers is increasing, as many formerly perennial rivers are becoming temporary because of increasing water demand. Kösely and Tócó are not intermittent rivers, partly because being under the influence of artificial impacts like introduction of irrigation water, and partly because being the recipients of treated sewage. In natural conditions Tócó would be an intermittent river.

The exceedances in pollution means that there is no ecological balance.

Thermal waters are not unrenewable but the renewal rate is very low.

The rate of abstraction is higher which is not a sustainable practice regarding quantity aspects.

8. CONCLUSION AND SUGGESTION

Further researches in order to develop available technologies to remove salts from used thermal waters is inevitable. Pressure is expected to grow with the realization of global warming and accompanying demand for more irrigation water.

Alternative measures of discharge (Hancz et.al, 2010) may also be taken into consideration.

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