POSSIBILITIES OF IMPROVING SALT-RELATED WATER QUALITY ON A HUNGARIAN RIVER

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Abstract

The purpose of the study was the assessment of the salt related quality of river Kösely and its tributaries and to determine with calculations whether it is feasible to achieve improvement of the demonstrated water quality by the means of dilution in the frame of a PhD study. Besides data collection a series of twenty-eight Electrical Conductivity measurement was carried out at thirteen sites along the river system. The resulting EC values all year long on every reach of the river exceeded even the tolerable values specified as irrigation water quality criteria and water quality standards in the Water Directive. In the paper we introduce the results of the survey along with authority surveillance data series from earlier years. Investigations in the water using anthropogenic activities causing this special water quality problem were also carried out and the results – quantitative and qualitative aspects as well – are introduced here. Since the pollutant is a conservative material, the calculations were performed using the simple dilution equation which is based on the law of conservation of mass. The findings of the calculations were the identification of those reaches of the river system where adequate water quality can be achieved by dilution considering the limiting factor of water delivery capacity. Our conclusion is that under current conditions of water management and water using activities there is no way to meet quality requirements with dilution. This can be achieved only by prevention or reduction of salt load.

Key words: *dilution of surface water, EC values, meet environmental quality standards, conservative pollution, irrigation water*

1. INTRODUCTION

Due to salt polluting activity of thermal bath operation the salt pollution turns the investigated water body inappropriate for irrigation. Since there exist no BAT for removing salts from used thermal waters, the possible response activity mean actions implemented to reduce directly the salt content of the water body (Peter, K., 2004.).Direct influence is a water quality control measure which is not considered a treatment but a control measure - namely dilution - which can be accepted when no best technology is available (BAT). Another reason to consider this measurement is that the only means of natural self-purification in case of high salt loads is dilution since salts are conservative pollutants that tend to be stable compounds that persist within the environment.

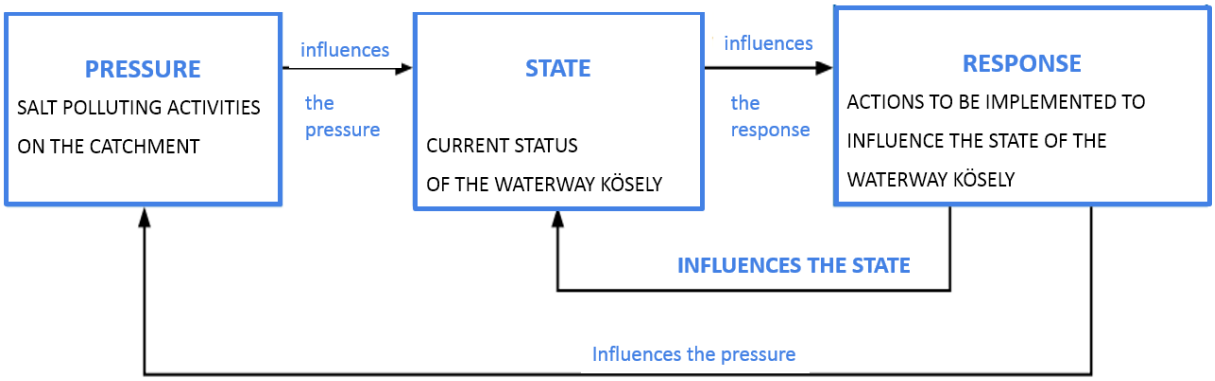

Figure 1. Pressures on irrigation water resources and response actions influencing the state of the water body

The objective of the paper is to identify the required amount of dilution water in order to restore the irrigation water status of the water body and to attain established Water Framework Directive (WFD) targets. Along with the identification of the required amounts of dilution water for each reaches of the compliance of the river channel capacity to carry the total calculated flow discharge will be surveyed.

During the calculations accounting of water available for dilution, sources of pollution and the effectiveness of such water quality measure in case of available water for this purpose are not considered (Figure 1.).

2. THE STUDY AREA

The study area is the river Kösely (Figure 2). One existing dilution possibility is provided by the irrigation canal. An alternative, theoretically possible dilution possibility is taken into account at 60+900, the ending section where two tributaries confluence with river Kösely. Four sampling sites are located on the river. The direct catchment area is 702 km^2, the total area including the catchment of the tributaries is 1067 km^2.

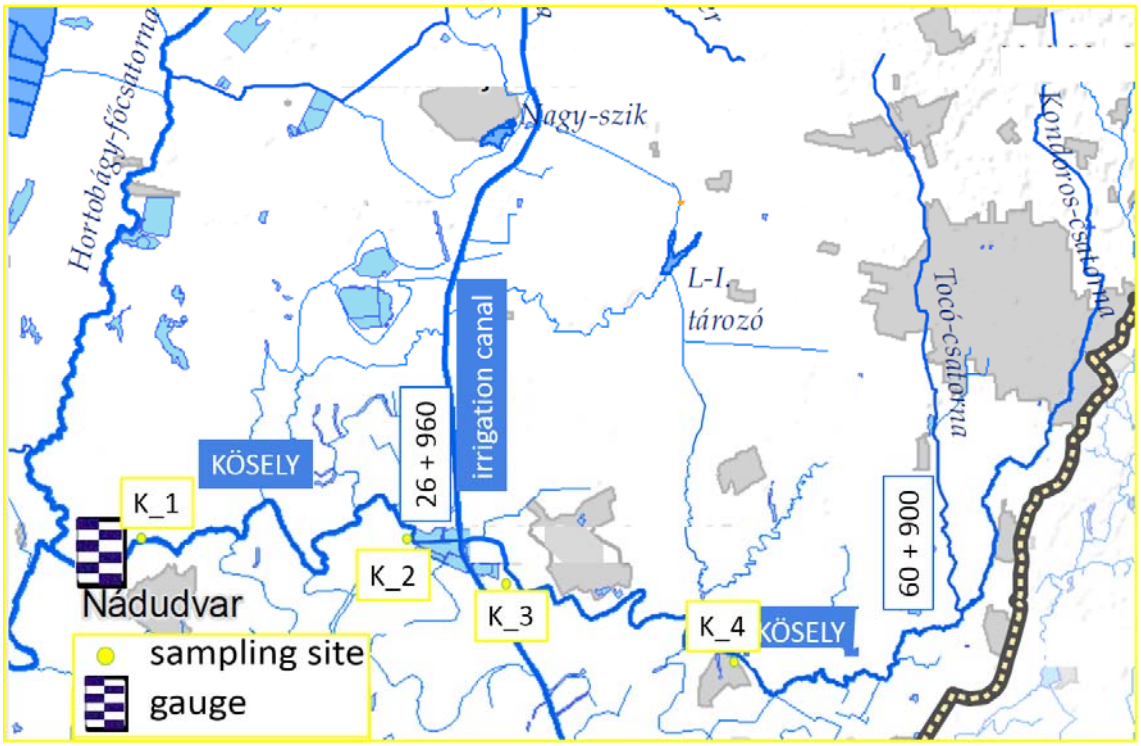

Figure 2. The study area of river Kösely, Hungary, Danube River Base

3. METHOD

3.1. Primary data collection

3.1.1. Hydrologic data, watershed characterization

- We could use an artificial gauged statistics - the river is artificial since the flow is influenced by diversions and water inlets through several control structures 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 3.). This Q_{90} = 3,8 m^3 /s value of discharge is considered to be the critical low flow for the calculations of dilution water requirement.

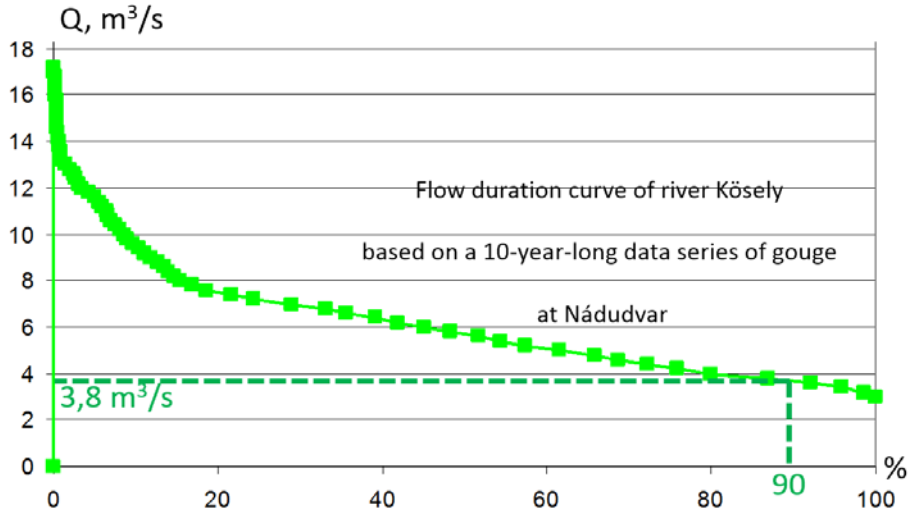

Figure 3. Flow duration curve of river Kösely based on 10-year-long data series of gouge at Nádudvar; Q_{90} = 3,8 m^3 /s

3.1.2. Design 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 design channel capacity (Table 1.).

KÖSELY REACHES			sampling site	channel capacity, m^3/s
1	00+000	11+980	K_1	15,9
2	11+980	26+870	K_2	7,2
3	26+870	31+210	K_3	5
4	31+210	43+000	K_4	5
5	43+000	48+470	K_4	5
6	48+470	51+000	K_4	9,5
7	51+000	60+900	K_4	9,5

Table 1. Channel design capacity of reaches of river Kösely in m3/s (source: State water authority)

3.1.3. Quality data

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 along with the ecological status are moderate below the irrigation canal and bad above it. The physico-chemical quality of the irrigation canal carrying the water of river Tisza is high.

3.2. Salinity of the water body – 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 described by (Figure 4.)

- the capacity of the river to receive salts has already been exceeded
- 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
- EC values are significantly higher above the irrigation canal and in Tócó which latter is the recipient of salty thermal waters from a spa in Debrecen.

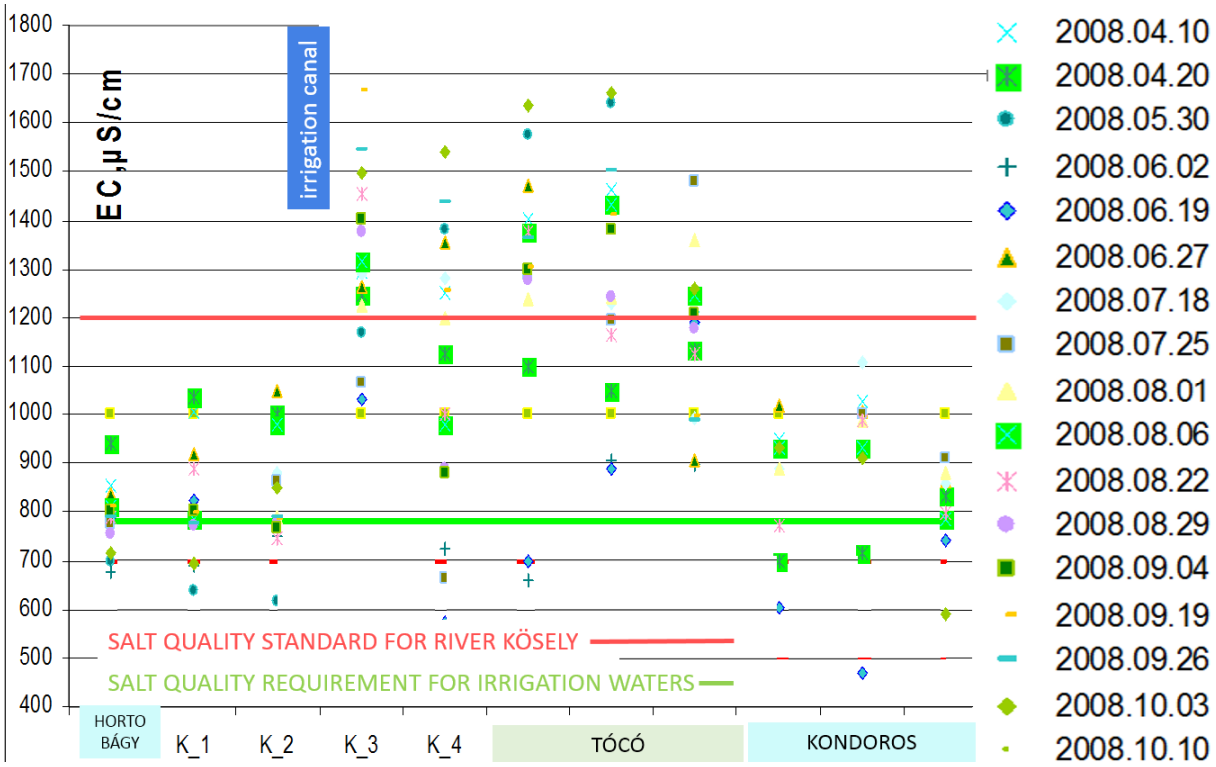

Figure 4. Longitudinal variation of measured Electric Conductivity values on seventeen dates within the vegetation period on river Kösely and its tributaries (Hancz, 2010.)

3.3. Relevant environmental standards regarding salt content

3.3.1. 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).

3.3.2. 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 Kösely which is water flow type17 (HunRBMP, 2016.).

3.4. Calculations

3.4.1. Application of the dilution equation

Considering a river and an effluent discharge with flows and concentrations not varying in time and assuming instantaneous full cross-sectional mixing of effluents with the river water the initial concentration C_o downstream of an effluent outfall can be calculated by the dilution equation, which stems from the balance equation of in- and outflowing fluxes written for the section of the discharge point (e.g. background river mass flux plus pollutant discharge mass flux equals the combined mass flow downstream of the point of discharge). This equation is used very frequently in simple analytical water quality models for calculating the initial concentration of pollutants.

$C_o = (C_e \cdot q_e + C_r \cdot Q_r) / (q_e + Q_r)$, where

C_r -background concentration of the polluting substance in concern in the receiving water body, (mg/l);

C_e - concentration of the pollutant in the effluent (waste) water, (mg/l);

Q_r- discharge (rate of flow) of the receiving water body upstream of the effluent outfall, (m^3/s);

q_e- the effluent discharge, (m^3/s);

The same equation with other meanings of the variables in it is used:

$C_i = (C_d \cdot q_d + C_r \cdot Q_r) / (q_d + Q_r)$, where

C_r -background content of salts in the receiving water body expressed in EC (µS/cm);

C_d - content of salts in the dilution water expressed in EC (µS/cm);

C_i – maximum content of salts in the irrigation water expressed in EC (µS/cm)

Q_r - discharge of the receiving water body upstream of the section of dilution water inlet, (m^3/s);

q_d - the dilution water discharge, (m^3/s);

3.4.2. Representing the critical conditions

Flow rate

Calculation of Q_r which is the discharge of the receiving water body upstream of the section of dilution water inlet in m^3/s is already carried out in 3.1.1.. Q_{90} = 3,8 m^3 /s is considered to be the critical low flow for the calculations of dilution water requirement. This represents the environmentally critical

conditions. This value needs to be distributed among the 7 reaches of the river having different design variables (Table 1.).

The following factors of proportionality were taken into consideration in the course of distributing the critical flow:

- design channel capacity
- precipitation height based on the data series of the closest precipitation gauges
- Q_{90} = 3,8 m^3 /s includes the sewage effluent of the towns discharging into Kösely
- $Q_{febr.}$ = 2.99 m^3 /s measured discharge value in February was closest to Q_{90}

Quality

The following factors were taken into consideration in the course of calculating the required amount of dilution water:

- Measured EC values in February, when flow rate was closest to Q_{90} represent the best the critical environmental condition for which required dilution water amounts were calculated.
- Salt related Quality requirement of irrigation water is C_i < 780 µS/cm
- Salt related Quality requirement of water quality according to WFD is C_i < 1200 µS/cm
- C_d = 497 µS/cm

3.4.3. Calculating the required amount of dilution water

The calculation of the required amount of dilution water for each reaches of Kösely and matching the results with the channel capacity is carried out using the dilution equation

$q_{d,i} = (C_r \cdot Q_r - C_i \cdot Q_r) / (C_i - C_d)$, where

C_i = 780 µS/cm

and

$q_{d, WFD} = (C_r \cdot Q_r - C_{WFD} \cdot Q_r) / (C_{WFD} - C_d)$, where

C_{WFD} = 1200 µS/cm (Table 2.)

The results of calculations are in columns 5-10 of Table 2.

Column 5 concludes the required amount of dilution water in case of Q_{90} and considering maximum accepted salt content in irrigation water.

Column 7 concludes the summation of Q_{90} and the required amount of dilution water.

Column 9 concludes those reaches of Kösely where the channel capacity is compromised by the summation of Q_{90} and the required amount of dilution water. Four reaches cannot carry the needed amount of water.

Column 6, 8 and 10 concludes the same results considering water pollution standards settled in the Water Framework Directive. Since this requirement is more manageable, it can be carried out on each reaches of Kösely.

1	2	3	4	5	6	7	8	9	10
reaches of KÖSELY	design flow	critical flow	critical EC	q_d irr. w. q.	q_d WFD q.	∑ Q diluted	∑ Q diluted	comprimising channel flow	
	m^3/s	m^3/s	µS/cm	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s
1	15.90	3.80	1131	4.71	-0.37	8.51	3.43	7.39	12.47
2	7.20	3.30	1204	4.94	0.02	8.24	3.32	-1.04	3.88
3	5.00	3.08	1493	7.76	1.28	10.84	4.36	-5.84	0.64
4	5.00	2.87	1493	7.23	1.20	10.10	4.07	-5.10	0.93
5	5.00	2.61	1258	4.41	0.22	7.02	2.83	-2.02	2.17
6	9.50	2.40	1258	4.05	0.20	6.45	2.60	3.05	6.90
7	9.50	2.02	1258	3.41	0.17	5.43	2.19	4.07	7.31
C_d = 497 µS/cm									
C_i = 780 µS/cm									
C_{WFD} = 1200 µS/cm									

Table 2. Calculated dilution water requirement for critical conditions of Q_{90}

4. INTERPRETATION OF THE RESULTS

On the reaches 2-3-4-5 the water quality of river Kösely cannot be improved enough to achieve irrigation water quality by means of dilution (Figure 5.).

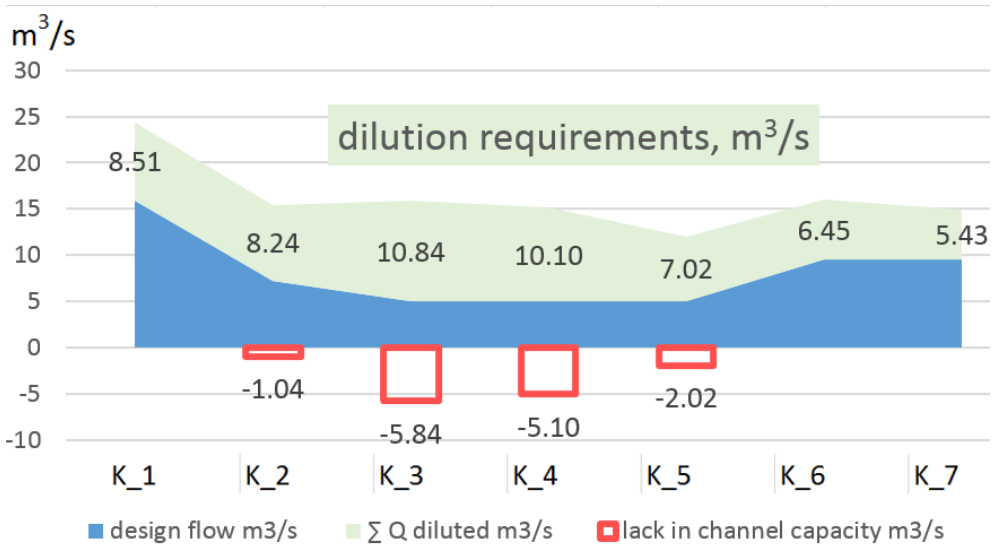

Figure 5. Representation of required amounts of dilution water matched with channel capacity in case of Q_{90} and considering maximum accepted salt content in irrigation water

The investigation was carried out without considering the amount of available dilution water. However, the results demonstrate that even in case of such resources the channel capacity would make it impossible to implement the measure of dilution into practice.

On the other hand, the environmental quality standard for salt content expressed in EC can be met by the measure of dilution (Figure 6.).

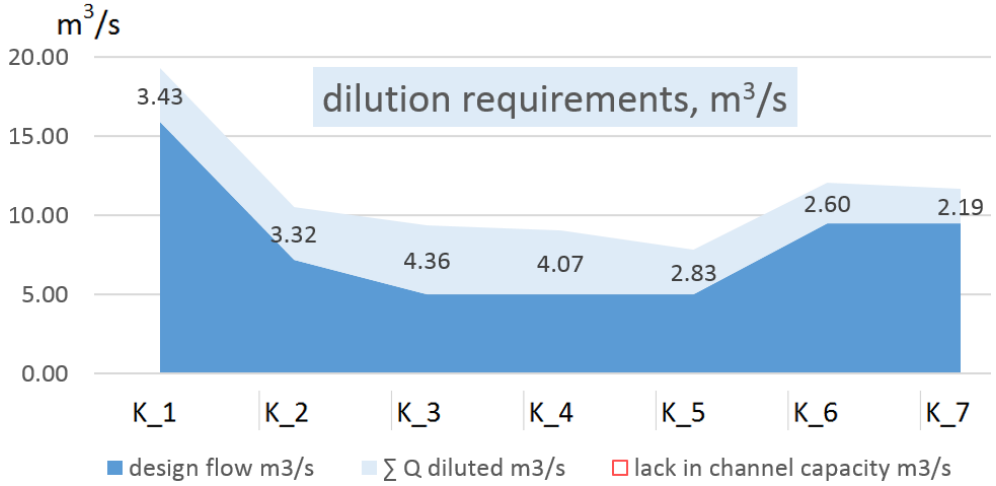

Figure 6. Representation of required amounts of dilution water matched with channel capacity in case of Q_{90} and considering water pollution standards settled in the Water Framework Directive

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