Comparison of different impact based guidelines for CSOs in the Benesov case study, Czech Republic

Comparaison de différentes règles pour les déversoirs d'orage basées sur l'évaluation de leurs impacts: étude de cas à Benesov, République Tchèque

Kabelkova I., Stastna G. and Stransky D.

Czech Technical University, Faculty of Civil Engineering
Department of Sanitary and Ecological Engineering
Thakurova 7, 166 29 Praha 6, Czech Republic
kabelkova@fsv.cvut.cz; stastnag@fsv.cvut.cz; stransky@fsv.cvut.cz

RÉSUMÉ

Trois méthodes ont été utilisées afin de comparer les résultats d'analyse des impacts des déversoirs d´orage de plusieurs cours d'eau en Allemagne, Autriche et Suisse. Une étude a été réalisée sur la ville de Benesov, en République Tchèque (14000 habitants, 125 ha_{red}, 7 déversoirs d'orage). L'évaluation numérique, biologique et écologique porte sur l'état actuel mais aussi sur la possibilité d'élargissement du circuit, tout en respectant la limite usuelle de dilution de 1:5. Les trois approches convergent vers la même estimation. Elles révèlent une perturbation hydraulique du cours d'eau au niveau du premier déversoir. Mais grâce à son faible pH, le déversement qui suit la pluie n'engendre pas d'importants impacts sur la qualité de l'eau. Seule la directive suisse a relevé une accumulation des substances insolubles habituelles. Les conditions des macroinvertébrés se sont détériorées sous les déversoirs et surtout au niveau des collecteurs N° 6, 2 et de la station d'épuration. Cependant, le profil de référence situé en amont de Benesov montrait déjà de mauvais indicateurs biologiques. A cette dégradation s'ajoute la régulation entre le déversoir N° 3 et la station d'épuration. Quand bien même on régulerait les facteurs chroniques, on ne saurait améliorer la dégradation hydraulique ni ses facteurs aigus, qui n'ont pas pour autant dépassé les limites.

ABSTRACT

In this paper results of the application of three impact-based guidelines for CSOs (German, Austrian and Swiss) are compared in the Benesov case study (14 000 inhabitants, 125 ha_{red}, 7 CSOs). Both the present state as well as the outlook situation after the connection of further subcatchments designed traditionally to comply CSO dilution ratio 1:5 were assessed. The numerical assessment was enhanced for the biological-ecological evaluation of Benesovsky Creek. All three guidelines applied give the same statement: Benesovsky Creek suffers from significant hydraulic stress already below the uppermost CSO, however, CSO discharges do not cause considerable acute water quality impacts thanks to the low pH. Only the Swiss guideline identified problems with turbidity and accumulation of suspended solids in the streambed agreeing with the field survey. The biological-ecological assessment of Benesovsky Creek confirmed the gradual degradation of the benthic invertebrate community below each CSO outlet. However, the stream biological status is poor already above Benesov and also the channel regulation between CSO3 and WWTP takes part on its deterioration. The planned measures are going to bring a significant reduction of the chronic pollution loading of Benesovsky Creek, however, the hydraulic stress will remain nearly the same and acute water quality impacts will become slightly more significant (but EQS will not be violated).

KEYWORDS

Acute pollution, combined sewer overflow, hydraulic stress, impacts, receiving water.

1 INTRODUCTION

In the Czech Republic the assessment of combined sewer overflows (CSOs) is not at a satisfactory level as appropriate legislation and guidelines are missing. So far usually very simple emission criteria regarding CSO discharges as the dilution ratio or critical rainfall intensity had to be met (with some exceptions of big cities as Prague and Brno where more sophisticated criteria are used). Thus, foreign approaches have been studied to become possibly a basis for the Czech legislation. In this paper three impact-based guidelines for CSOs (German, Austrian and Swiss) are compared in the Benesov case study. The environmental quality standards (EQS) used in these guidelines focus on hydraulic stress caused to the receiving water biocenosis by CSO spills and on acute impacts on water quality in terms of increased un-ionized ammonia and suspended solids concentrations and of dissolved oxygen depletion (the Swiss guideline involves chronic impacts of suspended solids as well).

This paper presents a study with the aim to:

- compare the meeting of different emission criteria and environmental quality standards for CSOs in Benesov,
- validate the indirect numerical evaluation by the biological-ecological assessment of Benesovsky Creek and check if problematic sites have really been identified,
- predict the efficiency of protective measures designed by a traditional General masterplan based on dilution ratios for the future situation from the impacts point of view,
- discuss the applicability of the different guidelines and criteria in the Czech Republic.

2 METHODS

2.1 Study catchment

Benesov town is situated in the middle of the Czech Republic on Benesovsky Creek (Tab. 1), which belongs among salmon waters. However, its water quality is poor as most of the water quality parameters below Benesov range to the lowest classes IV and V. The bedrock is formed by silica.

Tab. 1 N-year and m-day flows in Benesovsky Creek

N (year)	**1**	**2**	**5**	**10**	**20**	**50**	**100**						
Q ($m^3 s^{-1}$)	5,9	8,3	12,0	15,0	18,2	22,8	26,5						
m (day)	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**355**	**364**
Q ($l s^{-1}$)	210	148	116	95	79	66	56	47	39	31	23	14	8

Benesov is drained by a combined sewer system serving 14 245 inhabitants. The urban catchment reduced area equals 125 ha. Stormwater is relieved by 7 CSOs to Benesovsky Creek. CSO2 and CSO6 have a common outlet with the wastewater treatment plant (V2) (Fig. 1). The prescribed dilution ratio[1] 1:5 is not met only at CSO7 (1:4.8) according to the General masterplan from 2007.

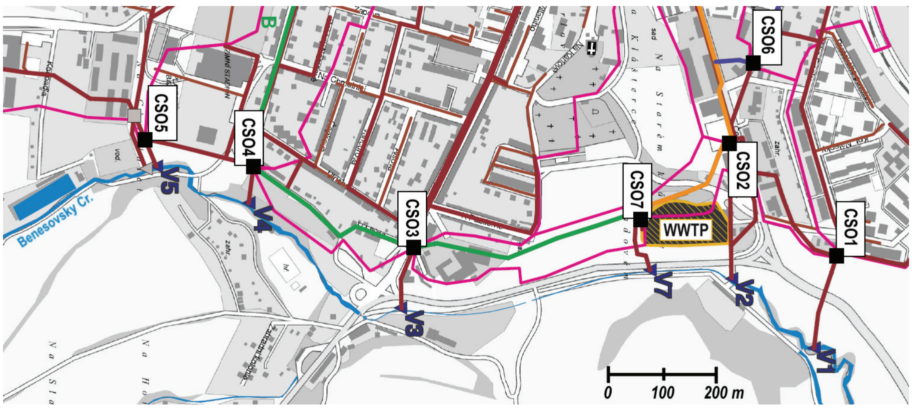

Fig. 1 CSO outlets to the Benesovsky Creek

[1] Dilution ratio in the Czech Republic is related to the sum of the peak hourly wastewater discharge and infiltrated water.

In the future wastewaters from subcatchments drained by a new separate sewer system will be connected to the present combined system (especially at subcatchments of CSO5 and CSO6) resulting in a dilution ratios decrease. CSO5, CSO6 and CSO7 would not comply with the prescribed value markedly whereas CSO1, CSO2 and CSO3 would meet it only very tightly. Thus, according to the General masterplan weirs at CSO6, CSO2 and CSO1 are to be heightened, trunk sewer diameter increased and a stormwater tank (1800 m^3) at CSO7 built.

2.2 German approach

2.2.1 Emissions

Commonly used emission criterion in Germany is the mean specific annual COD load discharged by individual CSOs, which is not allowed to be higher than 250 kg ha_{red}^{-1} (Sieker, 2004). We calculated the loads by software tool REBEKAII (Fankhauser et al., 2004) for the Benesov historical rainfall series of years 1996-2005.

2.2.2 EQS

A guideline BWK-Merkblatt 3 (2001) was developed for a rapid assessment of possible violations of environmental quality standards during rainy weather. It combines simulations of the urban catchment with a hydrologic or a hydrodynamic model to determine hydraulic loading and automated calculations in Excel to assess water quality. A more detailed assessment of critical cases can be performed according to the BWK-Merkblatt 7 (2008).

The first step is to define a closed urban area where the CSOs impacts in the receiving water overlap (Tab. 2). The distance of the first and last CSO outlet to the Benesovsky Creek is 1.75 km, thus, the outlets could be assessed all at once. However, we studied both their separate and cumulative impacts on the receiving water as well.

Tab. 2 Maximum distance of CSO impacts in the receiving water (BWK-Merkblatt 3, 2001)

		Mean velocity of the stream ($m\ s^{-1}$)		
		≤0.1	≤0.5	>0.5
Mean water depth (m)	≤0.1	<4 km	4 km	-
	≤0.5	5 km	7 km	10 km
	>0.5	10 km	12 km	-

In order to assess the amount of hydraulic stress, all CSO discharges from the closed urban area having the frequency 1 per year (Q_{CSO1}) have to be summed up and compared with the potentially natural one year flood $HQ_{1,pnat.}$ The ecologically tolerable value of Q_{CSO1} is considered to be 10% of $HQ_{1,pnat}$ (this value can be regionally differentiated in case more information is available). Hence, the stream discharge below the urban catchment is lower than 1.1 $HQ_{1,pnat}$ and approximately equal to Q_2 regarded as the channel-forming discharge accompanied by massive sediment transport. The specific potentially natural one year flood $Hq_{1,pnat}$ can be derived from graphs in the guideline for different natural catchment slopes and sizes (and thus CSO locations). $HQ_{1,pnat}$ is then calculated by multiplication of $Hq_{1,pnat}$ by the area of the natural catchment. The CSO discharges were simulated with the MOUSE programme for the Benesov rainfall series of years 1996-2005.

The assessment of the ambient water quality during rainy weather was performed with the help of Excel sheets, which are a part of the guideline. First, emissions of water and pollutants are calculated for the range of rainfall intensities $q_r = 2^n$ ($l\ s^{-1}\ ha^{-1}$), where n = 1 to 7. The basis is the mixing equation calculated gradually from the uppermost subcatchment. The discharge in the sewer system is the sum of the mean daily wastewater discharge, infiltration, rainfall discharge and throttled outflow from the above-situated CSOs. Pollution of both wastewater and rain water (BOD_5, NH_4^+-N and TSS) as well as the presence of sewer sediments is taken into account (by the increase of BOD_5 and TSS concentrations in the wastewater). Wastewater concentrations in the individual CSOs subcatchments were known from the General masterplan whereas default values were used for the rainwater pollution.

Second, mixing of CSO discharges and the receiving water flow is calculated. In Germany the value of the long-term mean of the lowest daily discharges in the year is used (MNQ), which according to the information of the Czech Hydrometeorological Institute equals Q_{330} to Q_{355}. We used values of 20-25 l s^{-1} for sites above the WWTP and 85 l s^{-1} below the WWTP. The oxygen deficit in the receiving water is calculated by the Streeter-Phelps model combining the deoxygenation due to BOD decay and reaeration. The minimum dissolved oxygen concentration in the stream is not allowed to drop below 5 mg l^{-1}. The maximum admissible concentration of un-ionized ammonia is 0.1 NH_3-N mg l^{-1}. The ammonia concentrations are determined based on NH_4^+-N, pH and water temperature (20°C). pH in the receiving water is calculated from pH and alkalinity of the CSO discharge and receiving water. Mean values of the background concentrations of BOD_5, NH_4^+-N and TSS in the Benesovsky Creek obtained by monitoring in the framework of the General masterplan were used. Values of pH, O_2 and alkalinity originate from our own measurements (Tab. 3).

Tab. 3 Background concentrations in Benesovsky Creek

BOD_5	**NH_4-N**	**TSS**	**pH**	**O_2 deficit**	**alkalinity**
mg l^{-1}	mg l^{-1}	mg l^{-1}	-	%	mmol l^{-1}
3.8	0.7	14	7.6	20	2.3

2.3 Austrian approach

2.3.1 Emissions

Novel of the guideline ÖWAW-Regelblatt 19 (2007) defines CSO emission standards as minimum percentages of annual loads of dissolved and suspended pollutants contained in wet weather flow, which have to be treated biologically at the WWTP. Values of the emission standards depend on the regional rainfall intensity and WWTP size (Tab. 4, interlaying values are interpolated). The minimum drainage efficiencies are not prescribed for individual CSOs but for the whole urban catchment irrespective of the number of receiving water bodies. The efficiencies must be proved by a long-term simulation. At the same time the dilution ratio higher than 1:8 must be reached at individual CSOs.

Tab. 4 Minimum drainage efficiencies (%) of dissolved and suspended pollutants in combined sewer systems in Austria (ÖWAW-Regelblatt 19, 2007)

Rainfall intensity $r_{720,1}$ (mm/ 12 h)	**WWTP size** (IE)			
	≤ 5 000		**≥ 50 000**	
	dissolved pollutants	suspended pollutants	dissolved pollutants	suspended pollutants
≤ 30	50	65	60	75
≥ 50	40	55	50	65

In case a subcatchment drained by foul sewer system is connected to the combined system, the minimum required drainage efficiencies increase as a function of their respective dry-weather flows expressed as inhabitant equivalents (IE) to $5*IE_{separate}/IE_{combined}$ (%), however, the maximum requirement is 65% for dissolved pollutants and 80% for suspended pollutants.

At present minimum 52% of dissolved pollutants (i.e. stormwater runoff) and 67% of suspended pollutants should be carried to the WWTP in Benesov during wet-weather (assuming $r_{720,1}$ ≤ 30 mm/ 12 h). In future after the connection of the separate system the requirements increase to 53.5% and 68.5%, respectively.

The real efficiencies were calculated based on the volume of stormwater runoff and volume of stormwater discharged through CSOs obtained by the simulations using the MOUSE programme for the Benesov rainfall series and assuming the sedimentation efficiency of the stormwater tank of 40% as following:

$$\eta_r = \frac{V_{Q_r} - V_{Q_{CSO}}}{V_{Q_r}}.100 \qquad \eta_{SS} = \eta_r + \frac{V_{Q_{CSO,tank}}.\eta_{sed}}{V_{Q_r}}$$

η_r, η_{SS}, η_{sed} efficiencies of the drainage of dissolved pollutants/stormwater runoff, suspended pollutants and sedimentation (%)

V_{Qr}	annual volume of stormwater runoff in the combined system (m³ a^{-1})
V_{QCSO}	annual volume of the stormwater discharge from CSOs (m³ a^{-1})
$V_{QCSO,tank}$	annual volume of the stormwater discharge from the stormwater tank (m³ a^{-1})

2.3.2 EQS

Environmental quality standards prescribed for rainy weather by ÖWAW-Regelblatt 19 are similar to those in the German BWK-Merkblatt 3.

Hydraulic stress: The maximum stormwater discharge from CSOs with the frequency 1 per year should not be higher than 10-50% of the one-year flood HQ1 in the receiving water. Thus, the number of natural streambed erosion events would not probably double and no substantial impacts on the biocenosis would be caused. The lower value applies to waters with predominantly sandy-clay streambed, low variability of the channel width and low potential of recolonization of disturbed stretches by aquatic organisms, whereas the higher value concerns waters with gravel bed, high variability of the channel width and high potential of recolonization. For most of the Benesovsky Creek the value of 10% is valid except for the lowest part (below CSO2) where 50% can be accepted (see chapter 3.3 and Tab. 7). The values of HQ1 were considered the same as in the German approach.

Ambient water quality: In order to exclude acute ammonia toxicity, even a short-term (1 hour) exceeding of NH_4^+-N concentration of 2.5 mg l^{-1} is not allowed for salmon waters and of 5 mg l^{-1} for carp waters. So, even at pH=8 a T=20°C concentrations of NH_3–N 0.1 mg l^{-1} and 0.2 mg l^{-1}, respectively, are not reached. The NH_4^+-N concentrations are to be calculated for different CSO discharges and receiving water flows by a mixing equation. Thus, results from the Excel calculations according to the German approach can be taken over. As Benesovsky Creek belongs among salmon waters, exceeding of NH_3–N=0.1 mg l^{-1} was looked at. Oxygen concentrations in river water are not allowed to drop below 5 mg l^{-1} due to the overflow. Modelling is considered very uncertain, thus, a possible oxygen deficit is to be examined by a field research.

2.4 Swiss approach

2.4.1 Emissions

CSO emissions are according to the VSA guideline STORM (2007) limited by the maximum allowed annual overflow duration, specific overflow volume and number of overflows depending on the receiving water type (Tab. 5). The emission standards compliance has to be proved by a long-term simulation of regional rainfall series or by measurement.

Tab. 5 Emission standards for CSOs in Switzerland (VSA - STORM, 2007)

Receiving water type	**Overflow duration** (h a^{-1}) *indicative parameter*	**Specific overflow volume** (m^3 ha$_{red}^{-1}$) *decisive parameter*	**Number of overflows** (n a^{-1}) *indicative parameter*
Spring	<1	<180	<5
Small stream in the middle land	<4	<450	<15
Small stream in the Alps foreland	<4	<450	<15
Big stream in the middle land	<5	<650	<20
Big stream in the Alps foreland	<5	<650	<20
Bigger stream	<9	<770	<30
Big river	<12	<870	<35

Benesovsky Creek belongs to the category “small stream in the middle land”. Calculation of the emissions was performed with the MOUSE programme for the Benesov rainfall series.

2.4.2 EQS

Hydraulic stress in receiving waters is according to the VSA guideline STORM (2007) limited by a maximum admissible annual number of overflows causing streambed erosion, which is differentiated in dependence on the stream ecomorphology upstream and downstream of the CSO and from it resulting recolonization potential (Tab. 6).

Tab. 6 EQS for hydraulic stress in streams in Switzerland (VSA - STORM, 2007)

Stream ecomorphological class above the CSO outlet	**Maximum annual number of streambed erosion events**		
	Channel width variability below the CSO outlet:		
	high	middle	none
I (natural)	10	5	3
II (little disturbed)	5	3	1
III, IV (very disturbed, artificial)	3	1	<1

The ecomorphological survey and classification of the Benesovsky Creek was performed according to the guidance BUWAL (1998). Resulting hydraulic stress criteria for individual CSO outlets are listed in Tab. 7. Their compliance was examined for the Benesov 10 year rainfall series with the simulation tool REBEKAII, which was developed for the purpose of this guideline and combines modelling of the rainfall-runoff processes in both the urban and natural catchments as well as in the stream. In REBEKAII Meyer-Peter equation for the calculation of shear stress acting on the streambed material is implemented. Streambed granulometry and channel width were determined during the stream survey; slopes were deducted from a map. The programme does not consider simultaneous impacts of more CSOs in the stream.

Tab. 7 EQS for hydraulic stress in the Benesovsky Creek

	V5	**V4**	**V3**	**V7**	**V2**	**V1**
Ecomorphological class above CSO outlet	II	II, (III)	IV, (II)	IV	IV	II
Width variability below CSO outlet	none	high	none	none	middle	high
Max. annual number of erosion events	1	5	<1	<1	1	5

Ambient water quality criteria concerning ammonia and turbidity caused by suspended solids are set as maximum frequencies of critical doses determined by concentration c and exposure t. The NH_3-N concentrations are expressed as c=0.025+1.5/t and maximum admissible frequency of their exceeding is n=0.2. For turbidity, curves describing different levels of physiological stress imposed on the fish population are given in the guideline. For the fish protection middle to important level was selected. Another set of criteria regarding suspended solids is related to their chronic impacts (Tab. 8).

Tab. 8 EQS for suspended solids accumulation in the streambed in Switzerland (VSA - STORM, 2007)

Criterion	**EQS**	**Max. duration of exceeding in a year**
Streambed colmation	625 g m^{-2} a^{-1}	20%
Accumulation of persistent toxic pollutants	25 g m^{-2} a^{-1}	5%
Oxygen depletion in the streambed	5 g m^{-2} d^{-1}	10% (0% Sept. - March)

The calculations were performed again with REBEKAII for the Benesov historical rainfall series. The NH_3-N concentrations in the receiving water are calculated for individual rainfall events discharging to the basic flow (Q_{347}). The suspended solids model enables to take into account their concentrations in wastewater and stormwater, first flush and sediment remobilization in the sewer system. In the receiving water suspended solids concentrations for individual rainfall events as well as the accumulation rate determined by sedimentation, erosion and decay are simulated. Default values of model parameters were used.

2.5 Ecological assessment

The ecological status and stream disturbances by CSOs were assessed based on the benthic invertebrates community structure. The invertebrates were sampled in the reaches downstream of individual CSO outlets and in the reference profile above CSO5 in May, August and September 2007. Simultaneously, stream morphology and visual disturbances by the urban drainage system were examined.

3 RESULTS AND DISCUSSION

3.1 Emission standards compliance

The annual stormwater runoff from the urban catchment is 330 017 m^3. At present 155 985 m^3 are discharged through CSOs to the Benesovsky Creek. Required specific overflow volumes as well as the recommended no. of overflows are highly exceeded at all CSOs except for CSO4, whereas the admissible specific COD load is exceeded at CSO3, CSO7 and CSO6 (Tab. 9). The minimum drainage efficiency for suspended pollutants is not met (Tab. 10).

The planned outlook solution is going to bring a significant decrease of loading from the Benesov CSOs (101 531 m^3). However, the Swiss criteria will still be hardly met. Also the specific COD loads from CSO3 and CSO7 remain too high (Tab. 9). The reason is a very little own catchment of CSO7 (0.9 ha_{red}). The Austrian criteria for both dissolved and suspended pollutants will comply due to the substantially increased efficiency of the drainage of stormwater runoff to the WWTP (Tab. 10).

Tab. 9 Emission standards compliance in Benesov for individual CSOs (bold – non compliance)

	Guide-line	Criterion		CSO5	CSO4	CSO3	CSO7	CSO2	CSO6	CSO1
Present state	CZ	Dilution ratio	1:n	13.8	28.1	8.1	**4.8**	6.9	6.7	7.0
	CH	Specific overflow volume	$m^3\ ha_{red}^{-1}$	**913**	411	**2499**	**13307**	**1056**	**1842**	**1032**
	CH	No. overflows	-	**63**	**30**	**55**	**51**	**49**	**81**	**57**
	D	Specific COD load	$kg\ ha_{red}^{-1}$	148	73	**512**	**8988**	248	**284**	224
Outlook	CZ	Dilution ratio	1:n	8.1	15.5	6.4	tank	15.8	16	7.0
	CH	Specific overflow volume	$m^3\ ha_{red}^{-1}$	**655**	**531**	**2013**	**13840**	359	**1078**	**755**
	CH	No. overflows	-	**54**	**36**	**56**	7	**20**	**52**	**53**
	D	Specific COD load	$kg\ ha_{red}^{-1}$	177	118	**652**	**4310**	101	200	220

Tab. 10 Emission standards compliance in Benesov for the whole catchment (bold – non compliance)

	Drainage efficiency dissolved pollutants %	**Drainage efficiency suspended pollutants** %
Present state	53	**53**
Outlook	69	70

3.2 EQS compliance

The assessment of hydraulic stress shows that Benesovsky Creek is significantly disturbed already by the uppermost CSO5 (Tab. 11) (the one-year CSO discharge Q_{CSO1} forms 65% of HQ_1 contrary to the admissible 10% in Germany and 10-50% in Austria). Considering separate impacts only, every single CSO (except for CSO1) violates the criterion. The most important increase of hydraulic stress occurs after the inflow of stormwaters from CSO2 and CSO6 (Q_{CSO1} is 142% of HQ1 considered separately or 284% of HQ1 cumulatively). Similarly, the Swiss approach identifies an important violation of the admissible number of streambed erosion events below CSO5 and CSO4. Further downstream the channel granulometric curve changes significantly as the channel is regulated, hence, the erosion criteria are met. However, REBEKAII treats the CSOs impacts only individually; thus, the number of erosion events may be higher in reality.

In the outlook, the hydraulic loading of the stream stays nearly the same in the upper part (to CSO3) whereas further downstream it slightly decreases due to the stormwater tank at CSO7. However, the German and Austrian hydraulic stress criteria will be still highly violated.

Acute water quality impacts: The oxygen deficit was determined neither mathematically, nor in the field. Toxic ammonia concentrations may occur only according to the Swiss guideline, however, just below CSO7 (Tab. 11). The reason is the silica bedrock and therefore a low pH of water (max 7.6) (Tab. 3) causing little dissociation of NH_4^+ to NH_3. REBEKAII simulations indicate also possible problems with increased frequency of turbidity below CSO7 and a significant sedimentation of suspended solids in the downstream reaches (below the outlets of CSO7 and CSO1), which corresponds to the field survey findings (see chapter 3.3).

In the future, the acute impacts will become slightly more significant in the upper part of the stream (to CSO3) as the wastewater will be more concentrated. German and Austrian EQS will be met whereas REBEKAII simulations indicate problems below CSO3 and CSO7. Turbidity and suspended solids accumulation below CSO7 will decrease substantially; however, CSO1 remains problematic (Tab. 11).

Tab. 11 EQS compliance in Benesovsky Creek (bold – non compliance)

	Guide-line	**Criterion**		**CSO5**	**CSO4**	**CSO3**	**CSO7**	**CSO2**	**CSO6**	**CSO1**
Present state	D, A	$Q_{CSO1}/HQ_{1,pnat}$ separ.	%	**65**	**21**	**47**	**20**	**142**		17
	D, A	$Q_{CSO1}/HQ_{1,pnat}$ cumul.	%	**65**	**82**	**125**	**142**	**284**		**287**
	D, A	max. NH_3-N separ.	mg l^{-1}	0.064	0.063	0.075	0.093	0.076		0.062
	D, A	max. NH_3-N cumul.	mg l^{-1}	0.064	0.064	0.069	0.085	0.072		0.072
	D	min. O_2 separ.	mg l^{-1}	8.2	8.0	7.6	7.8	8.2		8.5
	D	min. O_2 cumul.	mg l^{-1}	8.2	7.0	6.4	6.3	7.5		6.5
	CH	No. erosions	-	**54**	**23**	0	0	0	0	0
	CH	No. critical NH_3	-	0	0	0	**2.8**	0,1	0	0
	CH	No. TSS turbidity	-	5.6	0.4	8.7	**23.6**	5.4	5.4	0.8
	CH	TSS accumulation	%	0	0	0	**83.0**	0	0	**94.3**
	CH	TSS toxicity	%	1.2	0	**20.1**	**98.3**	**7.5**	**21.9**	**98.1**
	CH	TSS O_2 depletion	%	1.4	0.1	8.7	**19.9**	3.0	8.9	**18.0**
Outlook	D, A	$Q_{CSO1}/HQ_{1,pnat}$ separ.	%	**64**	**21**	**43**	tank	**122**		17
	D, A	$Q_{CSO1}/HQ_{1,pnat}$ cumul.	%	**64**	**82**	**121**	tank	**239**		**245**
	D, A	max. NH_3-N separ.	mg l^{-1}	0.084	0.065	0.083	0.008	0.069		0.062
	D, A	max. NH_3-N cumul.	mg l^{-1}	0.084	0.084	0.089	0.089	0.070		0.072
	D	min. O_2 separ.	mg l^{-1}	7.7	7.9	7.6	9.0	8.2		8.5
	D	min. O_2 cumul.	mg l^{-1}	7.7	6.9	6.2	6.3	7.7		6.8
	CH	No. erosions	-	**49**	**28**	0	0	0	0	0
	CH	No. critical NH_3	-	0,2	0	**0.6**	**1.0**	0	0	0
	CH	No. TSS turbidity	-	4.7	0.9	**14.7**	2.8	0.7	1.2	0.8
	CH	TSS accumulation	%	0	0	0	0	0	0	**93.9**
	CH	TSS toxicity	%	0.2	0.1	**25.1**	**14.4**	0	3.0	**98.1**
	CH	TSS O_2 depletion	%	0.9	0.6	8.5	0.6	0	1.3	**16.8**

3.3 Stream ecological status

The assessed reach of Benesovsky Creek can be divided into three parts from the morphological point of view (see also Tab. 7). The part above the outlet V5 to V3 is quite natural, at first with muddy streambed, later sand and gravel prevails. The channel between V3 and V2 is fortified by semi-permeable cement bricks with no variability at all. Sandy deposits and algae occur, riparian zone is missing. Below V2 the channel regains its natural meandering character with sandy-gravel streambed. However, sludge banks originating probably from CSO spills are present.

The stream biological status is poor already in the reference profile above Benesov. The highest number of benthic invertebrates species was found here (12), however, this number is very low (Fig. 2 left). Mainly rather tolerant species as to the water quality and habitats diversity were present. Then the biological status deteriorates gradually below each CSO outlet. Besides CSO impacts also the channel regulation between V3 and V2 takes part in the degradation. According to the Benthic Index of Biotic Integrity (IBI) comprising affects of water pollution, channel morphology and hydraulic stress, the status classification decreases from category ”poor” to the category “very poor”. The worst status appears below V2 (Fig. 2 right)

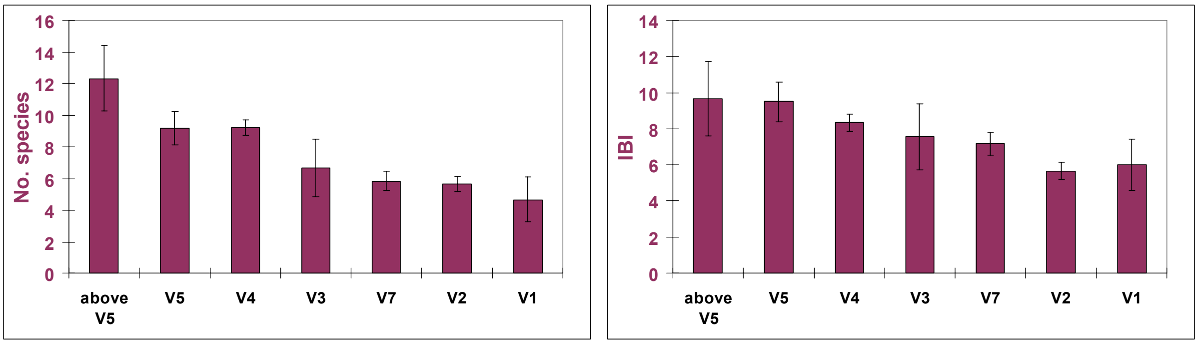

Fig. 2: Average number of macrozoobenthos species (left) and Benthic Index of Biotic Intergrity (IBI) (right) below CSO outlets in Benesovsky Creek (with standard deviations of three samplings)

4 CONCLUSIONS

The case study demonstrated that the dilution ratio is an insufficient criterion for the receiving waters protection from the impacts of CSO discharges. It depicted the necessity of the site-specific assessment of impacts (in this case of hydraulic stress and suspended solids accumulation) for an effective design of protective measures.

All three guidelines applied give the same statement: Benesovsky Creek suffers from significant hydraulic stress already below the uppermost CSO, however, the CSO discharges do not cause considerable acute water quality impacts (NH_3 toxicity) thanks to the silica bedrock accompanied by low pH. Only the Swiss guideline identified problems with turbidity and accumulation of suspended solids in the streambed agreeing with the field survey. The biological-ecological assessment of Benesovsky Creek confirmed the gradual degradation of the benthic invertebrate community below each CSO outlet.

Different emission criteria were met in a different way. Whereas the Swiss criterion of the maximum specific overflow volume was highly violated, the Austrian requirement on the stormwater and dissolved pollutants drainage efficiency was fulfilled. The German maximum specific COD loads were partly exceeded and the efficiency on the suspended pollutants drainage was deeply below the required one in Austria. The very low drainage efficiency of the suspended pollutants suggested problems in the receiving water, which were confirmed by both the EQS compliance assessment and the field survey.

In the future, the measures planned in the General masterplan based on dilution ratios and a stormwater tank construction are going to bring a considerable reduction of the chronic pollution loading of Benesovsky Creek, however, the hydraulic stress will remain nearly the same and acute water quality impacts will become slightly more significant at some parts of the creek (but EQS will not be violated).

The transferability of foreign guidelines to the conditions of the Czech Republic depends partly on the accessibility of necessary data (e.g. rainfall data and river discharges are processed in a different way in individual countries or information on runoff pollution is missing in the Czech Republic). In addition, fears appear if the criteria used in rich West European countries are not too severe and requiring unbearably high investments in a former East European country. However, foreign methodical approaches can be adopted but the criteria might be less stringent (at least during a transitional period) and priorities of reconstruction may be given.

The emission standards concerning the whole catchment seem to be more reasonable than the criteria related to the specific reduced areas of individual CSOs. We suggest to apply the Austrian requirements on the drainage efficiencies of dissolved and suspended pollutants (after the examination of regional rainfall intensities $r_{720,1}$) together with the minimum dilution ratio at CSOs.

As to the CSO impacts assessment, the German and Austrian guidelines are similar both in computational approaches and in using of simplified EQS with a high degree of safety. The differentiation of the permissible hydraulic stress in dependence on the channel character according to the Austrian guideline is preferable. The assumption of the overlapping of all CSO discharges in the defined closed urban area and of their time coincidence with the one-year flood in the receiving water might lead to an overestimation of the hydraulic stress by the German approach. On contrary, the results of the ammonia toxicity assessment considering cumulative impacts of CSOs downstream the creek are not always on the safe side (Tab. 11). Thus, also separate assessment of individual CSOs impacts is to be recommended.

The EQS used in the Swiss guideline are suitable for a detailed assessment of critical cases. However, the criteria for suspended solids are closely related to the supporting software REBEKAII, which was in contrary designed for a rapid assessment of small, not very complex systems as the schematization of the sewer system and of the river is very coarse. Nevertheless, the other EQS can be easily taken over and used for a detailed assessment of CSO impacts with another software.

The impacts based guidelines for CSOs are now under further detailed testing in several cities with different catchment and receiving waters characteristics (including morphology). The future Czech guideline will be probably inspired mostly by the Austrian approach but it will respect specific Czech conditions and feasibility.

5 ACKNOWLEDGEMENT

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