LEGISLATIVE FRAMEWORK REGARDING WASTEWATER TREATMENT IN THE REPUBLIC OF SERBIA AND FLOW AND TRANSPORT MODELLING IN THE DETERMINATION ON EFFLUENT QUALITY OF WASTEWATER TREATMENT PLANT OF BELGRADE CENTRAL SEWERAGE SYSTEM

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Abstract
The largest sewerage system in Belgrade is Belgrade Central Sewerage System, which covers the area of about 85% of the sewerage network, with about 1,250,000 inhabitants connected to the sewage infrastructure. The interaction of emission limit values, environmental quality standards, wastewater, effluent and recipient characteristic flows and qualities from the standpoint of environmental impact in the unfavorable environmental conditions was modelled to define the level of wastewater treatment at future Belgrade Central Sewerage System wastewater treatment plant.

Introduction
The largest sewerage system in Belgrade is Belgrade Central Sewerage System (BCSS), which covers the area of about 85% of the sewerage network, with about 1,250,000 inhabitants connected to the sewage infrastructure [1].

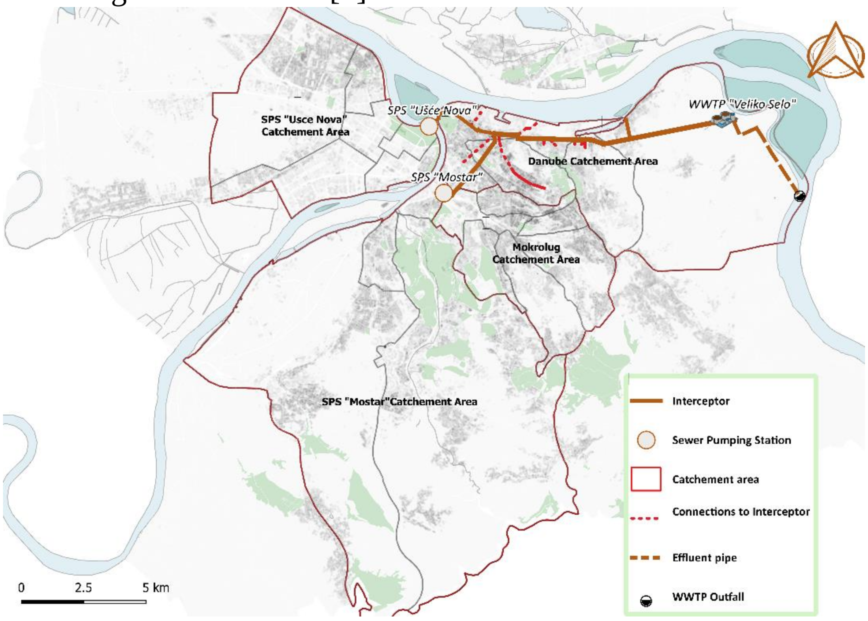

Figure 1. BCSS catchment area with sub-catchments, Interceptor and WWTP Veliko Selo [2]

All wastewater is discharged without treatment into the Sava and Danube Rivers. The level of wastewater treatment that should be reached at future BCSS WWTP was determined based on legislation requirements and the results of numerical modelling of MZ downstream of the effluent discharge point.

Legislation of the Republic of Serbia and the EU Water Framework Directive rely on the so-called combined approach in determining emission limit values (ELV) and environmental quality standards (EQS). Effluent discharge must comply with the more stringent of these two criteria. In this situation, a mixing zone is introduced in the water sector legislation to allow for local relaxation in achieving water quality standards near the point of discharge.
The size of the mixing zone (MZ) should be small enough not to interfere with the use and use of water and appropriate ecosystem uses (recreation, water supply, and fish habitats). Mixing zones are environmentally acceptable because the concentrations and effects of most pollutants decline rapidly after discharge, due to dilution in the MZ. MZs are a widely accepted technical concept introduced into the water legislative framework to ensure flexibility in meeting water quality standards. Within the MZ, the water quality limits may be exceeded, but at its edge, the concentrations of pollutants must meet the standards.

Method

The Law on Waters ("Official Gazette of the RS", No. 30/2010, 93/2012, 101/2016, 95/2018 and 95/2018 – anth. law) stipulates that wastewater, prior to its discharge into the recipient, must be treated to a level that corresponds to emission limit values of pollutants in waters, defined within the Regulation on Emission Limit Values of Pollutants in Waters and Deadlines for their Achievement ("Off. Gazette of the RS", No. 67/2011, 48/2012 and 01/2016)), or to a level that won't jeopardize EQS of the recipient, defined within the Regulation on Limit Values of Pollutants in Surface and Ground Waters and Sediment and Deadlines for their Achievement ("Official Gazette of RS", No. 50/2012), whichever is more stringent. The concept of the mixing zone was introduced for the first time in the Regulation on limit values for priority and priority hazardous polluting substances in surface waters and deadlines for their achievement ("Official Gazette of RS", No. 24/2014). Article 2 (paragraph 4) defines the mixing zone as a part of the recipient in the immediate vicinity of the location where certain priority substances are disposed of from point sources; in the mixing zone, initial mixing with ambient water takes place, and the concentration of priority substances may exceed the EQS level. Article 6 stipulates that the EQS is allowed to be exceeded within the mixing zone, if not affecting the compliance of the rest of the water body with the standards and defined limit values. A mixing zone should be established for a specific emission point/discharge location, and the spread of the mixing zone should be proportional to the concentration of priority substances included in the water permits issued in relation to the regulations on integral prevention and control of environmental pollution and the Water Law. The border of the mixing zone is defined at a distance from the source of pollution where 95% mixing is achieved.

Although the concept of the MZ is defined and adopted, there is yet no regulation at the national level to clearly define its dimensions. It should provide following basic information:

- Specifications of numerically expressed dimensions of the mixing zone in accordance with the type of watercourse and its biological characteristics,
- The width of the mixing zone (WMZ), should be limited to a part of the recipient's cross-section width (CSW), e.g. WMZ = n_tCSW, in order to allow unimpeded passage of river fauna (fish) through the greater part of the cross-section, and/or the mixing zone is limited in the longitudinal direction, e.g. LMZ = n_lCSW, to limit the level of pollution along large sections of the river bank. Factors n_t and n_l, which usually take values from 0.1 to 0.5 for n_t and from 1 to 5 for n_l,
- The specification of the dimensions of the mixing zone can be ad-hoc: after previous environmental assessments and forecasts, the wastewater emitter can request certain dimensions of the mixing zone with guarantees of compliance with the principle of

integral water protection. Based on an impartial assessment, the authorities can accept such a request, or put forth additional requirements and restrictions.

The basic concept of development of BCSS is the construction of Interceptor central collector and a wastewater treatment plant at the Veliko Selo site (WWTP "Veliko Selo") – Figure 1 [1]. The recipient of future WWTP effluent is the Danube River.

Based on previous experiences for wide riverbeds with a large B/H ratio (about 125 at the WWTP "Veliko selo" site), the use of planar hydrodynamic models in the horizontal plane, based on hydrodynamic equations and transport equations averaged over depth, is justified. The mixing of untreated wastewater or effluent and river water, i.e. impact of the untreated wastewater on the Danube and Sava rivers, and of effluent on the Danube River quality indicators was simulated by the RMA2/RMA4 models tandem. The RMA2 model is a hydrodynamic model based on flat flow equations in the shallow domain (depth-averaged Navier-Stokes equations). It solves the Reynolds form of the Navier-Stokes turbulent flow equations on a finite element mesh. Friction is calculated according to Manning's or Shezi's formula, and turbulence is described by turbulent viscosity coefficients. Steady and unsteady flows can be analyzed with the model. The model assumes a hydrostatic distribution of pressures in the vertical direction and as such is suitable for simulating mixing in zones at a greater and intermediate distance from the initial dilution zone. The RMA4 model is a transport model, which calculates transport equations based on the flow solution.

Three models were used, one for the simulation of flow and transport in the Sava River and Danube upstream from the confluence, comprising all the wastewater outlets, second for the Danube downstream of the confluence along the urban area also comprising all the wastewater outlets, and the third is the model of the Danube River downstream from Belgrade for the simulation of the influence of WWTP effluent discharge. The downstream boundary conditions are a fixed water levels at 5 percentile river stage (H_{95}=69.92 m a.s.l., H_{95}=69.86 m a.s.l. and H_{95}=69.80 m a.s.l. respectively) at the most downstream arrays of models' nodes. Danube river flow downstream of confluence was set as 5 percentile flow (Q_{95}=2,149 m_3/s). Wastewater flow at each outlet was set equal to the average discharge, and the effluent flow at the WWTP discharge was set as the sum of all outlet discharges. The representative quality parameter was BOD_5, concentration was set to the average value at the wastewater outlet, ELV for the effluent discharge (Table 1), and average values for the river inflow in the model.

Table 1. The upper limit values of the key parameters of quality of WWTP effluent as stipulated in the legislation

Parameters	Unit	Limit value	Lowest % of reduction
COD	mg/l	125	75
BOD_5	mg/l	25	70-90
SS	mg/l	35	90
Ntot	mg/l	10	80
Ptot	mg/l	1	80

Results and discussion

The level of wastewater treatment that should be reached at WWTP "Veliko Selo" (Figure 1) was determined on the basis of legislation requirements and the results of applied RMA2/RMA4 models for simulation of the effects of current untreated wastewater MZ downstream of the effluent discharge point.

The influence of wastewater treatment on the natural recipients is twofold – the raw wastewater discharge at all outlet points is discontinued, and effluent discharge downstream from Belgrade is introduced. The marked positive effects of the cessation of the detrimental influence of raw wastewater discharge can be easily inferred from the Figures 2 and 3, and the simultaneous very limited negative effects of the WWTP effluent discharge are illustrated by Figure 4. Having in mind synergy of the listed effects, it is clear that the discharge of effluent of stipulated quality (Table 1) would not jeopardize quality indicators of the recipient even for the Danube low waters, but rather improve them. Therefore, conditions both from Regulation on Emission Limit Values and Regulation on Limit Values of Pollutants are met when effluent quality complies with the ELV from the Regulation on Emission Limit Values of Pollutants in Waters and Deadlines for their Achievement (as presented in Table 1).

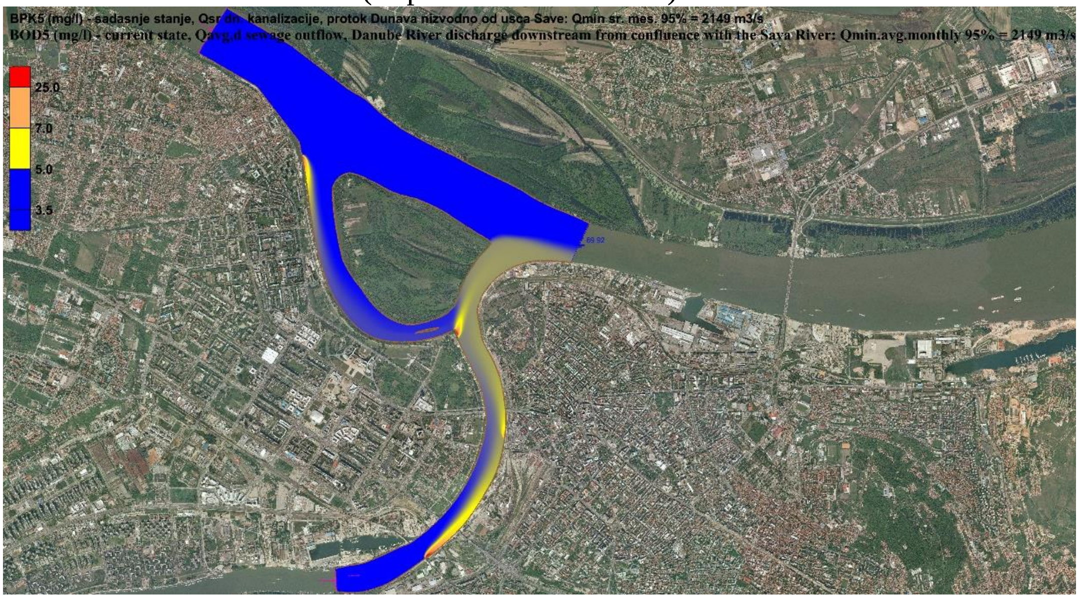

Figure 2. Wastewater discharges from BCSS (current state) into the Sava and Danube Rivers upstream from the confluence (average wastewater flow, low waters, dry period), BOD_5 [1]

Figure 3. Wastewater discharges from BCSS (current state) into the Danube River downstream from the confluence (average wastewater flow, low waters, dry period), BOD_5

The elimination of the negative impact of wastewater outlets on Sava River, that are clearly observed on the Figure 2, is perhaps the most significant positive effect of the Interceptor and WWTP on the environment as the Sava River is, due to the much lower discharge, markedly more sensitive than the Danube River.

Figure 4. Effluent discharges from WWTP "Veliko Selo" (future state) into the Danube River downstream from the city area (average wastewater flow, low waters, dry period), BOD_5

The very small dimensions of the MZ of effluent discharge point compared to the width of the Danube River, as well as fast downstream decrease of BOD_5 concentration to the ESV limit of 5 mgO_2/l allow for the circumvention of deficiencies in the legislation regarding the MZs.

Conclusion

The lack of legislative clarity regarding the MZs proves not to be a source of problems in determining the necessary effluent quality for WWTP "Veliko Selo" due to the small dimensions of the MZ of effluent discharge compared to the width of the Danube River, and a huge positive impact of the cessation of untreated wastewater discharge on the recipient's environmental quality upstream the WWTP. Nevertheless, this legislative deficiency poses a significant problem for the large settlements or other wastewater emitters on small watercourses, especially if there is no previous wastewater discharge already negatively influencing the recipient, and this issue must be addressed as soon as possible.

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