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Analysis of Requirements for Effluent Quality and their Impact on Status of Rivers

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Abstract. The article analyses Lithuanian rivers, 32 of which have been selected as non-complying with the requirements of good condition. Furthermore, 15 discharge facilities that discharge wastewater to the aforementioned rivers from agglomerations with population equivalent (PE) greater than 2,000 have been selected. The assessment of the quality of treated wastewater according to the allowable impact on the reception facility has been carried out and has been compared with the currently regulated minimum allowable values of concentrations of pollutants. The analysis of the impact of quality of treated wastewater on the ecological status of rivers has been presented. It has been established that the pollution of rivers would be decreased by an average 8% (organic pollutants and total nitrogen) and by 22% (total phosphorus), if the allowable concentrations of pollutants according to the impact on the reception facility were ensured in the analysed treatment plants with PE greater than 10,000.

Keywords: wastewater treatment plant, requirements, ecological condition.

Conference topic: Water engineering.

Introduction

The main objective of water policy is to ensure good condition of water bodies (EP 1991). Having analysed the results of the National Environmental Monitoring Programme for 2011–2014, one may state that the best ecological status of Lithuanian rivers is in the Eastern-South Eastern and Western regions of Lithuania that are least affected by human activity. The worst ecological status of surface water bodies is determined in Northern, Central and South-Western regions of Lithuania that are characterised by intensive agricultural activity (AAA 2015, 2014). According to the monitoring data, in 2014, the requirements of good and very good condition of water bodies were met by 49% of the Lithuanian rivers. The evaluation of the condition of surface water bodies is regulated by the Methodology of Determination of the Condition of Surface Water Bodies (LR Aplinkos ministro… 2005; LR aplinkos ministro… 2007). The levels of organic substances expressed in BOD and COD, total nitrogen and total phosphorus passing together with wastewater discharged to the rivers have a direct adverse effect on the ecology of rivers, i.e. cause eutrophication of water bodies (Bukantis *et al*. 2008; AAA 2010; Ferreira *et al.* 2011; Bagdžiūnaitė-Litvinaitienė, Litvinaitis 2014). The areas sensitive to eutrophication are in need for higher protection (Horn *et al.* 2004; Borja *et al.* 2006).

The norms of pollution of wastewater discharged to the natural environment are described in Waste Treatment Regulation (LR aplinkos ministro… 2006; LR aplinkos ministro…2014). The required quality of treated wastewater is evaluated according to the maximum allowable concentration of pollutant (MAC) and the impact on the reception facility, the minimum value of which is so far limited to the value of the minimum allowable concentration. If the quality of treated wastewater is assessed only according to the impact to the reception facility, the quality of wastewater treatment would become even stricter (LR aplinkos ministro … 2006). In such cases, the additional treatment of wastewater is necessary in order to achieve a higher degree of treatment.

The aim of work is to identify the number of rivers that do not comply with the requirements of good condition, to evaluate the quality of treated wastewater that is received from treatment plants with PE greater than 2,000, which ensures good condition of the reception facility, and also to evaluate the possible reduction of the pollution in rivers when the concentrations of pollutants in the treated wastewater have no impact on the reception facility.

Methodology

Based on the data of the monitoring of point pollution sources for 2014–2016 provided by the Environmental Protection Agency (LR aplinkos ministro… 2012), the rivers that do not comply with the requirements of good condition have been selected. Pursuant to the List of Wastewater Treatment Accounting Discharge Facilities provided in the Description of Procedure for Accounting of the Use and Treatment of Wastewater, the discharge facilities which discharge

wastewater from agglomerations with population equivalent (PE) greater than 2,000 to rivers that do not comply with the requirements of good condition have been selected. The size of agglomerations has been selected in view of the fact that the evaluation of impact on the reception facility is performed when the amount of wastewater source exceeds 1,000 PE. Unfortunately, the impact of treatment plants with PE from 1,000 to 2,000 on the reception facility has not been analysed due to the lack of hydrological data. Based on the selected discharge facilities, wastewater treatment plants with the size of wastewater source greater than 2,000 PE have been identified and the impact of the discharge facility of such treatment plants on the reception facility has been evaluated.

The impact to receivers by organic pollutants was assessed according to the formula (LR aplinkos ministro… 2006):

$$C_{ww} = \frac{1.1 \times C_{riv.(MAC)} \times Q_{ww} + 360 \times C_{riv.(MAC)} \times Q_{riv.}}{Q_{ww}}, \quad (1)$$

where: C_{ww} – the largest concentration of BOD_7 an average daily instantaneous or wastewater sample, at which will not be exceeded permissible exposure receivers, mg/L.

$C_{river\ (MAC)}$ – MAC BOD_7 a receiving (requirements of the receiving state of well-placed "Surface water status determination methodology (LR aplinkos ministro ... 2007)", which is equal to 3.30 mg/L.

Q_{ww} – discharges is calculated, the maximum hourly flow rate (dry season), m^3/h.

Q_{river} – the minimum consistent in the summer-autumn 80% probability 30 driest days in a row the average water flow of the sewage pipe m^3/s.

The impact to receivers in terms of nitrogen and phosphorus was evaluated according to the formula (LR aplinkos ministro… 2006):

$$T_{n,\,N_b} = \frac{1.1 \times C_{riv.(MAC)} \times Q_{ww} + 0.1 \times C_{riv.(MAC)} \times Q_{riv.}}{1000}, \quad (2)$$

where: T_n – annual load N or P, at which will not exceed the permissible impact on the receiving water body, t/year.

$C_{river\ (MAC)}$ – N or P a receiving MAC (requirements of the receiving state of well-placed "Surface water status determination methodology" (LR aplinkos ministro… 2007), which is equal to 3.0 mg / L N_t and 0.14 mg /L P_t.

Q_{ww} – a year volumes of discharged wastewater, thous. m^3/year.

Q_{river} – term average the receiving sewage runoff on the site, thousand. m^3/year.

The obtained measurement results of statistical processing on the condition:

$$\left(x_i - x\right) \le 2 \cdot s, \quad (3)$$

where: x – arithmetic average; x_i – i-th value of the index; s – standard deviation of sample indicator.

Results

The research resulted in the selection of 32 rivers that do not comply with the requirements of good condition out of total 117 analysed rivers and also the selection of 67 municipal wastewater discharge facilities that discharge wastewater to such rivers. Out of total 67 discharge facilities, 52 belong to agglomerations with PE lower than 2,000. 15 discharge facilities that discharge wastewater from agglomerations with PE greater than 2,000 have been selected. It has been established during the analysis that the point pollution from Lithuanian treatment plants with PE greater than 2,000 has a negative effect on the ecological status of 12 Lithuanian rivers (Fig. 1). The results of the calculation of the impact of selected wastewater treatment plants with PE > 2,000 on the reception facility and comparison with the minimum allowable concentration are provided in Table 1.

The comparative analysis of the values of allowable concentrations according to the impact on the reception facility and the values of minimum allowable concentrations revealed that the minimum allowable concentration according to BOD_7 index in the discharge facilities of all analysed treatment plants is higher than it should be to prevent from exceeding the allowable impact on the reception facility (Table 1). Thus, the minimum allowable pollution according to BOD_7 index exceeded the allowable pollution according to the impact on the reception facility from 1.4% to 57% (by an average 23.2%) in 8 analysed treatment plants with PE from 2,000 to 10,000 and from 3.8% to 61% (by an average 43.5%) in 6 analysed treatment plants with PE from 10,000 to 100,000. In Panevėžys wastewater treatment plant (PE > 100,000) the minimum allowable pollution according to BOD_7 index exceeded the allowable pollution according to the impact on the reception facility by an average 57%. After the reduction of concentration of treated wastewater according to BOD_7 from the minimum allowable to the allowable according to the impact on the reception

facility, the pollution of rivers with organic substances would be reduced by an average 0.84% from treatment plants with PE from 2,000 to 10,000, 7.2% – from treatment plants with PE from 10,000 to 100,000 and 12.5% from treatment plant with PE greater than 100,000. In order to achieve the effective reduction of the pollution of rivers with organic substances, the quality of treated wastewater must be improved in the treatment plants with PE greater than 10,000.

Fig. 1. Good condition ineligible river, which falls within the municipal waste water from agglomerations larger than 2000 PE

Table 1. Selected wastewater treatment plants (PE > 2000), which impact receivers with the calculation results and the comparison with the lowest allowable concentration

WWTP size of the PE**	Name of WWTP	Name of receiving (river)	$C_{wastewater}$ under BOD_7, mg/L*	Lowest AC by BOD_7, mg/L**	$C_{wastewater}$ by N_t, mg/L*	Lowest AC by N_t, mg/L**	$C_{wastewater}$ under P_t, mg/l*	Lowest AC by P_t, mg/L**
2000 < PE < 10 000	Kazlų Rūda	Jūrė	8,23	12	53,53	20	2,50	2
	Kybartai	Liepona	5,17		19,26		0,90	
	Švenčionys	Mera – Kūna	5,80		30,61		1,43	
	Skaidiškės	Nemėža	10,58		393,77		18,38	
	Akmenė	Dabikinė	10,52		607,11		28,33	
	Nemėžis	Nemėža	11,41		460,24		21,48	
	Krekenava	Nevėžis	11,83		1740,60		81,23	
	Juodupė	Juodupė	10,17		330,79		15,44	
10 000 < PE < 100 000	Varėna	Derėžnyčia	4,37	10	11,14	10	0,52	1
	Joniškis	Sidabra	4,25		9,37		0,44	
	Kėdainiai	Nevėžis	9,62		76,95		3,59	
	Rokiškis	Laukupė	8,43		47,03		2,19	
	Radviliškis	Obelė	3,87		5,74		0,27	
	Kaišiadorys	Lomena	4,75		13,50		0,63	
PE > 100 000	Panevėžys	Nevėžis	4,26		7,46	10	0,35	0,5

* **$C_{wastewater}$** – the largest BOD_7, N_t or P_t concentration in waste water sample at which will not be exceeded allowable impact receivers.

** According to the Wastewater Management Regulation (LR aplinkos ministro… 2006).

In the discharge facilities of 4 treatment plants out of total 15 analysed wastewater treatment plants, the minimum allowable concentration according to total nitrogen exceeded the allowable concentration according to the impact on the reception facility (Table 1). 1 treatment plant falls into the 2,000 < PE < 10,000 group, 2 plants – to 10,000 < PE < 100,000 group and 1 – to PE > 100,000 group. The minimum allowable pollution according to total nitrogen exceeded the allowable pollution according to the impact on the reception facility from 3.7% to 43% (by an average 19.5%). The aforementioned maximum excess was determined in Radviliškis and Panevėžys treatment plants and accounted for 43% and 25% respectively. After the reduction of N_b concentration in treated wastewater from minimum allowable to the established and not exceeding the allowable impact on the reception facility, the pollution of river with total nitrogen would be reduced by an average 17.5% in Radviliškis and 6.1% in Panevėžys. In respect of reduction of river pollution with nitrogen, it is also recommended to improve the quality of treated wastewater in treatment plants with PE greater than 10,000.

The minimum allowable concentration of total nitrogen is higher than the allowable concentration according to the impact on discharge facilities in 7 treatment plants (Table 1). 2 treatment plants fall into 2,000 < PE < 10,000 group, 2 plants – to 10,000 < PE < 100,000 group and 1 – to PE > 100,000 group. The minimum allowable pollution with total phosphorus exceeded the allowable pollution according to the impact on the reception facility from 28.5% to 55% (by an average 42%) in 2 treatment plants falling into 2,000 < PE < 10,000 group, from 37% to 73% (by an average 53.5%) in 4 treatment plants falling to 10,000 < PE < 100,000 group. In Panevėžys treatment plant (PE > 100,000) the minimum allowable pollution P_b exceeded the allowable pollution according to the impact on the reception facility by an average 30%. After the reduction of concentration of treated wastewater with P_b from the minimum allowable to the established and not exceeding the allowable impact on the reception facility, the pollution of rivers with total nitrogen would be reduced by an average 9.6% from treatment plants with PE from 2,000 to 10,000, 26% – from treatment plants with PE from 10,000 to 100,000 and 7.7% from treatment plant with PE greater than 100,000. As regards the pollution of rivers with phosphorus, the quality of treated wastewater is recommended to be improved in treatment plants with PE greater than 2,000.

The results suggest that in case of ensuring of allowable concentrations of BOD_7, N_b and P_b according to the impact on the reception facility in wastewater treated in analysed treatment plants with PE greater than 10,000, the pollution of rivers would be decreased by an average 8% according to organic pollutants and total nitrogen and by 22% according to total phosphorus. One of the possible and normally applied solutions for the reduction of the pollution concentrations in treated wastewater is the application of the tertiary wastewater treatment phase (Kimochi *et al.* 2008).

Conclusions

1. The data analysis of 2014–2016 proves that 32 rivers out of total 117 analysed Lithuanian rivers do not comply with the requirements of good condition. Treated wastewater from 15 treatment plants with population equivalent greater than 2,000 pass to these rivers.
2. The minimum allowable pollution according to BOD_7 index exceeded the allowable pollution according to the impact on the reception facility in all analysed treatment plants, pollution with total nitrogen – in 4 treatment plants and pollution with total phosphorus – in 7 treatment plants. The excess according to BOD_7 ranged from 1.4% to 61%, total nitrogen – from 3.7% to 43% and total phosphorus – from 28.5% to 73%.
3. To achieve the effective reduction of the pollution of rivers with organic substances and total nitrogen, the quality of treated wastewater needs to be improved in the treatment plants with PE greater than 10,000. Whereas for the effective reduction of the river pollution with total phosphorus, the improvement of the quality of treated wastewater is recommended even in treatment plants with PE greater than 2,000.
4. In case of ensuring of allowable concentration of BOD_7, N_b and P_b according to the impact on the reception facility in wastewater, which is treated in analysed treatment plants with PE greater than 10,000, the pollution of rivers would be reduced by an average 8% (organic pollutants and total nitrogen) and by 22% (total phosphorus)

Contribution

R. Dauknys declares involvement in conception and design of the work, participation in field measures. A. Mažeikienė declares involvement in analysis, interpretation of data.

Disclosure statement

The authors declare that they do not have any competing financial, professional, or personal interests from other parties.

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