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IMPACTS OF MUNICIPAL WASTEWATER TREATMENT PLANTS ON WATER QUALITY IN THE BERZE RIVER BASIN

Linda Dambeniece-Migliniece, **Ainis Lagzdiņš**
Latvia University of Agriculture
linda.dambeniece@gmail.com

Abstract
Eutrophication caused by water pollution with nutrients (nitrogen (N) and phosphorus (P)) is one of the main environmental problems nowadays. Poor water quality might be caused by many natural and anthropogenic factors. The most common anthropogenic factors are water pollution caused by intensive agriculture (e. g. intensive fertilizer use, high density of livestock) and discharges from municipal waste water treatment plants (WWTP). In this study, nutrient load from WWTP to the river Berze basin in time period from the year 2005 to the year 2015 was described. In total, 23 WWTPs of the study area were analysed using descriptive statistics to calculate average values of nutrient amount and concentrations discharged to river Berze basin. From 2005 to 2015 average N and P load from WWTP to the river Berze basin have been reduced, but concentration of N and P in treated wastewater (WW) have increased. The largest WWTP of the study area – Krigeri (WWTP of city Dobele) is subject to the regulations of treated WW quality set by Republic of Latvia Cabinet Regulation No. 34. The WWTP Krigeri meets the regulations, but overall situation in the study area suggests that strict control of smaller WWTP should be made.
Key words: waste water treatment, point source pollution, nitrogen, phosphorus.

Introduction

Important environmental issue in the European Union is eutrophication of the Baltic Sea. The Baltic Marine Environment Protection Commission, also known as Helsinki Commission (HELCOM) as its aim has highlighted good environmental status of the Baltic Sea, this includes concentrations of nutrients in the water close to the natural levels of a region (HELCOM, 2007). In order to reach these goals water quality has to be improved.

Water quality at a river basin scale can be affected by many natural and anthropogenic factors (Vega *et al*., 1998). These factors can be furthermore categorized as point source or diffuse pollution. Example of typical diffuse pollution can be fertiliser use in agricultural lands or forestry. These inputs are usually continuous, with a little variability over time (Carpenter *et al*., 1998). Point sources are relatively easy to locate and include the direct inputs from municipal sewage systems and/or industrial discharges (Thyssen, 1999). Both diffuse and point sources cause significant water pollution with nutrients (N and P) (Vega *et al*., 1998; Pieterse, Bleuten, & Jørgensen, 2003; Withers *et al*., 2011).

Municipal wastewater (WW) is a very composite mixture. It consists of a high number of substances. Mainly these components are domestic WW (sewage from households, municipal establishments, and small businesses (<50 employees)), sewage from larger (>50 employees) industrial and commercial companies and hospitals (Pescod, 1992). In Latvia, the treated WW quality is controlled and set to fit concentrations of nutrients (Ministru kabineta noteikumi Nr. 34, 2002). For WWTP (waste water treatment plant) larger than 10 000 PE (population equivalent) concentration of total Nitrogen and Phosphorus in treated WW shouldn't exceed 15 mg l^{-1} for N and 2 mg l^{-1} for P. Smaller WWTP (PE<10 000) is not controlled, but is subject to HELCOM recommendations. Treated WW concentration of total nutrients for WWTP with PE 300-2000 should not exceed N - 35 mg l^{-1}; P – 2 mg l^{-1}; WWTP with PE <300 N - 25 mg l^{-1}; P – 5 mg l^{-1} (HELCOM, 2007).

The aim of this study was to determine municipal waste water treatment plant impact on water quality affected by nutrient load to the Berze River basin during the time period of 2005-2015.

This study has been done as a part of author's doctoral thesis. Data used in this study have been obtained and prepared for hydrological modelling with HYPE model (Lindström *et al*., 2010) as part of the MIRACLE project.

Materials and Methods

The Berze River basin was used as a study area (Figure 1). The Berze River is situated in the central part of Latvia and is the tributary of the Svete River. The length of the Berze is 109 km with an elevation difference of 108 m per 109 km. The Berze River has a contributing drainage area of 872 km^2. The river starts around 120 m above the sea level in drained meadows in the southern part of the Eastern-Courland highland. In the middle part of basin there is a hydro-power plant 'Annenieki' with a reservoir that can possibly influence nutrient retention.

According to CORINE land cover data, the study area consists of mostly agricultural areas (56.6%) and forest and semi-natural areas (384%), remaining area: wetlands (1.2%), water bodies (1.1%), artificial surfaces (discontinuous urban fabric, industrial or commercial units, dump sites, green urban areas, sport and leisure facilities) (28.0%).

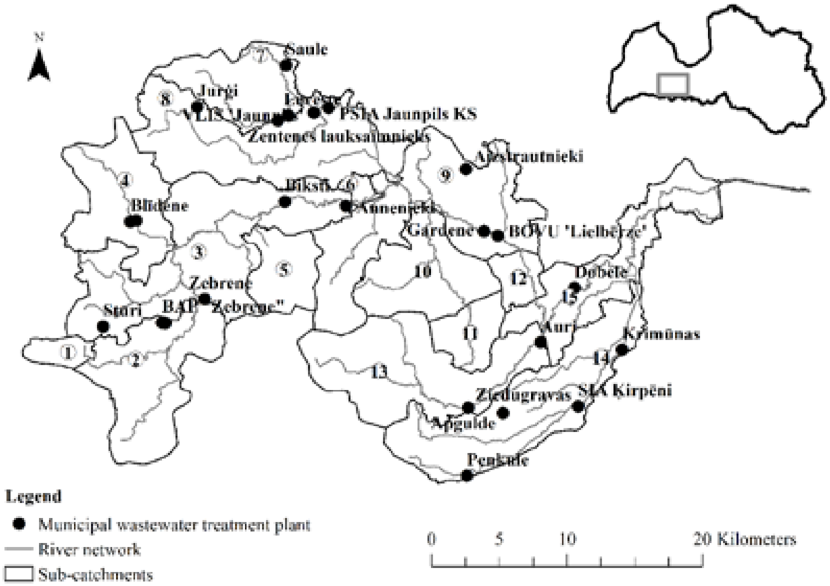

Figure 1. Location of the study area: WWTP in the Berze River basin.
(Map shows only still operating WWTP and the location of sub-basins).

Table 1

List of wastewater treatment plants in the Berze River basin

No.	WWTP title	Sub-basin ID	Population equivalent (year 2014)	Reconstruction/opened
1	‘BAP Zebrene’	2	0*	Opened in 2011
2	‘Zebrene’	3	20	2004
3	‘Annenieki’	3	76	2015
4	‘Stūri’	3	14	1988
5	‘Blīdene’	4	450	1985
6	‘Leveste’	7	119	2003
7	‘Saule’	7	37	2004
8	‘Biksti’	8	23	2010
9	‘Jaunpils’	8	7000	2002
10	‘Jurģi’	8	55	2003
11	‘VLIS Jaunpils’	8	1	1968
12	‘Lielbērze’	9	0*	1980
13	‘Gardene’	9	427	2014
14	‘Aizstrautnieki’	9	26	2010
15	‘Krigeri’	12	12187	2001
16	‘Zelta Druva’	12	-	Closed in 2007
17	‘Auri’	13	24	1987
18	‘Ziedugravas’	13	27	2010
19	‘Penkule’	14	21	1989
20	‘Krimunas’	14	44	2013
21	‘Ķirpēni’	14	51	1982
22	‘Strauti’	14	38	2010
23	‘Šķibes’	15	-	Closed in 2007

* Non-municipal WWTP.

Water quality in the basin is affected by agricultural diffuse pollution and variable point sources. The largest point sources of nutrient (nitrogen and phosphorus) loading in the Berze River basin are wastewater treatment plants (WWTP). Overall 23 waste water treatment plants are located in the Berze River basin area. The largest of WWPT serves the city of Dobele (10 000 PE (population equivalent)). Other WWTPs service small communities with a PE <2000. WWPT of Dobele draws up to half of all waste water discharged form WWTP in the Berze River basin.

In this study, the data obtained from 23 WWTP is used (Table 1). Two of the WWTPs ('Zelta Druva' and 'Šķibes') was in operation until 2007. Two new WWTPs have been in operation ('BAP Zebrene') since 2011, due to negligible discharges these two WWTPs have been reported as one in this study. WWTP 'BAP Zebrene' serves for a landfill 'Zebrene' and is not municipal WWTP. The largest WWTP ('Krigeri NAI' – WWTP of city of Dobele) is located in the sub-basin ID 12.

Data on wastewater discharges and nutrient concentrations was obtained from the publicly available data source of '2 – Ūdens' maintained by the State Limited Liability Company 'Latvian Environment, Geology and Meteorology Centre.' In this study data reported from 2005 to 2015 was used. In most of the cases waste water sampling are done once a year and values of nutrients are calculated to tons per year. Microsoft Excel used to describe data from 23 WWTPs of river Berze basin. Descriptive statistics used to describe the data – average values of nutrient amount and concentrations and standard errors for the nutrient concentrations have been calculated using Microsoft Excel.

Results and Discussion

Nutrient load changes in time are shown in Table 2. Amount of nutrients loaded into river Berze basin varies, reasons of it should be examine considering error made by missing values (data missing in the reports provided by WWTP operators) in the data set. Also, the date of making water sample is not specified, but seasonality strongly affects waste water quality (Redeker, 2011; Vega *et al*., 1998). Another possible reason of differences in amount of nutrients loaded to river Berze basin might be reconstruction of WWTPs (date of WWTP reconstruction can be seen on Table 1).

Most of the Nitrogen from point sources to river Berze are loaded to sub-basin ID 12 (76.252 t). The lowest amount of nitrogen has been loaded from sub-basin ID 2 (0.055 t – sub-basin ID2 is not displayed on the fig. 2) and 15, but WWTPs in these sub-basins have been closed (sub-basin ID 15) or opened recently (sub-basin ID 2, also not municipal WWTP) causing total amounts being the lowest. The lowest amount of phosphorus from still existing municipal WWTP have been loaded to river Berze sub-basins ID 4 (4.165 t) and 7 (4.981 t) (Fig. 2).

Most of the phosphorus from point sources to river Berze are loaded to sub-basins ID 8 (10.131 t) and 12 (8.770 t). These sub-basins are mostly agricultural areas (Corine land cover data). Livestock research station is located on sub-basin ID 8 most likely causing large amounts of phosphorus leaking to river Berze basin. It is known that the livestock causes P accumulation in soils (Bouwman *et al*., 2013). These results suggest that large amounts of livestock affect waste water as well most likely sourcing from farm sewage systems.

Table 2

Total yearly nutrient (Nitrogen and Phosphorus) load from WWTPs to River Berze basin in time from 2005 to 2015

Year	Total Nitrogen (tons)	Total Phosphorus (tons)
2005	21.578	5.246
2006	20.924	3.841
2007	17.421	3.986
2008	16.786	3.133
2009	9.375	1.104
2010	16.008	0.968
2011	7.274	1.829
2012	10.434	1.864
2013	8.894	1.613
2014	12.584	2.193
2015	9.994	1.533

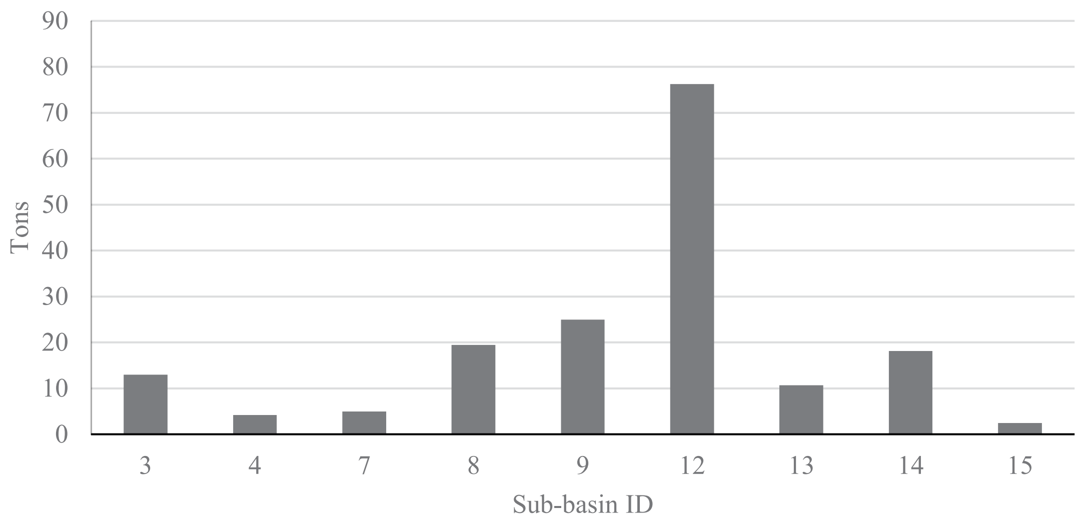

Figure 2. Total amount of Nitrogen loaded from WWTPs to river Berze basin from 2005 to 2015.

The lowest amount of phosphorus has been loaded from sub-basin ID 2 (0,000 tons – sub-basin ID2 is not displayed on the fig. 3) and 15 (0.326 t), but WWTPs in these sub-basins have been closed (sub-basin ID 15) or opened recently (sub-basin ID 2, also not municipal WWTP). The lowest amount of phosphorus from still existing municipal WWTP have been loaded to river Berze sub-basins ID 4 (0.850 t) and 7 (0.998 t) (Fig. 3).

As seen on Fig. 4 average nutrient (N and P) loads from single WWTP to River Berze basin have reduced in time, but not significant. Nitrogen spikes in year 2010 to average 1.21 tons of Nitrogen (15.458 tons of Nitrogen loaded to sub-basin ID 12). In year 2010 the largest WWTP (Krigeri – WWTP of city of Dobele) went under reconstruction (Table 1). Reconstruction might be reason of Nitrogen load peak, if the WWTP did not function properly at the time.

The maximum permitted concentration of N and P in treated WW are set by local legislation (Ministru kabineta noteikumi Nr.34, 2002) only applies to WWTP larger than 10 000 PE. For these WWTP maximum N concentration is 15 mg l^{-1} and maximum P concentration is 2 mg l^{-1}. Fig. 5 shows reduction of nutrient concentration in treated WW from WWTP ´Kriger' over time. The WWTP Krigeri meets N concentration regulations, but peaks in 2010 (15,90 mg l^{-1}) when the WWTP was under reconstruction. Starting with 2006 WWTP Krigeri meets regulation for Phosphorus concentration in treated WW.

Total average nutrient concentration in treated WW loaded to river Berze basin have not reduced

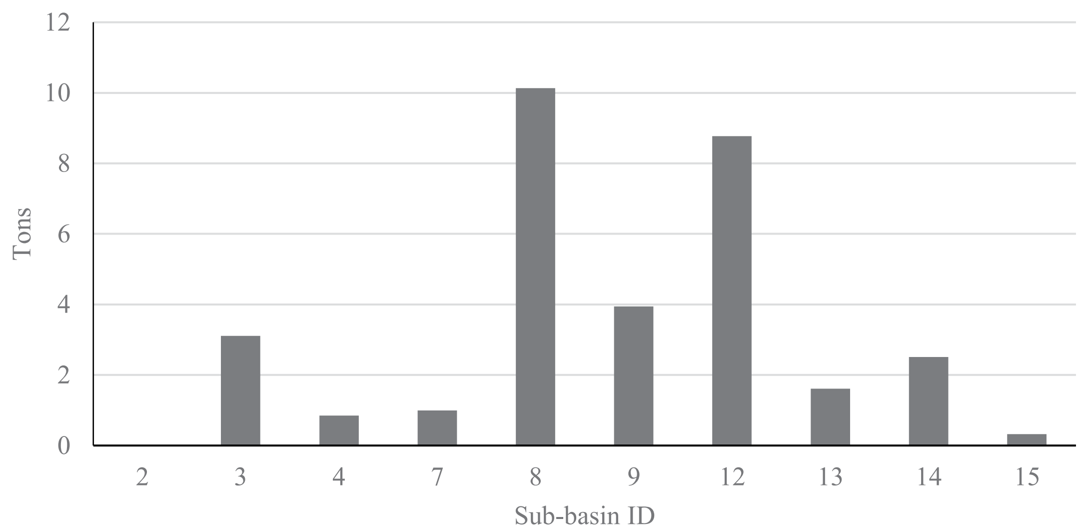

Figure 3 Total amount of Phosphorus loaded from WWTPs to river Berze basin from 2005 to 2015.

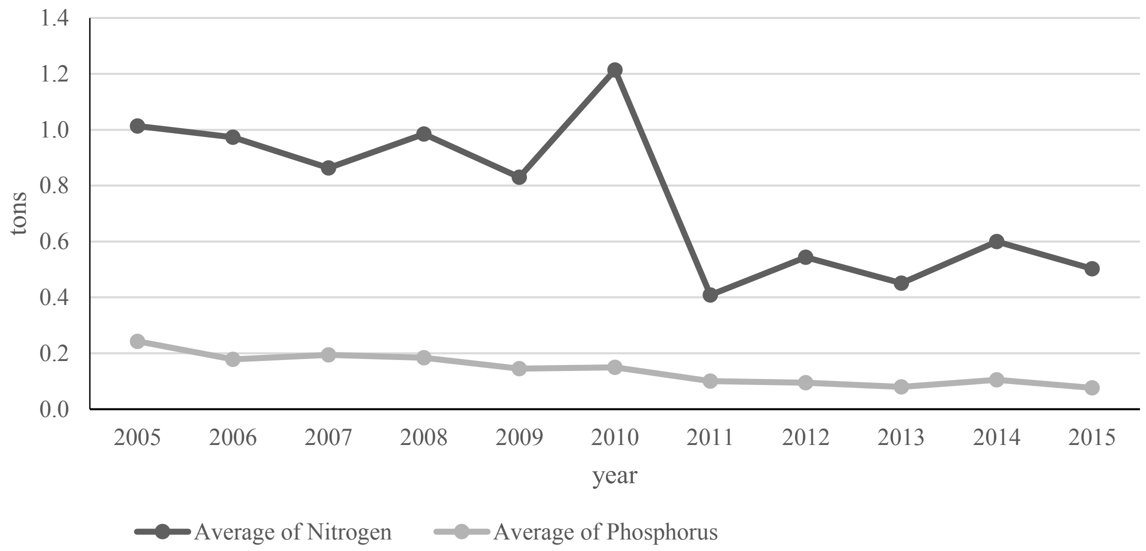

Figure 4. Average N and P load from WWTPs to the Berze River basin changes in time (2005 – 2015).

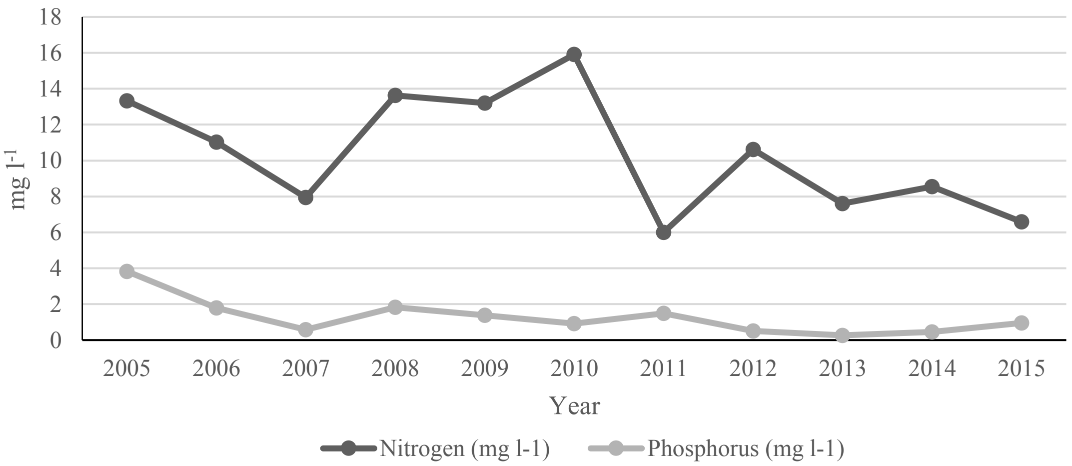

Figure 5. Concentration of nutrients (N and P) in treated WW from WWTP 'Krigeri' changes over time.

over time (Fig. 6). Average nitrogen concentration has met regulations (concentration of nitrogen 15 mg l^{-1}) only in years 2011 (14.56 ± 2.54 mg l^{-1}) and 2012 (14.04 ± 13.19 mg l^{-1}) and since then have increased to 32.57 ± 4.34 mg l^{-1} in year 2015. Average phosphorus concentrations have reduced from 7 ± 1.35 mg l^{-1} (in year 2005) to 3.69 ± 0.44 mg l^{-1} (in year 2015) and these concentrations are higher than set in the state regulations.

All the results indicate that to reduce N and P loads to river Berze basin from point sources small WWTP (PE < 10000) have to be targeted. The largest WWTP 'Krigeri' meets all the legislation set by state government and have reduced nutrient load to river Berze basin, but overall situation in the basin shows nutrient concentration increase suggesting other (PE > 10000) WWTP causing the problem. In Poland, poorly treated waste water has been recognized as one of the main eutrophication causes in the Baltic sea region (Kiedrzyńska *et al*., 2014). Results of this research stress the importance to target small WWTPs as the main pollutant with nutrients of the river basins in Latvia.

Conclusions

It was recognised in this study that the average amount of nutrients (N and P) loaded to river Berze basin from WWTP (waste water treatment plants) have reduced over time.

The largest amount of nutrients is loaded to sub-basin ID 12 where city of Dobele and its WWTP are located. In time from 2005 to 2015 in total 76.252 tons on nitrogen and 8.770 tons of phosphorus have been loaded to the river Berze basin sub-basin ID 12.

The WWTP Krigeri (the larges WWTP in the study area) meets N and P concentration in treated WW

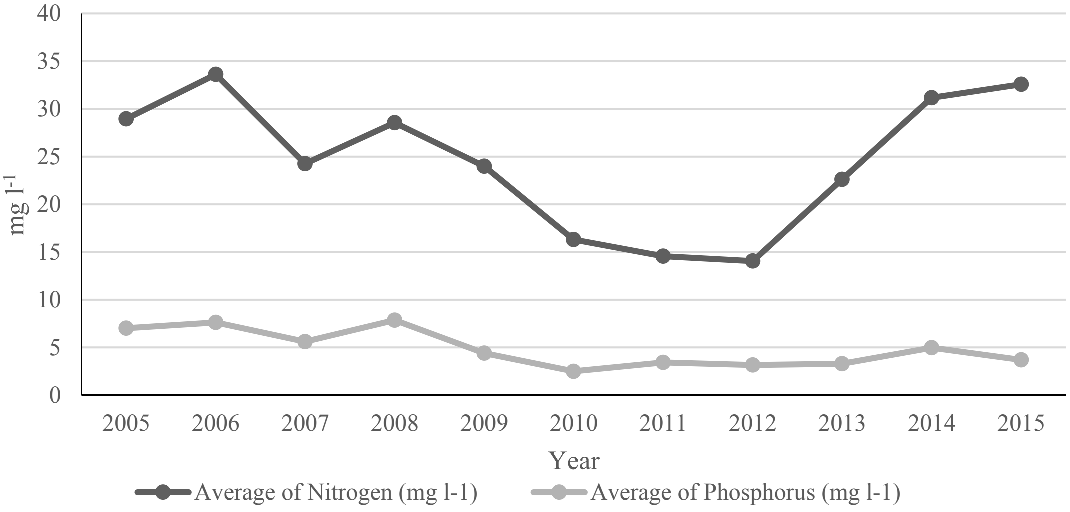

Figure 6. Average concentration of nutrients (N and P) in treated WW loaded from WWTPs to river Berze basin changes over time.

(waste water) regulations set by Republic of Latvia Cabinet Regulation No. 34. But the concentration of nutrients in treated WW loaded to river Berze basin haven't reduced in time pointing out that the problem might be the smaller WWTP (PE < 10000). Thus, to reduce nutrient load to river Berze basin small WWTP should be targeted.

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