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THE IMPACT OF RURAL SETTLEMENTS ON WATER QUALITY IN SMALL RIVERS AND DRAINAGE CHANNELS

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Abstract. According to the requirements of the EU Water Framework Directive 2000/60/EC, good water quality in all EU countries should have been achieved by 2015. One of the most important environmental problems is river pollution with insufficiently treated wastewater. Often untreated wastewater of whole or some part of a settlement or separate households is discharged directly to rivers or drainage channels. The aim of this paper is to introduce the impact of the settlements in rural areas on water quality in small rivers and drainage channels. Water quality has been analyzed in Kedainiai and Panevezys districts above and below the villages. The amount of oxygen in water, water temperature and flow rate are measured at the study site. The water samples are collected for identification and evaluation of chemical parameters. The obtained data brings to the conclusion that all the studied villages have a significant impact on small water bodies, especially during the dry season.

Keywords: rural areas, water streams, drainage channels, biogenic substances, pollution, wastewater treatment.

1. Introduction

Intensification of human activity causes increasing occurrence of polluting substances in water environment. This attracts attention of political organizations, environmentalists and the society. Many scientists and state organizations make every effort to centralize wastewater treatment for the biggest possible number of households. Nevertheless, centralized water supply and wastewater management system is not available for all inhabitants of many districts; some settlements cannot equip such system due to technical and material reasons. Therefore, the untreated household wastewater usually goes to the next water body (Kuhl *et al.* 2010).

Lithuania has accumulated much information on various methods, technologies and exploitation of wastewater treatment in cities. However, the technologies, which are used in cities, are not quite good for treat-ment of small amounts of wastewater, due to specific conditions in villages and small towns (Levitas 2000; Levitas *et al.* 2008).

Management – collection and treatment – of small amounts of wastewater requires great expense, which is not proportional to the amount of wastewater and pollution load. The smaller settlement, the stronger variations of wastewater amount and pollution. This determines the necessity to distinguish the management of small amounts of wastewater as a separate category, which requires specific solutions, essentially different from those in the management of normal or big amounts of wastewater (Jucius and Rimeika 2006).

In Lithuania most of the small wastewater treatment systems (WTS), constructed 20–30 years ago, do not work properly, require repairs or reconstruction. Thousands of households discharge untreated wastewater to agricultural reclamation systems and natural waters, pollute surface and ground water bodies. Besides, in Lithuania a number of holiday homes have been turned to or are about to become living houses with no possibility to be connected to wastewater treatment system (Levitas *et al.* 2008; Šikšnys and Žibas 2000).

Rising use of water resources causes increasing pollution load in waterbodies. Also, rivers, streams and drainage channels play an important role in assimilation of municipal and industrial wastewater and its removal from agricultural areas (Singh *et al.* 2005; House *et al.* 1997, House and Denison 1997).

The household and industrial wastewater gets to the streams and channels crossing or flowing near the small rural areas. Leaching from agricultural areas also influences water quality in small waterbodies (Qadir *et al.* 2007). Wastewater contains the pollutants that impact the eutrophication of small rivers and drainage channels, which, in turn, causes degradation of the ecosystems (Varol and Sen 2009; Finnegan *et al.* 2009).

Chemical quality of waterbodies is an important factor in ecological evaluation of the ecosystem and application of environmental management (Neal *et al.* 2005). For example, nutrient enrichment, resulting in excessive growth of aquatic plants and reductions in dissolved oxygen, is a growing problem particularly in rural areas (Neal 2002; Neal and Whitehead 2002).

The main purpose of the study is to determine the impact of small rural areas on water quality in streams and drainage channels. According to this aim, it was provided to establish the changes of water quality in drainage channels and streams above the rural areas and below them, or below the sewage treatment plant, if it was in this area. According to data obtained and existing legislation the next task was to assess the scale and importance of the water quality changes in chosen areas.

2. Materials and methods

The investigations to evaluate the impact of villages on small waterbodies covered the settlements with population of 200 – 2000 inhabitants. Water samples from channels and streams were analyzed. All water samples were taken during the dry period of the year 2010, from the end of June till the beginning of October, when drainage systems did not work. Selection of this period aimed to evaluate the impact of settlements on small water collectors without additional attenuation and the pollutants coming with drainage water from agricultural areas, which could misrepresent the influence of settlements on small rivers and drainage channels.

Selection of the sampling sites depended on the size of the wastewater collector, relief and existence of the wastewater treatment system.

The investigation objects of two types were chosen:

1. The settlements, which had wastewater treatment system;

2. The settlements, which had no water treatment system.

The samples were taken from the streams and drainage channels with average flow of up to 0.2 m^3/s above and below the chosen rural settlement. In the villages, which had wastewater treatment systems, the samples were taken above the village, before the sewage discharger, from the discharger and below it, thus determining the efficiency of the wastewater treatment plant. Table 1 presents the list of the rural settlements, where the investigations were carried out. Some settlements were places of episodic investigations (one – two samplings), others – of permanent investigations.

Table 1. List of the investigated objects

N^0	Name of the settlement	Population	Waterbody– wastewater receiver	Dates of sampling	Wastewater treatment system
1	Krakės	991	Smilgaitis	2010 06 17, 2010 07 01, 2010 08 04, 2010 10 05	+
2	Pernarava	299	Upelis	2010 06 09, 2010 07 01, 2010 08 26, 2010 10 05	-
3	Akademija (Kėdainiai distr.)	873+1111*	Jaugila	2010 06 17, 2010 10 06	+
4	Baisogala	1913	Kiršinas	2010 06 30, 2010 07 29	+
5	Pakiršinys	698	Kiršinas	2010 06 30, 2010 07 29	+
6	Pelutava	239	Drainage channel	2010 06 09, 2010 08 26	-
7	Ramygala	1643	Upytė	2010 07 28, 2010 10 12	+
8	Devynduoniai	223	Drainage channel	2010 08 04	-
9	Paaluonys	215	Aluona	2010 06 09	-
10	Pavermenys	341	Drainage channel	2010 07 28	-
11	Pociūnėliai	535	Garduva	2010 06 30	-
12	Šlapaberžė	583	Kruostas	2010 06 22	+

* There are 873 inhabitants in Akademija village, but Vainotiškiai (population 1111) is connected to the same wastewater treatment system.

In five settlements samples were taken one time, in other five settlements – two times, and in two settlements – four times. The number of measurements depended on the settlement's suitability for the analysis with respect to the investigation results. This is a longitudinal study, so in most places the samples will be taken in the following dry period.

In the sampling sites oxygen concentration in water and water temperature were estimated with a portable measurer. Cross-section of the waterbody was also measured and formula 1 was used to calculate the water flow velocity

$$v = (1.23 + \frac{n_{30}}{30} + 24.73) / 100 \tag{1}$$

where: v – flow velocity, m/s; n_{30} – rotations of hydrometric mill, times per 30 seconds.

The stream (channel) discharge was calculated according to the formula 2

$$Q = S * v \tag{2}$$

where: Q – stream (channel) discharge, m^3/s; S – cross-section area of the stream (channel), m^2.

The water samples were analyzed by the following parameters, which were identified in the chemical analytical laboratory:

- BOD_7, mgO_2/l;
- Total N, mg/l;
- $N\text{-}NH_4$, mg/l;
- $N\text{-}NO_3$, mg/l;
- Total P, mg/l;
- $P\text{-}PO_4$, mg/l;
- Chlorides, mg/l;
- COD (Mn), mgO_2/l;
- COD (Cr) mgO_2/l.

Evaluation of water quality above and below the settlement or the wastewater discharger was based on the determined concentrations.

The impact coefficient (formula 3) was used to estimate the possible impact of the settlement on the quality of the waterbody. The estimation focused on three main indices of water quality: BOD_7, total N and total P.

$$Z = (\frac{C^t_{BDS}}{C^o_{BDS}} + \frac{C^t_N}{C^o_N} + \frac{C^t_P}{C^o_P}) : 3 \tag{3}$$

where: Z – impact coefficient (times); $C^o_{BDS}; C^o_N; C^o_P$ respectively BOD_7, total N and total P concentration in the stream (channel) water above the settlement; $C^t_{BDS}; C^t_N; C^t_P$ respectively BOD_7, total N and total P concentration in the stream (channel) water below the settlement.

The pollution loads (tones/year) according to BOD_7, total N and total P were calculated according to the formula 4 in all the studied waterbodies:

$$T = (C_t - C_0) * Q_{river} \tag{4}$$

where: T – load according to BOD_7, total N or total P, t/year; C_t - respectively BOD_7, total N or total P concentration below the settlement or the waste discharger; C_0 - respectively BOD_7, total N or total P concentration above the settlement or the waste discharger; Q_{river} – stream or drainage channel discharge.

As all the investigated streams had suffered strong anthropogenic influence and had been straightened, while the drainage channels could be attributed to the artificial waterbodies, estimation of their ecological potential followed Chapter IV of „Methodology for the Surface Waterbodies' Condition Evaluation" (Official Gazette, 2010, Nr. 29-1363). Table 2 presents the classification of ecological potential estimation, based on this methodology.

The wastewater quality evaluation was based on the maximum permissible concentrations (MPC) of the wastewater, discharged to natural environment, as provided in The Wastewater Management Regulations (Official Gazette, 2010-05-22, Nr. 59-2938).

Table 2. Ecological potential classes of the rivers, attributed to strongly changed waterbodies, and channels by physical-chemical quality indices (Official Gazette, 2010, Nr. 29-1363)

No	Index	Criteria of ecological potential classes by the values of physical-chemical quality indices				
		Maximum	Good	Average	Poor	Bad
1	NO_3-N, mg/l	<1.30	1.30–2.30	2.31–4.50	4.51 –10.00	>10.00
2	NH_4-N, mg/l	<0.10	0.10–0.20	0.21–0.60	0.61–1.50	>1.50
3	N total, mg/l	<2.00	2.00–3.00	3.01–6.00	6.01–12.00	>12.00
4	PO_4-P, mg/l	<0.05	0.050–0.09	0.09–0.18	0.18–0.40	>0.40
5	P total, mg/l	<0.10	0.10–0.14	0.14–0.23	0.23–0.47	>0.47
6	BOD_7, mg/l	<2.30	2.30–3.30	3.31–5.00	5.01–7.00	>7.00

3. Results and discussion

Evaluation of changes in concentrations of chemical parameters above and below the settlement shows the negative impact of the settlements without centralized wastewater management system on streams and drainage channels. The average discharge of the investigated streams and channels was 0.0051 m^3/s, and the maximum one – only 0.021 m^3/s. Actually, in all the sites concentrations of the investigated parameters below the settlement significantly exceeded the ones above the settlement.

4. Rural settlements without wastewater treatment systems

The settlement Pernarava has no wastewater treatment system, the households are illegally connected to the rain wastewater collection system, which discharge the collected wastewater to the nearest stream.

Table 3 presents water investigation indices of the Upelis stream that crosses Pernarava.

Table 3. Concentrations of the investigated water parameters in the streams crossing settlements Pernarava and Pelutava

Water source	The Upelis		Drainage channel	
Parameter	Above Pernarava*	Below Pernarava*	Above Pelutava	Below Pelutava
BOD_7, mgO_2/l	1.02±0.27	3.78±1.18	1.83-3.89	1.98-4.99
Total N, mg/	2.07±0.81	2.59±1.01	1.49-2.01	3.07-4.72
$N\text{-}NH_4$, mg/l	0.08±0.02	0.87±0.69	0.074-0.178	1.38-1.68
$N\text{-}NO_3$, mg/l	1.74±0.74	0.87±0.92	0.624-1.38	0.55-2.86
Total P, mg/l	0.04±0.01	0.59±0.48	0.067-0.164	0.48-1.07
$P\text{-}PO_4$, mg/l	0.02±0.01	0.26±0.33	0.028	0.43
Chlorides, mg/l	15.68±7.9	22.48±3.79	21.4-25.3	32.3-41.0
COD (Mn), mgO_2/l	5.78±1.53	11.25±2.98	9.6-10.8	9.6-8.8
COD (Cr), mgO_2/l	13.97±4.19	24.03±10.19	21.5	21.5

*Values of parameters from villages, which have been studied more times, are shown as average value ± standard deviation.

The average discharge of the stream Upelis, flowing by the settlement Pernarava, at the time of studies was 0.0026±0.0019 m^3/s. Investigations show that Pernarava settlement impacts the increase of phosphorus concentrations in the stream. Average increase of the $P\text{-}PO_4$ concentration was 17 times, of total P concentration - 16.3 times, of $N\text{-}NH_4$ – about 11.5 times in the stream Upelis.

A drainage channel crosses the village Pelutava. In the period of investigations the discharge fluctuated within 0.001 – 0.002 m^3/s. Concentrations of all the studied parameters in the channel below Pelutava were significantly higher than those above the village. The strongest observed increase was that of $N\text{-}NH_4$ concentration. Concentrations above and below the village differ 7.75 - 22.7 times. Concentrations of total P and $P\text{-}PO_4$ also increased significantly – 6.5-7 and 15 times respectively.

In some settlements episodic investigations of the waterbodies were carried out. Results of the studies are presented in Table 4. Analysis of BOD_7 and total N concentrations brings to the assumption that these settlements had no significant impact on the streams. However, the impact becomes obvious in the analysis of phosphorus concentrations. The total P concentration increased 1.5-5.4 times in the sampling places below the settlements.

Table 4. Values of the investigated parameters for the settlements without wastewater treatment systems

Parameter	The Aluona		The Garduva		Drainage channel		Drainage channel	
	Above Paaluonys	Below Paaluonys	Above Pociūnėliai	Below Pociūnėliai	Above Pavermenys	Below Pavermenys	Above Devynduoniai	Below Devynduoniai
Discharge, m^3/s	0.066		0.028		0.021		0.0002	
BOD_7, mgO_2/l	3.37	4.81	6.75	6.08	9.74	7.38	2.16	2.1
Total N, mg/l	4.62	5.2	3.31	2.48	6.5	2.51	5.61	3.06
$N\text{-}NH_4$, mg/l	0.237	0.344	0.798	0.145	1.48	0.614	0.047	0.229
$N\text{-}NO_3$, mg/l	4.14	4.39	1.05	0.98	2.63	< 0.0	5.14	1.65
Total P, mg/l	0.067	0.163	0.145	0.21	0.154	0.864	0.069	0.373
$P\text{-}PO_4$, mg/l	-	-	0.024	0.072	0.009	0.243	0.019	0.302
Chlorides, mg/l	48.7	69.6	22.7	21.4	27.7	47.9	41	23.3
COD (Mn), mgO_2/l	17.43	19.01	13.7	18.8	12.2	26.7	12.5	33.9
COD (Cr), mgO_2/l	-	-	55	58	37.3	74	52	39

Estimation of the settlements‘ influence on the small waterbodies was based on the impact coefficient Z, calculated according to the formula 3. Calculation of this coefficient involves analysis of three main quality parameters – changes of BOD_7, total N and total P concentrations in the waterbody above and below the settlement. This index shows how many times the average total concentration of these parameters in the stream or drainage channel increases or decreases below the settlement.

According to the data, presented in the Table 5, Pernarava settlement has the strongest impact coefficient.

Table 5. Impact of the settlements without wastewater treatment systems on the waterbody.

Settlement	Impact coefficient Z (times)
Pelutava	3.39-3.45
Pernarava*	8.2±5.77
Paaluonys	1.66
Pociūnėliai	1.03
Pavermenys	2.35
Devynduoniai	2.31

*Values of parameters from villages, which have been studied more times, are shown as average value ± standard deviation

Water quality is also under the influence of the by-flowing water discharge and the load of pollutants. The load of pollutants according to BOD_7, total N and total P is presented in Table 6.

Table 6. Load of pollution in waterbodies according to BOD_7, total nitrogen and total phosphorus in the settlements without wastewater treatment system

Watebody/ settlement	Load according to BOD_7, t/year	Load according to N, t/year	Load according to total P, t/year
Drainage channel/ Pelutava	0.007-0.052	0.074-0.128	0.019-0.043
Upelis/ Pernarava*	0.226±0.1	0.066±0.08	0.045±0.04
Aluona/ Paaluonys	0.3	0.12	0.02
Garduva/ Pociūnėliai	-	-	0.006
Drainage channel/ Pavermenys	-	-	0.470
Drainage channel/ Devynduoniai	-	-	0.0018

*Values of parameters from villages, which have been studied more times, are shown as average value ± standard deviation

The settlement Pavermenys has been distinguished for the pollution load of the bypassing water sources, where the highest calculated load is 10 times higher than corresponding index of other settlements.

Analysis of ecological potential of the waterbody is one of the most important criteria for water condition evaluation. In this work, evaluation of the ecological potential of small rivers and drainage channels, as strongly transformed waterbodies, is based on „The Methodology for Evaluation of Surface Waters‘ Condition“ (Official Gazette, 2010, Nr. 29-1363).

Analysis of water quality in the drainage channel, crossing Pelutava village, includes evaluation of the ecological potential above and below the settlement. Concentrations of all parameters during one measurement above the settlement indicate average or good ecological potential, during other measurement – maximum potential. However, a concentration in the samples from the point which is below the village shows poor or bad ecological potential. Significant increase of $N\text{-}NH_4$, total P and $P\text{-}PO_4$ was observed.

Evaluation of ecological potential of the Upelis, which crosses Pernarava village, is based of average data of four measurements. According to concentrations of the four parameters – BOD_7, $N\text{-}NH_4$, total P and $P\text{-}PO_4$, ecological potential of the Upelis above the settlement can be estimated as maximum, according to total N and $N\text{-}NO_3$ – very good. However, below the settlement after the discharger that brings untreated wastewater from the village, ecological potential according to $N\text{-}NH_4$, total P and $P\text{-}PO_4$ concentrations is poor or bad, according to BOD_7 – average.

In other settlements concentrations of the studied parameters below the settlement usually exceed those above the settlement, but decrease of ecological potential is not such strong. The investigation results show that even small settlements have essential impact on small waterbody and, usually, worsen its ecological potential to impermissible limits.

5. Rural settlements with wastewater treatment systems

Similar to the case of the villages without wastewater treatment systems, evaluation of the settlements that have wastewater treatment systems is based on the differences between the investigated parameters above and below the wastewater treatment plants.

The Smilgaitis stream, which crosses Krakės village, has the water discharge of 0.0412±0.028 m^3/s. Below Krakės village the strongest increase of $P\text{-}PO_4$ and $N\text{-}NH_4$ concentrations in the stream water was observed – about 12 and 13 times respectively. All other investigated parameters’ concentrations also increased significantly.

The Upytė stream, which crosses Ramygala village, has the discharge of 0.012-0.35 m^3/s. The impact of the settlement on the stream water quality is similar to that in the Smilgaitis below Krakės. The strongest increase of $P\text{-}PO_4$ and $N\text{-}NH_4$ concentrations in the stream water is observed – 10.3 and 11.5 times, respectively. Concentration of total P increases 6 times. Concentrations of other parameters do not differ so much.

Wastewater from Akademija settlement treatment plant is discharged to the Jaugila stream, its discharge is 0.048±0.1 m^3/s. Analysis of the investigated parameters in the Jaugila stream above and below the treatment plant indicates the strong changes of all concentrations. The strongest impact has been established on $N\text{-}NH_4$ and total P concentrations.

Table 7. Concentrations of the investigated water parameters in the streams, crossing the settlements Krakės, Ramygala and Akademija

Waterbody	The Smilgaitis		The Upytė		The Jaugila	
Parameter	Above Krakės* wastewater treatment plant	Below Krakės* wastewater treatment plant	Above Ramygala	Below Ramygala wastewater treatment plant	Above Akademija wastewater treatment plant	Below Akademija wastewater treatment plant
BDS_7, mgO_2/l	5.16±2.18	6.11±2.41	2.81-4.68	7.1-9.54	1.92-2.66	6.57-6.84
N total, mg/	3.47±1.36	5.34±1.84	2.52-3.02	6.87-11.6	2.8-8.77	6.1-11.9
$N\text{-}NH_4$, mg/l	0.08±0.04	1.73±1.28	0.11-0.245	1.36-2.74	0.039-0.151	4.15-4.81
$N\text{-}NO_3$, mg/l	1.93±1.10	2.01±1.01	0.807-1.23	3.14-6.37	2.01-7.99	1.88-6.83
P total, mg/l	0.10±0.06	0.38±0.18	0.082-0.093	0.471-0.597	0.036-0.069	0.316-0.682
$P\text{-}PO_4$, mg/l	0.02±0.02	0.26±0.18	0.04-0.048	0.382-0.524	0.02-0.025	0.305-0.672
Chlorides, mg/l	20.6±0.35	22.27±4.57	14.9-17	31.5-42.3	17.0-23.6	32.8-41.1
ChDS (Mn), mgO_2/l	22.9±8.52	23.47±5.75	22.3-30.6	13.5-22	11.3-11.6	9.7-11.8
ChDS (Cr), mgO_2/l	55.15±17.32	56.0±21.07	39.6-71.1	49.2-39.2	11.45	10.45

*Values of parameters from villages, which have been studied more times, are shown as average value ± standard deviation

Increased concentrations of the investigated parameters below the settlements in other studied waterbodies also took place. Table 8 presents summary of other waterbodies with changes in concentrations above and below the settlements.

Table 8. Values of the investigated parameters in the settlements with wastewater treatment systems

Parameter	The Kruostas		The Kiršinas		The Kiršinas	
	Above Šlapaberžė	Below Šlapaberžė	Above Baisogala	Below Baisogala	Above Pakiršinys	Below Pakiršinys
Discharge, m^3/s	0.1310	0.0843	0.03-0.138	0.03-0.138	0.042-0.139	0.042-0.139
BOD_7, mgO_2/l	2.88	3.75	4.28-5.14	3.02-3.66	4.66-5.71	4.1-7.94
N total, mg/l	3.78	4.28	1.61-1.85	1.62-2.99	1.66-2.94	2.97-3.09
$N\text{-}NH_4$, mg/l	0.176	0.884	0.241-0.458	0.257-1.64	0.113-0.694	0.235-0.778
$N\text{-}NO_3$, mg/l	2.9	2.71	0.115-0.14	0.102-0.222	0.221-1.21	0.657-1.6
P total, mg/l	0.093	0.182	0.172-0.216	0.152-0.377	0.226-0.48	0.326-0.365
$P\text{-}PO_4$, mg/l	0.017	0.124	0.073-0.101	0.073-0.124	0.141-0.249	0.218-0.32
Chlorides, mg/l	18.6	24.3	17-22.10	23.3-24	18.9-27.1	23.3-30.3
COD (Mn), mgO_2/l	16.5	16.5	14.5-17.3	13.4-14.5	11.8-13.6	10.6-20.6
COD (Cr), mgO_2/l	-	-	30-36.1	35.0-39.0	26.3-31	31.5-35

The obtained investigation data is used for calculation of the coefficient of the settlement impact on the waterbody. Table 9 presents values of this impact coefficient.

Table 9. Impact of the settlements with wastewater treatment systems on the waterbody

Settlement	Impact coefficient Z (times)
Akademija	4.57-4.84
Krakės*	2.26±1.21
Šlapaberžė	1.46
Baisogala	0.76-1.58
Pakiršinys	0.8-1.73
Ramygala	3.67-4.1

*Values of parameters from villages, which have been studied more times, are shown as average value ± standard deviation.

Wastewater treatment plant in Akademija settlement has the strong impact on the Jaugila stream, Ramygala settlement – on the Upytė stream.

Table 10 presents data of pollution load on waterbodies.

The Kiršinas stream, which crosses Pakiršinys settlement, gets the biggest load according to BDS_7. One of the two conducted measurements shows negative load from this settlement, therefore, estimation of the real amount of the pollutants, coming from Pakiršinys, requires more measurements. The strongest load according to total N and total P goes to the Jaugila stream.

Estimation of the ecological potential of the investigated streams and drainage channels above and below the settlements indicates a significant decrease of this potential downstream the wastewater discharge.

Table 10. Load of pollution in waterbodies according to BOD_7, total nitrogen and total phosphorus in the settlements with wastewater treatment system

Waterbody / settlement	Load of pollution according to BDS_7, t/year	Load of pollution according to total N, t/year	Load of pollution according to total P, t/year
The Jaugila / Akademija	9.1-11.4	7.3-7.7	0.65-1.4
The Smilgaitis / Krakės*	3.5±1.6	2.0±1.3	0.29±0.26
The Kruostas / Šlapaberžė	3.6	2.1	0.4
The Kiršinas / Baisogala	-	3.7	0.54
The Kiršinas / Pakiršinys	14.3	0.086-6.2	0.61
The Upytė / Ramygala	0.3-0.4	3.2-6.4	0.29-0.37

*Values of parameters from villages, which have been studied more times, are shown as average value ± standard deviation.

Thus, for example, ecological potential of the Smilgaitis stream above Krakės settlement according to BOD_7 and total N is average, according to $N-NH_4$ and $N-NO_3$ – good, but according to total P and $P-PO_4$ – maximal. Meanwhile, below the discharger the ecological potential according to BOD_7, $N-NO_3$, total P and $P-PO_4$ becomes poor. Analysis of the wastewater, discharged from the treatment plant, shows that the treatment requirements are not met. This points to the low efficiency of the treatment plant.

The ecological potential of the Upytė stream above Ramygala according to BOD_7, total N and $N-NH_4$ is good during one measurement and average during other measurement. Both measurements show maximum ecological potential according to $N-NO_3$, total P and $P-PO_4$. However, below this settlement both measurements show significant increase in concentrations of all investigated parameters and the potential becomes poor or bad.

During one measurement the ecological potential of the Jaugila stream above Akademija settlement is good according to all parameters except total P and $P-PO_4$, according to which the potential is maximum.

During the other measurement the ecological potential according to total N and $N-NO_3$ is poor, but according to other parameters – maximum. However, below the settlement the ecological potential of the stream is poor and bad according to all investigated parameters. This indicates that in the case of too low water stream discharge, the wastewater dilution and treatment should meet strengthened requirements.

In Krakės, Ramygala and Akademija settlements the wastewater plants do not treat the waste to the sufficient level, which causes the decrease of ecological potential in water bodies to impermissible values. This indicates that the wastewater treatment plants in the settlements with population of over 1000 at small wastewater accumulations should meet very strict wastewater treatment requirements.

6. Conclusions

Evaluation of the impact of rural settlements on small streams and drainage channels during the dry period shows decline of water bodies‘ state below the investigated villages irrespective of the (not)existing wastewater plants. The differences are observed only in the analysis of the impact degree and amounts of the pollutants.

The highest impact on waterbodies - wastewater receivers in all investigated settlements was established in Pernarava village - the estimated coefficient is 8.2±5.77. The highest impact on chosen waterbodies of settlements with equipped wastewater treatment system was in Akademija village – calculated impact coefficient is from 4.57 to 4.84.

The strongest negative influence on the water quality in streams has been established according to ammonia nitrogen and total phosphorus concentrations.

According to BOD_7, total nitrogen and total phosphorus the largest load in all treated waterbodies was in Jaugila. The samples were taken above and below wastewater treatment plant collecting sewage from Akademija ir Vainotiškės villages with population about 2000 inhabitants all together. Determined loads ranged from 9.1 to 11.4 tons/year by BOD_7, from 7.3 to 7.7 tons/year by the total nitrogen and from 0.65 to 1.4 tons/year by the total phosphorus. The largest load of the settlements without sewage treatment system was in drainage channel near Pavermenys village with a population of about 300 people. Estimated load on this waterbody is about 0.47 tons per year by total phosphorus.

In almost all investigated settlements ecological potential of the streams below the settlements worsen to poor and very poor condition.

To improve water quality in small streams, the wastewater treatment in the settlements with population under 2000 should meet special requirements related to BOD_7, total nitrogen and phosphorus.

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