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Hauled liquid waste as a pollutant of soils and waters in Poland

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Abstract: *Hauled liquid waste as a pollutant of soils and waters in Poland.* Improperly maintained holding tanks are often underestimated source of contamination of soil, groundwater and surface water. As a rule, wastewater stored in holding tanks, should be transported and treated in municipal wastewater treatment plants (WWTPs). There are 2,257,000 holding tanks in Poland, located mainly in rural areas. The article presents the results of analysis of wastewater management in 20 rural and urban-rural communes, which were chosen at random from the total number of 2,174 communes in Poland. The only criterion of commune selection was total or partial lack of sewerage system. Analysis of the collected data showed that on average only 27% of liquid waste from holding tanks ended at the WWTPs. The median is even lower and amounts to 17.5%. More than 4,000 Mg of P and 26,000 Mg of N is dispersed in the environment in uncontrolled manner. Those diffuse point sources of pollution may be one of the reasons in the difficulty of achieving of good ecological status of rivers and affect the quality of the Baltic Sea.

Key words: on-site wastewater management, holding tank, uncontrolled discharges, nitrogen, phosphorus

INTRODUCTION

Protection of water resources against pollution covers the reduction of emissions from point sources, using accepted emission limits, and reduction of emissions from non-point sources (mostly rural areas) through the application of best available techniques (Water Law Act 2001). Point sources are usually well identified, and a lot has been done last years to limit pollutants load from wastewater treatment plants (WWTPs). In Poland, implementation of the National Programme of Municipal Wastewater Treatment (2003) for agglomerations of above 2,000 PE, resulted in significant increase of population connected to municipal WWTPs. Between 2003 and 2012 more than 300 new municipal WWTPs have been constructed and more than 900 modernized. Wastewater treatment plants serving more than 10,000 PE must provide enhanced removal of nutrients. Ecological effect of the mentioned programme is reduction of 82.3% of BOD_5, 70.7% of total nitrogen and 78.6% of total phosphorus reached in 2013 (Sumisławski 2013). Non-point sources, often understood as agricultural runoff, are responsible for significant inputs of pollutants, mostly nutrients, to surface waters (Verheyen et al. 2015). Suburban and rural areas however, generates pollutants not only at the arable land but also at the connected infrastructure, as well as in residential areas not connected with agricultural production, e.g. small settlements, summer houses, recreation areas etc. Reducing only diffuse inputs from agriculture without considering the contributions of dispersed point sources, e.g. septic tanks or holding tanks may therefore undermine eutrophication control strategies in rural watersheds (Withers et al. 2014, Wood et al. 2015).

The possible variants of management of domestic wastewater from single houses are: connection of the property to the existing sewerage network or, in case where the sewage system is technically or economically unjustified, using the wastewater holding tank or installation of on-site wastewater treatment plant (Act on maintaining... 1996). Sewer system ended with municipal wastewater treatment plant is the most popular method of wastewater management in urban areas in Poland (93.3% of total population in cities), but only 35.3% population of villages is connected to municipal WWTPs (Environment 2014). In rural areas, on-site wastewater treatment is getting more and more popular. Increased interest in this area is expressed by the number of on-site treatment plants constructed in recent years. In year 2000 only 578 on-site wastewater treatment plants with a total capacity of 502 $m^3 \cdot day^{-1}$ have been installed, but in 2005 1,782 (capacity of 2,101 $m^3 \cdot day^{-1}$), in 2010 10,159 (19,250 $m^3 \cdot day^{-1}$), in 2012 11,791 (22,657 $m^3 \cdot day^{-1}$) and in 2013 15,871 plants with a total capacity of 25,012 $m^3 \cdot day^{-1}$ (Environment 2014). However, still septic tank with the drainfield is the most popular solution for on-site wastewater management in Poland and many other countries (Eveborn et al. 2014). In Europe 26% of households rely on this system (Williams et al. 2012). Simple septic systems have many disadvantages and can create environmental risks. According to Withers et al. (2014), it can be a major, and potentially underestimated, source of water pollution. The environmental risk increases significantly if density of such systems is high (Szustakowski and Halicki 2004, Arnscheidt et al. 2007). More advanced on-site wastewater treatment plants are also implemented, but without proper maintenance they often fail, and the quality of effluent is comparable to simple septic system (Karczmarczyk

FIGURE 1. Wastewater from household holding tanks is transported to municipal wastewater treatment plants

et al. 2009). Ecological engineering solutions e.g. constructed wetlands and sand filters, which are effective as on--site systems still are used marginally.

This study focuses on wastewater collected in holding tanks, which if managed properly, should be transported and treated in municipal wastewater treatment plant (Fig. 1). In Poland 90% of population not connected to municipal WWTPs use holding tanks as a solution for wastewater management. The rest is served by on-site treatment systems, mostly septic systems with infiltration (Municipal infrastructure… 2014). The goal of the study is to estimate the scale of the abnormalities in wastewater management and related environmental hazard on the example of Poland. Uncontrolled sources of pollutants can be a hidden reason of difficulties with reaching good ecological status of rivers as well as unbalanced loads of pollutants discharges to Baltic Sea.

MATERIAL AND METHODS

Data for analysis were collected base on the questionnaire. The survey included information such as: (1) population; (2) water consumption; (3) number of people connected to the water supply system; (4) number of people connected to the sewerage network; (5) number of people using on-site wastewater treatment systems; (6) wastewater holding tanks; (7) volume of wastewater treated in municipal WWTPs; (8) volume of sewage transported by trucks from holding tanks and treated in municipal WWTP (9). Data collected in the survey were supplemented by information from the Internet: e.g. type of the commune (rural/urban-rural), the area etc. To compare obtained results against the background of the whole country, official statistics were used (Environment 2014, Municipal infrastructure… 2014). The only criterion of selection of analyzed commune was total or partial lack of sewerage system. The analysis comprised 20 communes located in 5 voivodeships, of which 16 was rural and 4 urban-rural. Publication does not disclose the names of communes. Also the population and the area data have been rounded. The analysis covers years 2011–2014.

Based on the collected data and calculations: (1) the amount of wastewater from holding tanks transported to WWTPs (as the percent of wastewater collected); (2) the load of pollutants discharged to the environment in an uncontrolled manner were estimated. For the calculation of the volume of wastewater produced by holding tanks owners, unit water use (typical for each commune) and four people living in one household as an average was used. Obtained volumes were compared with official data collected from communes (volume of wastewater delivered to the receiving stations of WWTPs). The difference shows the volumes of wastewater discharged to the environment in an uncontrolled manner. Estimation of pollutant loads was limited to two indicators (nitrogen and phosphorus), and calculated base on the unit loads given by German standard ATV-DVWK-A 131 E (Table 1), as it is used as a rule in Poland in the process of designing of wastewater infrastructure.

TABLE 1. Unit loads of pollutants in raw wastewater [g·person^{-1}·day^{-1}]

Index	Rural areas Polish research (Biedugnis 2006)	Municipal German standard (ATV-DVWK-A 131 E)	Municipal Polish research (Heidrich and Kozak 2009)
Solids	65–90	70	66
BOD_5	45–85	60	68
COD	–	120	125
N_{tot}	10–18	11	12.8
P_{tot}	2–7*	1.8	1.96

From the time of this publication unit load of P decreased significantly as the result of progressive changes in the composition of detergents used in households. According to Pistelok (2010), the unit P load for Polish conditions amounts 1.9 g·person^{-1}·day^{-1}.

RESULTS

There are in total 2,174 communes in Poland. Analyzed group of 20 communes is described in details in Table 2. They differ both in terms of population, area and location, as well as the infrastructure: amount of population served by the water supply system and sewerage network.

Population connected to water supply system varied in different communes from 35.2 to 97.3% (with the average at 77.4%), which is less than the Polish average (88%). The unit water use varied from 19 to 55.3 m^3·person^{-1}·year^{-1} (mean 36.3) and is higher than the country average. Unit water use in Poland in cities amounts to (34 m^3·person^{-1}·year^{-1} and in rural areas to 26.3 m^3·person^{-1}·year^{-1} (Municipal infrastructure… 2014). In one of analyzed communes only 6.6% residents were connected to sewer system, by contrast, in another 97.8%. The average (40.5%) was lower than for the country (65.1%). The population using wastewater holding tanks in analyzed group of communes varied over a wide range from 1.7 to 93.2%.

In 9 out of 20 analyzed communes, the amount of sewage transported and discharged to the WWTPs was less than 10% of wastewater produced, including 5 communes below 5% (Table 2, Fig. 2). In the leading commune nearly 86% of wastewater from holding tanks was discharged to the receiving station of WWTP. On average, for the analyzed group of communes, 27% of stored wastewater ended in WWTPs. It means that on average, more than 70% of raw wastewater somehow were dispersed in the environment. Even more frightening picture can be obtained by analyzing official statistics (Environment 2014, Municipal infrastructure… 2014). Annual production of wastewater in Polish households amounts to 912.6 hm^3·year^{-1}. Considering 65.1% of wastewater served by sewerage systems and WWTPs there is still 318.5 hm^3·year^{-1} of wastewater out of municipal treatment systems. Share of 90% of those households are served by wastewater holding tanks, what gives about 298.1·hm^3·year^{-1} of wastewater, which should be transported to WWTP receiving stations. According to data of Central Statistical Office (Municipal infrastructure… 2014) from individual households only 15.6 hm^3 of wastewater was collected during the year, what gives the number of 5.2%. That means

TABLE 2. Summary of the characteristics of the analyzed communes

Commune aea (value rounded) (km^2)	Population (value rounded)	Population connected to water network (%)	Unit use of water ($m^3 \cdot p^{-1} \cdot year^{-1}$)	Population connected to (%)			Share of wastewater from storage tanks treated in WWTP (%)	Data from the year	Type of commune; Voivodeship
				sewerage system and WWTP	on-site treatment system	wastewater holding tank			
80	3 500	35.2	19.0	33.3	5.2	61.5	3.8	2013	rural, LOD
25	13 000	92.1	39.4	39.0	7.9	53.1	0.8	2013	rural, LOD
95	6 000	75.8	39.4	28.8	<0.1	71.2	5.6	2013	rural, MAS
180	12 500	80.0	34.9	72.8	7.8	19.4	5.3	2014	urban-rural, MAS
80	10 500	88.0	37.6	53.0	<0.1	47.0	80.9	2013	urban-rural, MAS
105	10 500	83.7	36.4	46.8	3.0	50.2	16.6	2013	urban-rural, SIL
110	5 500	67.3	27.1	23.1	26.2	50.7	34.9	2013	rural, LUB
100	4 500	82.9	34.0	50.0	33.8	16.2	6.7	2013	rural, KUY-POM
105	19 500	36.4	27.0	10.9	<0.1	89.1	3.3	2014	urban-rural, MAS
130	5 000	82.3	42.4	38.9	3.0	58.1	85.7	2013	rural, MAS
160	10 000	78.3	38.2	12.4	<0.1	87.6	49.6	2012	rural, LUB
100	9 000	90.0	55.3	48.0	3.0	49.0	18.4	2010	rural, MAS
95	8 500	75.3	30.0	23.6	8.3	68.1	49.6	2012	rural, MAS
65	17 500	84.3	44.2	53.9	0.3	45.8	0.03	2013	rural, MAS
245	13 500	97.3	37.9	96.5	0.2	3.3	84.1	2012	rural, LUB
310	17 500	87.2	28.8	32.3	19.5	48.2	46.8	2013	rural, LUB
150	7 500	81.9	24.6	22.4	0.1	77.5	6.1	2011	rural, MAS
180	61 500	95.0	37.8	97.8	0.5	1.7	22.9	2013	rural, LOD
95	7 000	71.6	49.4	17.4	3.3	79.3	20.2	2014	rural, MAS
145	7 500	63.0	42.6	6.6	0.2	93.2	3.6	2012	rural, LUB
Poland	38 478 602	88.0	30.9	65.1	34.9 in that 90% holding tanks		×	2013	Poland
Towns	×	95.5	34	87.4	×	×	×	2013	towns
Villages	×	76.6	26.3	30.9	×	×	×	2013	villages

Voivodeships: LOD – Łódź, MAS – Masovian, SIL – Silesian, LUB – Lublin, KUY-POM – Kuyavian-Pomeranian.

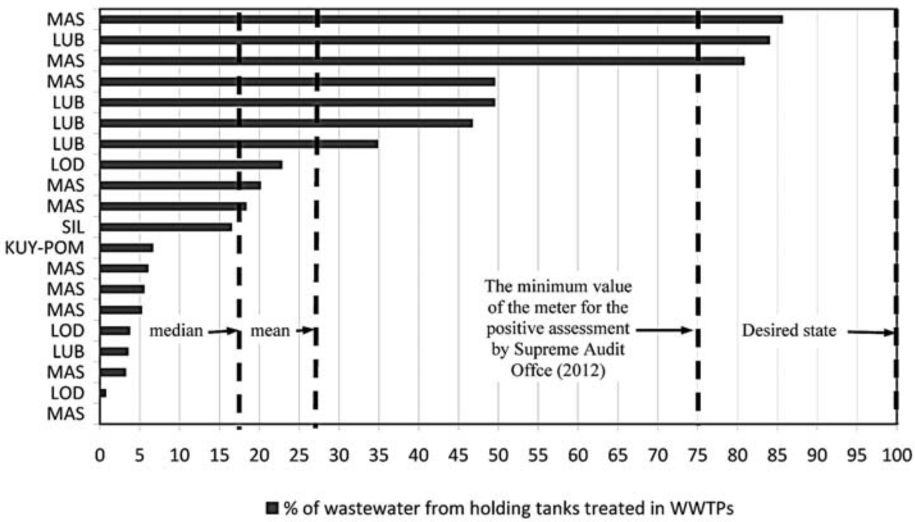

FIGURE 2. Precentege of liquid waste from holding tanks reaching receiving stations of WWTPs on example of analysed communes. Mean and median values are marked

that 282.6 $hm^3 \cdot year^{-1}$ of wastewater is dispersed in environment through the holding tanks leaking or pumping out on the fields. Due to failure of holding tank management, waste water treatment plants are hydraulically under-loaded causing problems in their operation (Bugajski and Satora 2009).

DISCUSSION

About 2,257,000 wastewater holding tanks were registered in Poland in 2013 (Municipal infrastructure… 2014), what gives population of about 9,000,000 served by this type of wastewater management. The group of communes analyzed in the study is small comparing total number of communes in Poland (about 1%), however comparing to other studies (Szustakowski and Halicki 2004, Municipal wastewater… 2012), author dares to say that obtained results more reflect Polish realities than official statistical data. Calculations show, that wastewater holding tanks can be a dispersed source of more 4,000 Mg of phosphorus and 26,000 Mg of nitrogen in the environment. To point out significance of those numbers, the total load of P and N to the Baltic Sea from the area of Poland estimated on 19,768 and 404,522 $Mg \cdot year^{-1}$, respectively (HELCOM 2015). It gives significant share of 20% for P and 6% for N which is out of control. For comparison with actual outcomes, dispersed residential buildings in Gliwice district in Poland generates 15% of the load of phosphorus and 12.5% of nitrogen to the watershed (Dudek et al. 2014).

Analyzed communes discharged into the environment in an uncontrolled way from 0.05 to 11.4 Mg of P and from 0.29 to 69.8 Mg of N during the year. Per unit area it gives annual loss per ha of up to 0.2 kg of P and 1.25 kg of N. Such loss of P is high, e.g. if compare with P export from arable land of 0.08–0.28 kg·ha^{-1}·year^{-1} of P (Verheyen et al. 2015). The majority of P leaching from leaky holding tanks will be adsorbed and precipitated in the soil, depending upon soil composition, groundwater velocity and loading history. Due to the passage of time natural sorption capacity of soil will be saturated and exposure on the outflow P to groundwater will increase (Harman et al. 1996). Szustakowski and Halicki (2004) stated the outflow of sewage from leaking holding tanks resulted in associated increased phosphorus concentration in the Quaternary groundwater. Phosphorus contained in sewage spilled from holding tanks is a potential source of contamination of surface water due to run-off. For example for agricultural areas, the loss P by surface run-off is 30 times greater than that due to leaching and infiltration (Frissel 1997). A relatively small percentage of P may, however, also contaminate groundwater, especially in the areas where groundwater form the baseflow of rivers. For example in Ireland annual average contributions ranges from 30 to 80%, with the maximum at the areas where aquifers are in good hydraulic connection to the river (Gill et al. 2009). According to German data, phosphorus content in groundwater can vary in the range of 0.03–0.11 mg·dm^{-3} (Pistelok 2010). Raczuk et al. (2009) estimated phosphate concentrations in Polish wells on 0.2–4.9 mg·dm^{-3} for shallow wells and 0.1–0.57 mg·dm^{-3} for deep wells. Despite the fact that more and more people use the water supply systems (88% of population in Poland), high P concentration in groundwater may limit its usefulness for other purposes, e.g. for filling backyard ponds (Karczmarczyk et al. 2015). The sewage pumped out from holding tanks e.g. to roadside ditches contaminate the surface water directly. Generally it is believed that surface water is the last stage of P life cycle, but preliminary studies (Patent application 2013) indicate that it can be recovered from the water and reused. In the case of nitrogen, as it is vulnerable to leaching, we will have to deal mostly with groundwater contamination. Elevated nitrate concentrations in groundwater are an indicator of wastewater or agricultural pollution. Nitrates also indicate potential microbial risk if the groundwater is used as a drinking water supply (Gill et al. 2009).

Any attempts to determine the statistical relationship between the amount of wastewater from holding tanks transported to the WWTPs and parameters of the commune (area, population, the amount of water consumed, level of development of water and sewerage infrastructure, number of holding tanks etc.) have not been successful. This suggests that we are dealing with the problem of people's mentality and the lack of appropriate control mechanisms of wastewater handling. The key question is what happens with wastewater from holding tanks if they don't reach municipal WWTPs. There are four possibilities: (1) the holding tank is leaking; (2) the owner empties it and spills the wastewater on soil or pumps it to the ditch (Fig. 3); (3) liquid waste haulers are unfair and instead bringing sewage to the receiving station of WWTP spilling them into a ditch or in a nearby forest; (4) unfair haulers deliver the liquid waste to receiving stations and/

FIGURE 3. Wastewater from holding tank pumped out by the owner on the soil reaches the surface water (ditch)

/or hidden sewerage manholes, but without any legal confirmation (Błażejewski and Nawrot 2009). All these illegal activities could be restricted if municipalities fulfill their statutory duty of supervision. The control and keeping the records of the frequency of emptying holding tanks is one of the municipality duties, as well as the control of the liquid waste haulers (Water Law Act 2001). The cost of transport of sewage in Poland ranges from 3.4 to 10.3 EUR·m^{-3}. In some areas it is significant burden on the household budget. The lack of control offers the chance to avoid these costs. For comparison, the fee for sewage discharge to sewer stands at 0.3–8.3 EUR·m^{-3}. This fee cannot be avoided.

Results obtained in presented study are similar to those performed 10 years ago by Szustakowski and Halicki (2004). They estimated the outflow of sewage from leaking holding tanks at 80%. That means, that although much has been done in the development of sewerage networks and municipal WWTPs, the inspection and education with regard to individual sewerage systems is still insufficient. Paradoxically, successful education in this field is becoming more and more difficult because contaminated wells already do not bother anyone as the water pipes are common. Low environmental awareness in this regard and the incompetence of the authorities, often driven by the convenience of officials and even fear for their own status. The majority of audits in municipalities is done on the basis of neighbors' denunciations but permanent control mechanism basically doesn't function.

Unequal development of water supply and sewerage network in Poland can be identified as a potential reason of described problem. The total length of water supply network in 2013 amounted 287.7 thousand km and the length of sewerage system only 132.9 thousand km (Municipal infrastructure… 2014). Although the even development of these networks was recorded as a duty in the Water Law Act (2001), its performance is often impossible for economic reasons. Most of the investments in the area of water and wastewater management in Poland are not implemented at the same time, but in the order, which leads to ridiculous situations, e.g.: multiple destroying and repairing the road surface, first as a result of pursuing water supply pipes, after that the sewage system in the coming years.

In this analysis, environmental impact of on-site wastewater treatment systems was not taken into account. In 2013 there were in total 155,000 of on--site wastewater systems in Poland (Municipal infrastructure… 2014), of which the vast majority are septic tanks with the drainfield (STS). They also can create real risk to the environment (Hartman et al. 1996, Szustakowski and Halicki 2004, Gill et al. 2009, Withers et al. 2014). According to a study of Jucherski and Walczowski (2001) wastewater discharged from STS to the soil have quality in the range of 331–558 mg·dm^{-3} for BOD_5, 88–164 mg·dm^{-3} for total nitrogen and 14–50 mg·dm^{-3} for P-PO_4. The value of 152 mg·dm^{-3} for total nitrogen has been also reported by Hartman et al. (1996). Comparing to the quality of the raw wastewater, treatment efficiency is inadequate. Moreover, in STS wastewater is distributed under the surface of the soil, making the control of the quality of discharged wastewater impossible. Following the recommendations of HELCOM (2007) maximum daily load per capita for wastewater treated in on-site systems should not exceed 8 g·person^{-1}· ·day^{-1} for BOD_5, 0.65 for total phosphorus and 10 for total nitrogen. It reflects the reduction of 80, 70 and 29%, respectively. Wastewater discharges from decentralized system (STS) may reach 0.05 Gg·year^{-1} of P (Ott and Rechberger 2012). They may have more eutrophication impact than previously thought, requiring action at the household level (Withers et al. 2014). Legacy P in soils, sediments and groundwater is an endemic and long-term source of P inputs to surface waters via runoff, and is delaying the restoration of good ecological quality in many surface waters (Sharpley et al. 2013).

CONCLUSIONS

Under the EU Waste Framework Directive (Directive 2008/98/EC) domestic wastewater involving holding tanks or individual wastewater treatment must be recovered or disposed of without endangering human health or the environment. The reality deviates significantly from the objectives. No leakage control and lack of tank-emptying monitoring, unfair and fraudulent people behavior, submitting financial benefits over the state of the environment and the lack of environmental awareness – this is a picture reveals from the content of this publication. Negative ecological effect of improper management of wastewater holding tanks in Poland is increased by on-site wastewater treatment in rural areas, where N and P discharges are not limited in proper regulations. First step for the improvement has been made at the beginning of 2015, thanks to new legislation (Regulation… 2014), which requires treatment of domestic sewage in on-site plants to the standards for the agglomeration (depending on PE). Unfortunately, rural areas are not the part of this legislation.

Holding tanks are the dispersed sources of pollution and cannot be ignored in catchment management programs. Regulation of individual sewage management should be a priority in Phosphorus

Reduction Programs being established on a base of the National Water Environment Programme (2010). Poland is the example but not only country in UE with holding tanks or STS as a dominating solution for on-site wastewater management. The result of analysis presented in this paper shows that there are still large gaps in the scale of wastewater management. This requires absolute compliance with the rules and the introduction of efficient control mechanism. Without resolute actions the EU objectives on achieving good ecological status of rivers and the protection of the Baltic Sea against eutrophication will not be achieved. The future of holding tanks in Poland depends on the education of the tank owners and the authorities of municipalities and their attention to compliance with the obligations of control stated in the Water Law Act (2001).

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Streszczenie: *Zbiorniki bezodpływowe jako potencjalne źródło zanieczyszczeń wód i ziemi w Polsce.* Niewłaściwie eksploatowane zbiorniki bezodpływowe są często niedoszacowanym źródłem zanieczyszczeń odprowadzanych do ziemi, wód gruntowych i powierzchniowych. Co do zasady nieczystości ciekłe gromadzone w zbiornikach bezodpływowych powinny być transportowane i oczyszczane w oczyszczalni ścieków. W Polsce użytkowanych jest 2 257 000 zbiorników bezodpływowych, głównie na obszarach niezurbanizowanych. W artykule przedstawiono wyniki analizy zagospodarowania nieczystości ciekłych w 20 gminach wiejskich i miejsko-wiejskich, które zostały losowo wybrane spośród ogólnej liczby 2174 gmin w Polsce. Jedynym kryterium, które musiała spełniać gmina, był częściowy lub całkowity brak sieci kanalizacyjnej. Analiza zgromadzonych danych wykazała, że średnio tylko 27% nieczystości ciekłych ze zbiorników bezodpływowych trafia do punktów zlewnych oczyszczalni ścieków. Wartość przeciętna (mediana) jest jeszcze mniejsza i wyniosła 17,5%. W efekcie nieprawidłowej gospodarki nieczystościami ciekłymi, ponad 4000 Mg fosforu i 26 000 Mg azotu rozprasza się w środowisku naturalnym w sposób niekontrolowany. To niekontrolowane źródło zanieczyszczeń może być jednym z powodów istnienia utrudnień w osiągnięciu dobrego stanu ekologicznego rzek i co w konsekwencji może wpływać na jakość wód Morza Bałtyckiego.

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