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Wastewater management in rural areas in the light of the principles of sustainable development

Abstract: The article presents the principles of sustainable development in relation to protecting natural waters against pollution. It also presents the development of water supply and sewage networks in rural areas in Poland over the years 1989-2015. Increased rate of constructing sewage disposal systems has been demonstrated, which occurred thanks to obtaining EU funds. It was found that the problem of wastewater management in rural areas with dispersed buildings is mainly tackled by the use of individual on-site devices. Based on the analysis of sewage test results, the author assessed the efficiency of selected household sewage treatment plants based on various technologies of operation. Using the analysis of sanitary state of Commune of Lubiewo in years 2012 to 2016 as an example, delay in building of a sewage system in the rural areas and increase in number of private sewage purification equipment were exposed.

Keywords: water and sewage infrastructure, wastewater management, rural areas.

1. Introduction

Important factors affecting people's standard of living include the availability of water suitable for drinking in the sufficient amounts, and the possibility of disposal and treatment of wastewater. Development of industry, services, agriculture, as well as sanitary and hygienic living conditions depend on these factors. A cause for anxiety is the fact that significant improvements in collective water supply are not accompanied by a concomitant rate of construction of sewage networks and treatment plants. This is particularly true of rural areas with dispersed buildings. In recent years, the state of water and sewage utility infrastructure in such areas has improved significantly thanks to absorption of EU funds. However, despite the large number of investments completed, the sanitary condition of rural areas is still unsatisfactory, which affects the implementation of a sustainable economy in these areas.

The aim of this article is to present the course of development of water and sewage infrastructure in rural areas in Poland and draw attention to the threat of environmental pollution in these areas, resulting from inadequate wastewater management.

2. Test methods

The article contains an analysis of:

- the condition of water and sewage infrastructure and the dynamics of its development in rural areas, based on the data regarding the length of water supply and sewage systems from 1989 to 2015 and the percentage of people using them between the years 2005 and 2015;
- the state of wastewater management in rural areas, based on data ranging from 2005 to 2015 regarding the percentage of Poland's population connected to collective sewage treatment plants and the number of household sewage treatment plants in the years 2009-2015;
- technological efficiency of on-site wastewater treatment plants, based on source litera-

ture data, comparing the quality of treated wastewater and reduction of pollution with the values specified in the Regulation of the Minister of the Environment;
– exemplary sewage management in the years 2012 - 2016 in the Commune of Lubiewo and sanitary state of the Commune in reference to the existing wastewater infrastructure in Polish rural areas.

The key sources of information used in this work were the Annals of Utility Infrastructure of the Polish Central Statistical Office (Statistical Yearbook…, Yearbooks 2012-2016), the Report of the National Water Management Board: Sewage management in Poland (Krajowy Zarząd Gospodarki Wodnej, 2016) and Environmental Protection Program for the Lubiewo Commune for the years 2016-2020 (Program Ochrony Środowiska…, 2016).

3. Water protection in the light of the principles of sustainable development

The adoption of the principles of sustainable development took place in Rio de Janeiro during the Earth Summit in 1992, with the signing of the so-called Rio Declaration (The Rio Declaration …, 1992). According to the Declaration, socio-economic development is supposed to consist in exercising the rights and fulfilling responsibilities towards the natural environment by states and citizens, which were announced in Agenda 21 (United Nations Conference…, 1992).

Among the 27 principles formed in the Declaration of sustainable development formulated, there are provisions regarding environmental protection, and thus also protection of water resources. They say that (after Rauba, 2013):
– The right to develop current and future societies should be guaranteed with a fair right to meet ecological and development needs.
– Environmental protection is an integral part of the sustainable development process and cannot be considered separately.
– States establish universally binding legal acts regarding liability for environmental damage and pollution, as well as compensation for victims.
– State authorities should strive to implement the principle that the polluter bears the cost of his pollution, in line with the public interest and without interfering with the course of international trade and investment.

Protection and ecological use of water consists primarily in ensuring safe and constant access to drinking water, so as to ensure the development of modern society and future generations. Therefore, it is necessary to carefully manage the resources of natural waters and create a sewage management system suitable for a given area, which will ensure the protection of natural waters from degradation. Environmental protection, including water, must be taken into account when planning and implementing socio-economic activities. This pro-ecological approach should be guaranteed by appropriate legislation that takes into account economic factors. An example of this is the principle that entities using the aquatic environment incur costs on this account, e.g. the cost of water intake or sewage disposal. On the other hand, the "polluter pays" principle means that the full costs of removing the resulting pollution of water and restoring the state from before the pollution occurred should be incurred by the perpetrator who caused the damage to the environment.

4. Development of water and sewage infrastructure in rural areas

Availability of water and sewage disposal networks in a given area has a significant impact on the standard of living of the area's residents, and contributes to protecting the natural environment, in particular ground waters and soil. In recent years, numerous investments in the development of water and sewage infrastructure have been undertaken in Poland, which

were largely financed with assistance programs and EU pre-accession programs (e.g. PHARE ISPA, SAPARD) and after Poland's accession to the European Union, with post-accession programs (e.g. Structural Funds, Cohesion Funds, Post-Accession Rural Support Program). They were implemented both in cities and in rural areas, which over the past twenty-five years has brought a mote than threefold increase in the length of the water supply network. The development of water supply and sewage networks in cities has not been as dynamic as in rural areas, as illustrated by the data shown in Figures 1 and 2. This was caused by the need to make up for a backlog of negligence in the sanitary infrastructure in rural areas.

In the years 1989-2015, the length of the water supply network in rural areas increased from 65 to 231 thousand kilometers, and that of the sewage network from 4.2 to 87.6 thousand kilometers. It is worth emphasizing that already in the year 2010 the length of the sewage network in rural areas was equal to the length of the network in cities and continued to grow dynamically. However, the length of the network does not provide a clear picture of the extent to which the needs of the population have been met, as rural areas are often characterized by dispersed housing and much smaller population densities than cities. A better indicator is the percentage share of the population using the network, whose values from 2005 to 2015 are provided in Table 1. As the data show, within ten years the share of the total population of Poland connected to the water supply network rose by 5.7 percent – from 86.1 to 91.8 percent, and the share of residents of rural areas by 12.5 percent – from 72.2 to 84.7 percent. Overall, the entire population's access to the sewerage network in the country increased in this period by 9.5 percent (from 59.2 to 68.7 percent), and in rural areas by 18 percent (from 19 to 37 percent). Despite such a significant

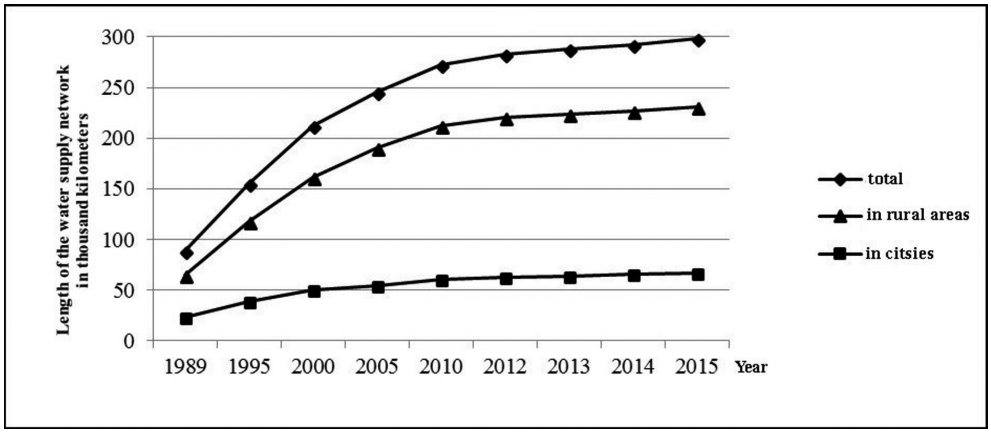

Figure 1. Overall length of the water supply network in Poland in the years 1989-2015 (Prepared based on Bogdanowicz, 2013; Statistical Yearbook…, Yearbooks 2012-2016)

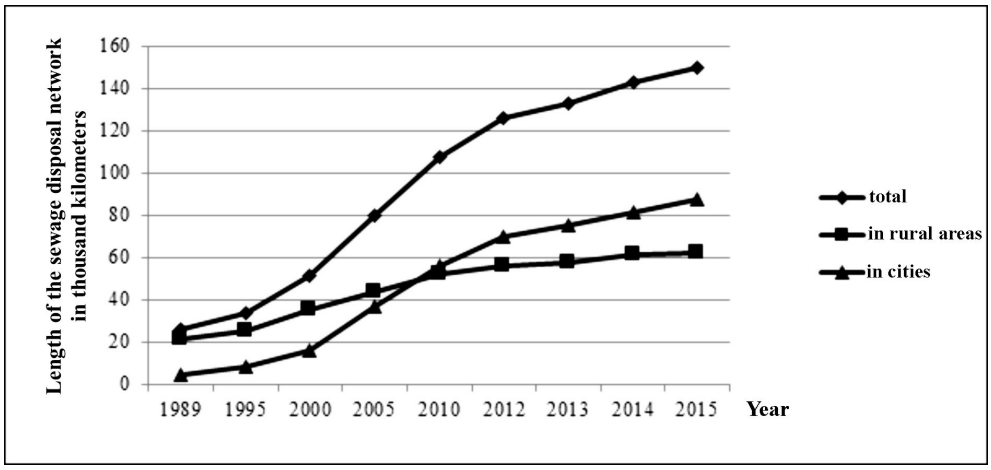

Figure 2. Overall length of the sewage disposal network in Poland in the years 1989-2015 (Prepared based on Bogdanowicz, 2013; Statistical Yearbook…, Yearbooks 2012-2016)

increase in the length of the sewerage network by the end of 2015, no more than six people out of ten living in rural areas had direct access to it.

The data quoted above indicate that the percentage of residents using water and sewage infrastructure increased more in rural areas than in cities. Despite this, there still remain large areas of neglect in wastewater management in rural areas. This is because access to water is a priority in the hierarchy of needs of rural residents and requires less financial investment than construction of sewage systems. However, the development of waterworks causes even a several-fold increase in the amount of sewage generated, which in rural areas is often discharged without proper treatment. Improvement of wastewater management in rural areas depends to a large extent on the development of sewage systems.

Table 1. Share of the population with access to water supply and sewage disposal networks in the years 2005-2015 (Prepared based on Bogdanowicz, 2013; Statistical Yearbook…, Yearbooks 2012-2016)

Year	Population with access to the network [%]			
	In Poland		In rural areas	
	Water supply	Sewage disposal	Water supply	Sewage disposal
2005	86.1	59.2	72.2	19.0
2006	86.4	59.8	72.8	20.2
2007	86.7	60.3	73.5	21.3
2008	87.0	61.0	74.2	22.5
2009	87.3	61.5	74.8	23.5
2010	87.4	62.0	75.2	24.8
2011	87.6	63.5	75.7	27.8
2012	87.9	64.3	76.2	29.4
2013	88.0	65.1	76.6	30.9
2014	91.6	68.7	84.3	37.0
2015	91.8	69.7	84.7	39.2

5. Sewage systems in rural areas

In rural areas, poor wastewater management is still a major problem. Insufficient access to sewage networks in these areas contributes to pollution of water and soil, and deterioration of the sanitary condition of the village due to illegal sewage disposal points cropping up, along with the fact that septic tanks used to collect sewage often do not meet the requirements for robustness (Heidrich, 2008). The implemented EU programs have led to gradual improvement of sewage management, by means of constructing collective sewerage systems and treatment plants.

Most villages show linear or dispersed patterns of building arrangements. In such cases, constructing a classic gravity sewer is not a good solution, as it requires long conduits with small diameters, arranged with appropriate differences in elevation. As a result, it becomes necessary to put the canals at large depths, and build intermediate pumping stations, which generates additional costs of construction and operation alike (Totczyk, 2001). Therefore, in rural areas, with the criterion of population density of less than 120 inhabitants per one kilometer of the network adopted in Poland, and less than 150 inhabitants per one kilometer in Europe, septic sewage systems is recommended (Kotowski, 2012). In areas where domestic wastewater is discharged into individual septic tanks, a small-scale gravitational sewage systems are increasingly being built from pipes with diameters of 0.05 to 0.25 m (Kalenik, 2009). They are is used for disposing of sewage cleaned of larger solid contaminants. Small-diameter sewers are characterized by lower investment and operating costs than conventional gravity sewers (Błażejewski and Skubisz, 2005).

An alternative to gravity sewerage is pressure sewerage, in which transport of wastewa-

ter is forced by means of pumps cooperating with devices grinding mechanical impurities. This type of system is used in areas with varied terrain and linear arrangements of buildings. When planning wastewater management in rural areas, especially with densely clustered buildings, solutions based on a collective sewage system and a collective sewage treatment plant should be treated preferentially. Despite this, few village residents may benefit from access to a collective wastewater treatment plant. In 2015, the share was 39.6 percent of the rural population, compared to 94.6 percent in cities (Krajowy Zarząd..., 2016). In Fig. 3, showing the percentage of the population served by the cleanable aggregate, we can see that every year there is a slight improvement of this situation. In the years 2005-2015, the increase in the number of residents using collective sewage treatment plants is more dynamic for rural areas (19.2%) than for cities (9.4%). However, taking into account the large backlog of neglect in rural areas in this respect, it should be noted that this is still insufficient.

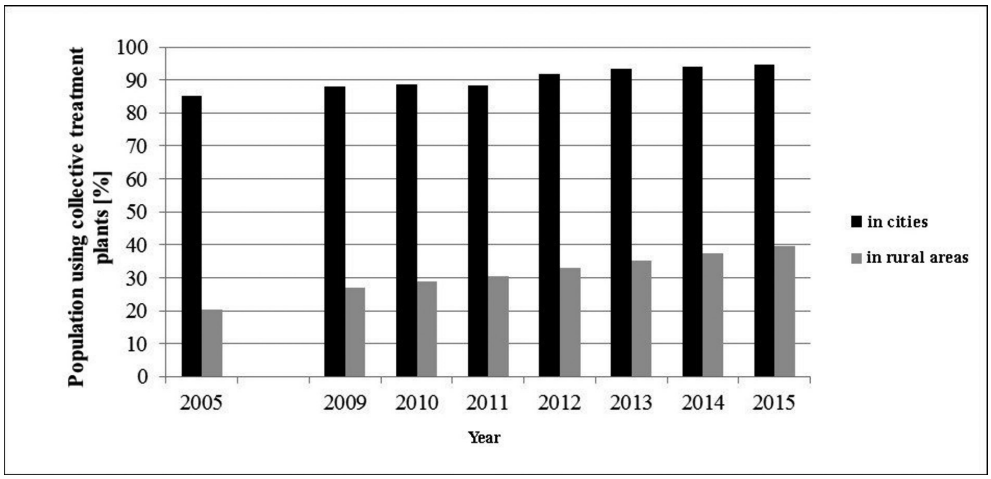

Figure 3. Percentage share of the population using collective sewage treatment facilities in the years 2005-2015 (Prepared based on Krajowy Zarząd..., 2016)

In the case of village with dispersed housing, sewage management consists mainly in discharging sewage into septic tanks or in treating it in household treatment plants. It was found that the number of septic tanks decreased by 296 thousand, from around 2,433,000 in 2009 to 2,136,000 in 2015 (Statistical Yearbook…, Yearbooks 2012-2016). At the same time, the number of household sewage treatment plants increased by 142,000 – from 62,000 in 2009 to 203,000 in 2015 (Fig. 4). This is a favorable trend, as household sewage treatment plants neutralize wastewater, which is then directly discharged to the receiver. In contrast, septic tanks only accumulate sewage, which is periodically transported by tanker trucks to collective treatment plants.

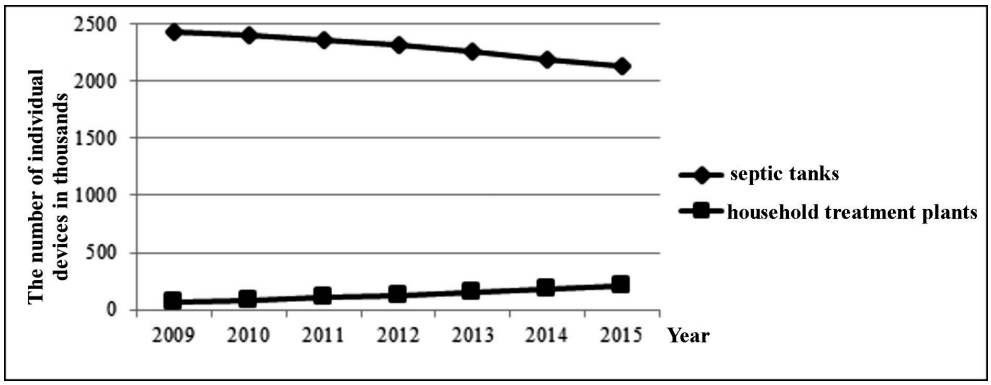

Figure 4. The number of septic tanks and household treatment plants between the years 2009 and 2015 (Prepared based on Statistical Yearbook…, Yearbooks 2012-2016)

Table 2. The highest allowable values of pollution indicators and the minimum level of pollution reduction for wastewater discharged into water or into the ground, depending on the type of receiver

Indicator	Unit	Type of sewage receiver		
		water	water infrastructure	ground
Biological Oxygen Demand over 5 days $(BOD)_5$	mg $O_2 \cdot dm^{-3}$	40	25	-
	min. reduction (%)	-	70-90	20
Chemical Oxygen Demand (COD)	mg $O_2 \cdot dm^{-3}$	150	125	-
	min. reduction (%)	-	75	-
Overall suspended solids	mg·dm^{-3}	50	35	-
	min. reduction (%)	-	90	50
Overall nitrogen	mg N·dm^{-3}	30*	15*	-
	min. reduction (%)	-	-	-
Overall phosphorus	mg P·dm^{-3}	5*	2*	
	min. reduction (%)	-	-	-

* Values required solely when discharging sewage into lakes and their tributaries or directly into artificial reservoirs within flowing watercourses (Source: Rozporządzenie Ministra Środowiska…, 2014)

The increase in the number of household sewage treatment plants in rural areas results from greater awareness of the residents, and it is also related to economic reasons, as their operating costs are lower than the costs of sewage disposal by septic tankers, while the savings can offset the related investment outlays within several years. In addition, this is a positive development from the perspective of environmental protection.

The technical and technological solutions in household sewage treatment plants offered on our market make it possible to meet the requirements as to the quality of treated sewage (Table 2), as specified in the ordinance of the Minister of the Environment (Rozporządzenie Ministra Środowiska..., 2014).

Table 3 presents example results of analytical studies of wastewater coming to treatment

Table 3. Example results of analyses of sewage treated using household treatment plants based on different technologies (Prepared based on Kalenik, 2009; Łomotowski and Szpindor, 1999; Totczyk, 2001)

Type of treatment	Sewage type	BOD_5	COD	Total suspensed solids
	-	mg $O_2 \cdot dm^{-3}$	mg $O_2 \cdot dm^{-3}$	mg·dm^{-3}
Sewage treatment plant with activated sludge	coming to sewage treatment plant	282.0	540.0	155.0
	treated	23.6	128.0	32.1
Reduction of pollution, %		91.6	76.3	79.3
Sequencing batch reactor (SBR)	coming to sewage treatment plant	415.0	-	118
	treated	87.0	-	42
Reduction of pollution, %		79.0	-	64.4
Rotating biological contactor	coming to sewage treatment plant	188.5	-	222.6
	treated	35.9	-	39.1
Reduction of pollution, %		79.8	-	81.6
Hydrophyte sewage treatment plant	coming to sewage treatment plant	450.0	1019	94.3
	treated	9.0	87	16.2
Reduction of pollution, %		98.0	91.5	83.1

plant and treated in household treatment plants using different technologies (with activated sludge, with sequencing batch reactor (SBR), with rotating biological contactor, with hydrophyte sewage treatment plant). Wastewater treated in each of the sewage treatment plants tested met the requirements of the applicable ordinance of the Minister of the Environment. In practice, however, it does happen that the quality of sewage is unsatisfactory due to negligent workmanship and improper operation of equipment. Users of home treatment plants are often convinced that they are trouble-free and maintenance-free. They do not realize that the plants do require regular, sometimes even tedious servicing, such as periodic removal of pollutants or adjustment of the aeration installation. Therefore, the quality of treated wastewater is usually inferior to the quality obtained in large municipal treatment plants, which have highly efficient technologies and are subject to systematic control and supervision. Hence, there are opinions that in rural areas household treatment plants should only be used for supporting collective sewage treatment systems and not as the basic means of wastewater management.

6. Wastewater management in the Commune of Lubiewo in the years 2012 - 2016

The Commune of Lubiewo is located in the Voivodeship of Kujawsko – Pomorskie, in the Poviat of Tuchola (Fig. 5).

Lubiewo is a rural commune with an area of 163 square kilometers, in which agricultural land accounts for 48 percent, and forests for 42.7 percent of the area. Within its borders there are areas subject to legal protection, i.e. nature reserves, landscape parks, monuments of nature, NATURA 2000 areas, which constitute 59.4 percent of the area (Program ochrony środowiska..., 2016). The commune is characterized by dispersed buildings, the exception are the centers of the villages, where the buildings are clustered. In 2016, the commune had 5,926 inhabitants. At that time, there were 357 business entities there, operating mainly in the sectors of construction and commerce. In the commune, in Bysław, there is a communal sewage treatment plant. Its location, along with the lakes through which treated wastewater flows before it reaches the river Brda is shown in Fig. 6.

Construction of sanitary infrastructure in the Commune of Lubiewo can be assessed positively, although in 2012-2016 the length of the active water supply network and the collective sewage system did not change. These were respectively 168.3 and 49.6 kilometers. In the analyzed years, however, there was a grad-

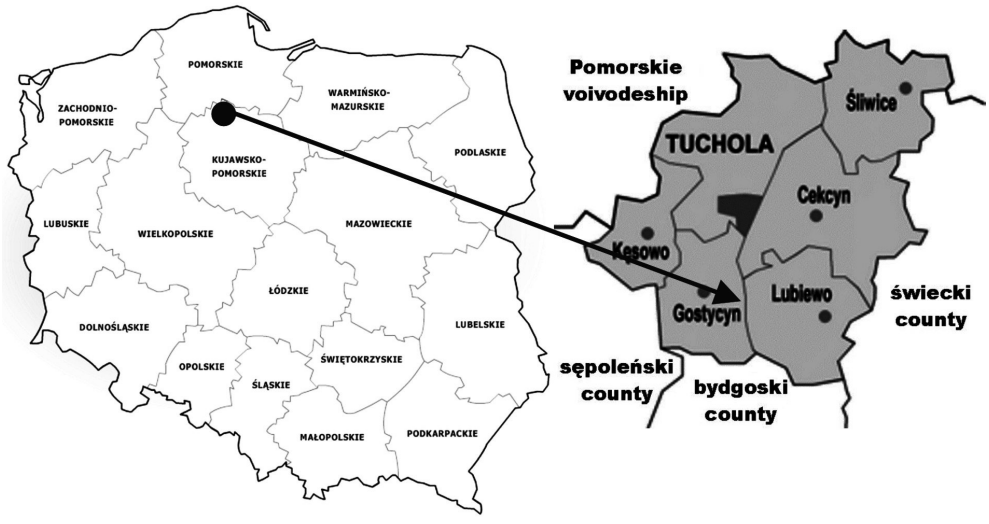

Figure 5. The location of the Commune of Lubiewo in the County of Tuchola (the author's own study, based on: Program ochrony środowiska…, 2016)

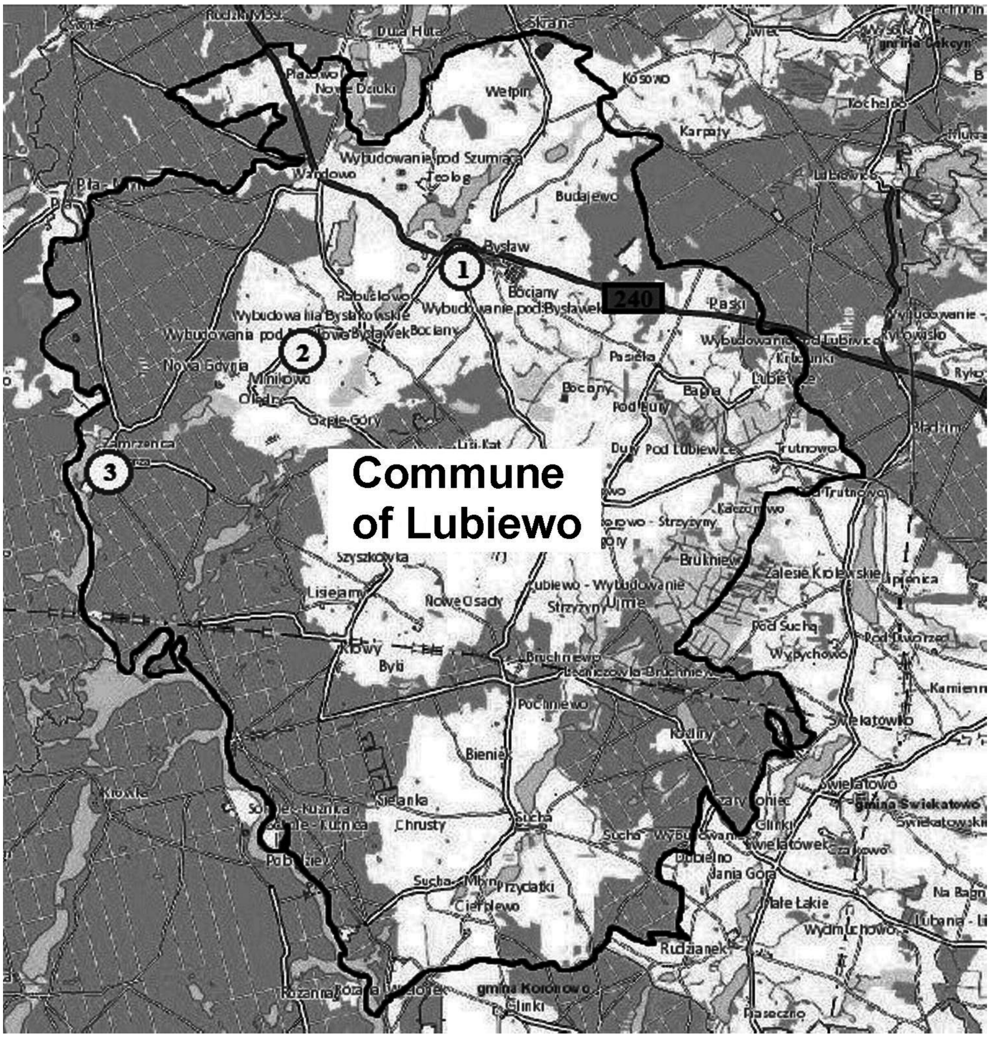

Figure 6. Territorial scope of the Commune of Lubiewo, with the location of the sewage treatment plant in Bysław: 1 – the Commune Treatment Plant, 2 – Lake Minikowskie, 3 – Lake Zamrzeńskie (the author's own study, based on: http://mapy.geoportal.gov.pl/imap (date of access June 13, 2018)

ual increase in the number of connections to the water supply and sewage networks, which occurred alongside the construction of new buildings in the areas covered by the existing sewerage and water supply networks. In 2012, 80 percent of the commune's residents used the central water distribution system, and 38 percent the sewerage system. These values are higher than the overall data on the access of rural residents in Poland to the water supply and sewage networks (Table 1). In the following years, the situation improved further. In 2016, 97 percent of the population had access to tap water, and 45 percent of the residents used the central sewage disposal – i.e. 46 percent of those who used the central water supply system were also connected to the collective sewage system. Wastewater generated by the inhabitants is transported by a gravity-pressure sewage network to the municipal sewage treatment plant in Bysław. In order to ensure proper flow of the sewage, 16 pumping stations are installed within the network. In contrast, wastewater from areas that have no connection to the network is treated in household treatment plants or collected in septic tanks and periodically removed by sewage trucks to the municipal wastewater treatment plant.

The data characterizing the sanitary infrastructure of the Commune of Lubiewo in 2012-2016 are presented in Table 4.

Analyzing the data on household sewage management facilities, it can be said that in 2014 and 2015 the number of household sewage treatment plants significantly exceeded the number of septic tanks. This positive trend is the result of the municipality obtaining EU funds, which were allocated for co-financing activities related to sewage management. As a result, some of the septic tanks were replaced

Table 4. Water and sewage infrastructure in the Commune of Lubiewo (the author's own study based on Kafetka, 2018)

Year		2012	2013	2014	2015	2016
Number of residents		5856	5898	5932	5917	5926
Number of people using the infrastructure	water	4758	4742	5760	5743	5761
	sewage	2259	2151	2650	2646	2665
Length of the water supply network(km)				168.3		
Length of the sewage network(km)				49.6		
Number of water network connections		1609	1624	1641	1676	1703
Number of sewage network connections		748	758	771	774	781
Number of household sewage treatment facilities		149	149	314	314	314
Number of septic tanks		577	577	200	200	473

with a more ecological method of sewage accumulation and treatment, afforded by household sewage treatment plants.

Sewage is transported to the municipal mechanical and biological treatment plant by a sewage system and tanker trucks. In 2016, the amount of wastewater delivered to the plant by trucks was 3930 cubic meters, which accounted for four percent of the overall waste delivered to the treatment plant. Thanks to the modernization of the treatment plant in 2012, the plant's treatment technology is based on integrated processes for removing carbon, nitrogen and phosphorus._The plant also has an installation for chemical dephosphatation. The treated sewage is discharged by a drainage ditch into Lake Minikowskie, and then through Lake Zamrzeńskie into the Brda (Fig. 6). Sewage treated in the treatment plant in Bysław don't have direct influence on the quality of river Brda's waters, which chemical and bacteriological conditions and ecological potential have been assessed for many years as good (Raport o stanie środowiska…, 2012-2016).

The sewage treated in the commune treatment plant meets all the requirements as to the quality of treated wastewater discharged into the receiver in accordance with the ordinance of the Minister of the Environment (Rozporządzenie Ministra Środowiska…, 2014). Average values of pollutant concentrations occurring in treated wastewater are presented in Table 5. They have increasing trend, which may be caused by the increase of the number connections to the sewage system, which is higher amount of treated wastewater. However, it doesn't influence the general, good grade of work of the sewage treatment.

Table 5. Average results of analyses of treated sewage for the years 2012 – 2016 (Source: Kafetka, 2018; Rozporządzenie Ministra Środowiska…, 2014)

Year	BOD_5 [mg $O_2 \cdot dm^{-3}$]	COD [mg $O_2 \cdot dm^{-3}$]	Overall suspensed solids [mg·dm^3]	Overall nitrogen [mg N·dm^3]	Overall phosphorus [mg P·dm^3]
2012	5.28	48.95	8.1	10.86	1.41
2013	5.75	52.05	12.93	14.23	1.52
2014	5.23	60.83	9.65	11.39	1.00
2015	6.8	63.9	13.35	12.33	1.36
2016	6.38	60.4	15.13	9.82	1.28
Allowable value	25	125	35	15	2

Excessive sludge formed during the treatment is mechanically dehydrated, disinfected with lime and, after the necessary storage period, used for agriculture or land reclamation.

Summing up the wastewater management of the Lubiewo commune in the years 2012-2016, it should be stated that it is implemented at a good level. The state of sanitary infrastruc-

ture utilities is gradually improving. The activities ensuring efficient functioning of the collective treatment plant and aimed at reducing the number of septic tanks in favor of on-site household treatment plants demonstrate care about the environment and its protection.

7. Conclusions

The data presented in the article allow formulating the following conclusions:

- The state of rural infrastructure in Poland in the area of water supply and sewage disposal over the years 1989-2015 is characterized by progressive expansion;
- There are large disparities in the development of water supply and sewage systems in rural areas. In the years 1989-2015, the length of the water supply network in rural areas increased from 65 to 231 thousand kilometers, and sewage system from 4.2 to 87.6 thousand kilometers. Finally, in 2015, 84.7 percent of the rural population used the water supply network, while only 39.2 percent used the sewerage system;
- Sewage management in rural areas is insufficient in relation to the existing needs. In 2015, 39.6 percent of residents of rural areas used collective sewage treatment plants. Notable positive trend are the decrease in the number of septic tanks, the increase in the number of household sewage treatment facilities and the successive connection of individual properties to collective sewage systems;
- In order to improve sewage management in densely built rural areas, it is necessary to develop collective sewage systems. On-site solutions should be used in other cases;
- In 2016, 97 percent of the residents of the Commune of Lubiewo were connected to the water supply network, and 45 percent used the collective sewerage system. These values are higher than the given, for rural areas in Poland, by General Statistics Office. Wastewater management and skillful use of EU funds allocated for this purpose contribute to improvements in environmental protection.

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