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Evaluation of Effectiveness of On-site Wastewater Treatment Systems Located at Roadside Rest Areas: Recognition and Diagnosis of Existing Problems in the Operation of Selected Facilities

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Abstract
The effects of a dynamic increase in the total length of expressways in Poland include the issue of wastewater generation and disposal at roadside rest areas, which has been gaining importance, especially regarding the safety of local water ecosystems. Currently, the total number of roadside rest areas in Poland is nearly 400, yet in the future it could double, because of road infrastructure expansion and the need to improve road travel comfort. The most common approaches to wastewater disposal are septic tanks or wastewater treatment plants. In view of Poland's environmental goals, only the second solution can be regarded as a form of final wastewater disposal. The aim of this study was to analyse available solutions for wastewater treatment at roadside rest areas, analysis of the effectiveness of their performance and identification, and diagnosis of existing problems. The tested facilities contained solutions based on biological wastewater treatment, preceded by a mechanical stage with the use of a two-chamber primary settling tank. Two solutions involved a sequencing batch reactor, and the remaining ones used submerged fixed-bed bioreactors. Finally, the obtained results showed unsatisfactory wastewater treatment effectiveness. Parameters such as chemical oxygen demand (COD) were exceeded at five of the six study sites, biochemical oxygen demand (BOD5) was exceeded at three sites, and total suspended solids was exceeded at two sites, which indicates a disturbance in the operation of the treatment plant. The reason for the poor effluent was primarily inadequate technological supervision of the operation of these facilities.

1. INTRODUCTION

Poland's road network has become more and more coherent with successively completed fragments merging into longer motorway sections. In 2021 alone, the General Directorate for National Roads and Motorways (GDDKiA) put into service over 425 km of new routes, which means that currently the length of highways in the country is 4624.9 km, of which 1753.6 km are motorways and 2871.3 km are expressways [GDDKiA 2021]. The target length of the motorway network is over 8000 km [Government Programme...2021]. Road construction is not only about making traffic flow more smoothly but also about enabling travellers to stop and rest safely, hence, there roadside rest areas have been established. One of the indispensable elements of these sites are toilets and sanitary facilities used by road travellers, and as a consequence, wastewater is generated and must be disposed of.

Even with Poland's quite developed road infrastructure, the issue of wastewater management at roadside rest areas has remained unsolved. Currently, three methods of wastewater disposal are applied:

– collecting wastewater in septic tanks (the so-called cesspools) and directing it to a wastewater treatment plant or for use in agriculture
– connecting with a sewer system and disposal to a centralised wastewater treatment plant
– establishing on-site wastewater treatment plants

In practice, the first solution – collecting and storing wastewater in sealed septic tanks – should not be presumed a final solution in terms of wastewater management, as in this case, the aim is just to store wastewater for some time and then transport it to another installation or a treatment plant. Currently, as far as the use of wastewater in

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agriculture is concerned, septic tanks are seldom used (and if so, mainly in the potato industry), and new technologies based on biological treatment (aerobic and/or anaerobic) are used to treat wastewater for agricultural use. On the other hand, direct wastewater discharge from roadside rest areas to the centralised treatment plant (e.g. located in an agglomeration) is often not possible due to economic and infrastructural factors. In general, expressways, as the main transport corridors, are located outside urbanised areas equipped with sanitary sewers [Pawęska, Bawiec 2018].

On–site wastewater treatment systems seem a promising solution. These systems operate similarly to household wastewater treatment plants, commonly based on the use of sequencing batch reactors (SBR) or submerged fixed-bed bioreactors. In local wastewater treatment systems, artificial wetlands can also be used to treat wastewater, and if needed, oil and grease separators can be used as pre-treatment facilities. Wastewater treatment plants (WWTPs) located at roadside rest areas are small facilities with capacities often not exceeding a few tens of cubic metres per day. The size of these treatment plants and their location outside of designated agglomerations classifies them as facilities with population equivalents (p.e.) below 2000. For small WWTPs, the only indicative measures regulated are COD, $BOD_{5,}$ and total suspended solids (150 mgO_2/L, 40 mgO_2/L, and 50 mg/L, respectively) [Regulation...2019]. In treated wastewater, nitrogen and phosphorus compounds are not regulated, unless wastewater is discharged into lakes and their tributaries or directly into artificial water bodies located on flowing waters.

The principle of SBR technology is to treat wastewater by the activated sludge method using a single tank, in which both biochemical processes and the separation of treated wastewater from activated sludge take place. The unit processes occur sequentially in a batch method. The operation of this system is divided into cycles and cycle phases. A cycle defines the time interval in which all phases of the process occur sequentially. One cycle lasts from the filling of the reactor to the beginning of the next filling. Each cycle is divided into a series of following phases. The simplest SBR systems consist of filling, reaction, sedimentation, decantation, and resting phases. The submerged bed technology used at roadside rest areas is based on the naturally occurring phenomenon of microorganisms developing on a given bedding progressing due to the decomposition of organic matter by these organisms. As a result of passing sewage through the bed, the process of multiplication of microorganisms on the bed filling takes place. A biological membrane is then formed that has the ability to remove contaminants from wastewater. In general, the process of wastewater treatment on biological beds is an aerobic process [Blaszczyk 2019].

When designing this type of local wastewater treatment system, many factors must be taken into account. According to Pawęska and Bawiec [2018], a significant difficulty in this type of facility can also be the type of wastewater generated at local wastewater treatment systems, which does not have the same characteristics as typical domestic wastewater. These wastewaters, due to the high proportion of urine in their composition, have an increased amount of ammonium nitrogen, a higher pH, and a lower amount of organic matter. They also contain large amounts of biocidal cleaning agents, due to the treatments undertaken in this type of facility to maintain hygiene [Pawęska, Bawiec 2019]. An additional problem is implied by the limited possibilities for control, as local wastewater treatment systems along with environmental facilities are often leased to private entities or investors, which often makes it impossible to determine the scale of the problem. Another factor that hinders the operation of local treatment systems is the large variation in the amount of incoming wastewater in different seasons, so it is important to analyse both daily, weekly, and annual trends when designing and commissioning this type of investment [Makowska, Mazurkiewicz 2016].

This study identifies solutions used in local wastewater treatment plants established at roadside rest areas and evaluates their effectiveness in conducted field tests.

2. STUDY SUBJECT AND METHODOLOGY

The study is composed of analyses focused on technical solutions for wastewater treatment and characteristics of wastewater generated, as well as treatment effects at the level of local wastewater treatment plants at three roadside rest areas located in southern Poland (rest areas "A" and "B" were located in Śląskie voivodeship and rest area "C" in Małopolskie voivodeship). Two treatment plants established at each rest area were studied (on both sides of the expressway). Wastewater in all the rest areas under the study was generated basically in toilets and sanitary facilities (not as a result of, e.g. catering services).

In order to determine the actual load on the treatment plant, the authors performed aggregate readings of water consumption, analytical tests on raw wastewater, and counts of people using the sanitary facilities.

The study was conducted in the fall of 2018. Physicochemical tests were conducted on 24-hour average samples taken on three consecutive days. Samples were taken using a mobile autosampler. The analysis of the results was based on the arithmetic average values of the measurements taken. Samples of raw sewage were taken from the input to the primary settling tank (due to technical reasons it was not possible to take samples at the outlet of the primary settling tank). Samples of treated wastewater were taken from the channel discharging the treated wastewater. Dissolved oxygen concentration was tested in situ using a Hach LDO field optical probe. Indicators and parameters were determined in the collected samples according to the standards in the table below (Table 1).

One solution tested was based on SBR (rest area "A"), and the two remaining ones were based on submerged bed technology (rest areas "B" and "C"). Both types of

Table 1. Parameters tested in the samples, and regulations defining the method of making the assays

Parameter/Indicator	Regulation specifying the method and procedure for chemical analysis
pH	PN-EN ISO 10390:2022-09
total alkalinity	PN-90/C-04540.02
BOD_5	PN-EN ISO 5815-1:2019-12
COD (total and dissolved)	PN-ISO 15705:2005 PN-ISO 6060:2006
forms of nitrogen (total nitrogen, total Kjeldahl nitrogen, ammoniacal nitrogen, nitrite nitrogen, and nitrate nitrogen),	PN-EN 25663:2001 PN-ISO 7150-1:2002 PN-EN ISO 13395:2001 PN-82/C-04576/08
total phosphorus	PN-EN ISO 6878:2006
total suspended solids	PN-EN 872

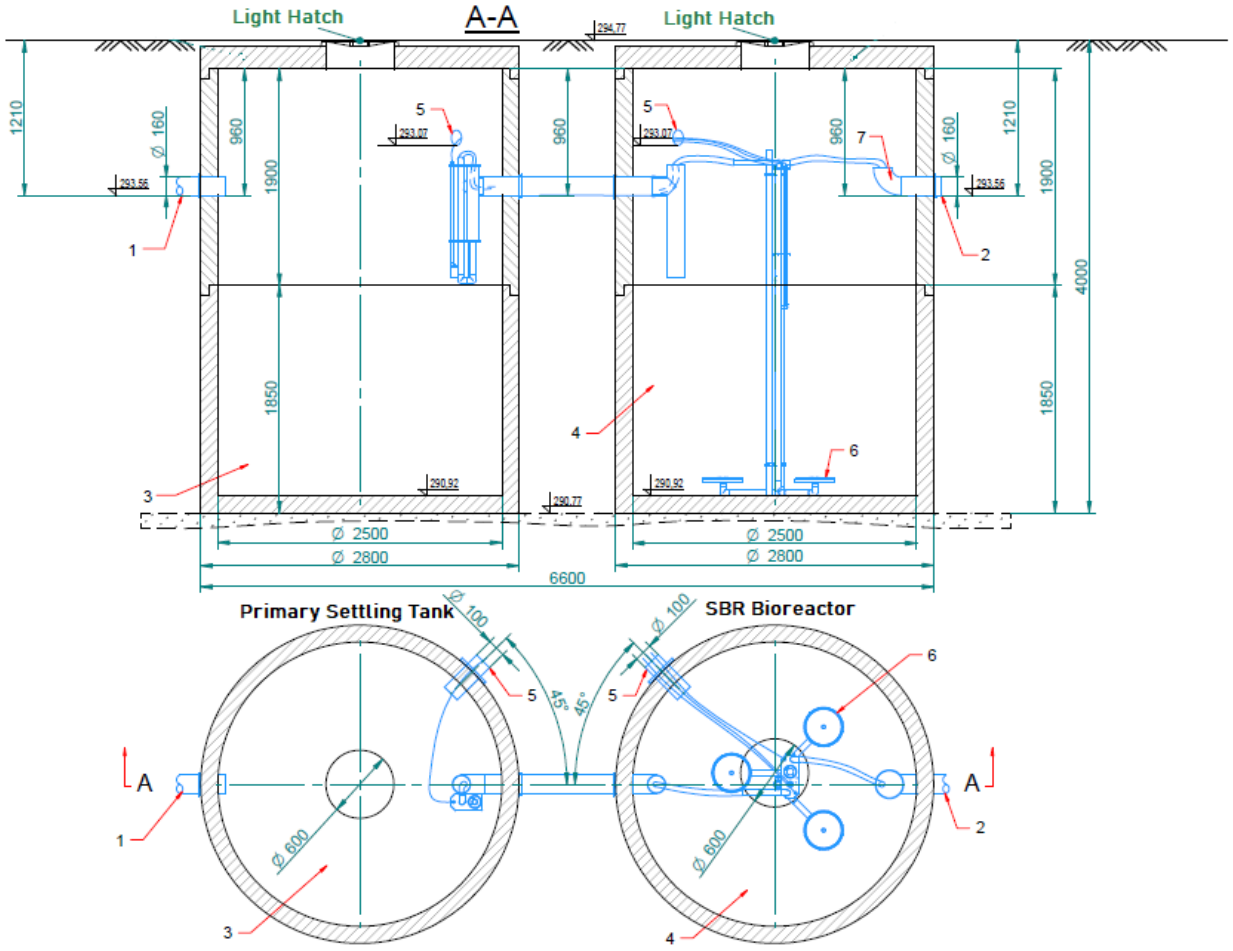


Figure 1. Diagram of the treatment plant at roadside rest area "A" 1- inlet, 2- outlet, 3- settling tank and retention and averaging buffer, 4- SBR reactor, 5- compressed air inlet, 6- aeration disc, 7- drainage bed (own elaboration)

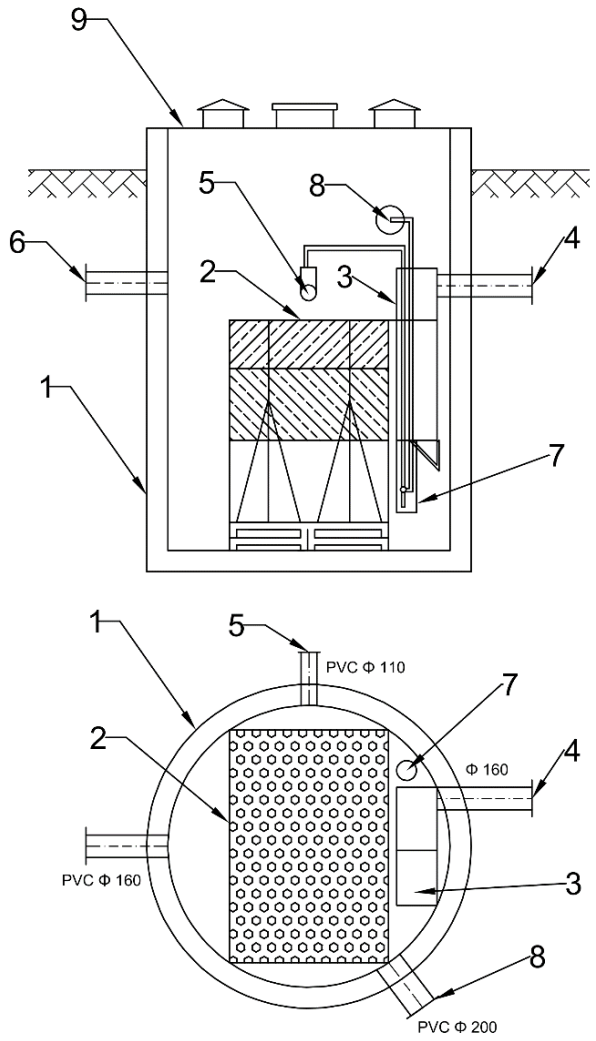


Figure 2. Diagram of biological reactor at roadside rest area "B" and "C": 1- concrete tank, 2- biological bed, 3- effluent filter, 4- effluent outlet, 5- secondary sludge outlet, 6- settling tank wastewater inlet, 7- recirculating device, 8- air duct protection pipe, 9- aluminium lid (own elaboration)

Table 2. Technical parameters of discussed plants

Installation technical parameters	Rest Area „A"		Rest Area „B"		Rest Area „C"	
	L	R	L	R	L	R
Projected inflow	5.00 m^3/d		8.00 m^3/d		8.00 m^3/d	
Average real inflow	6.25 m^3/d		3.35 m^3/d		3.80 m^3/d	
Volume of primary settling tank	3.30 m^3		6.70 m^3		7.20 m^3	
Reactor volume	3.30 m^3		5.65 m^3		5.95 m^3	
Projected retention time	>15 h		>17 h		>17 h	

the tested solutions included a preceding mechanical treatment stage with an averaging function in the primary settling tank. Information about the flows was read from the control system of the treatment plant. Technological diagrams of the discussed solutions are shown in Figures 1 and 2. Technical information about the discussed plants are shown in table below (Table 2).

3. RESULTS AND DISCUSSION

The analysis of raw wastewater composition showed that the predominant pollutants were nitrogen compounds, primarily ammonium nitrogen (Table 3). The concentration of ammonium nitrogen in the tested raw wastewater ranges from 103 mgN/L to 253 mgN/L, which is a significantly elevated value compared to typical municipal wastewater. Studies in various European countries have shown that nitrogen concentrations in municipal wastewater generally do not exceed 50–80 mgN/L [Pons et al. 2004, Dymaczewski et al. 2011]. Also, the ratio of BOD_5 to nitrogen was quite unfavourable in view of biological nitrogen removal; it was just about 1:1, which may imply a shortage of organic substrate in the denitrification process. The optimum BOD_5/N value in the effluent flowing into the biological reactor should be from 3 to 5 [Klaczynski 2019]. In roadside rest areas equipped just with sanitary facilities, wastewater composition is dominated by urea, with a smaller amount of faeces and toilet paper. According to German data [Bever et al. 1997], the main component of this wastewater type is nitrogen in the form of ammonium nitrogen (up to 80%–100%). In comparison, in municipal wastewater, ammonia nitrogen accounts for about 50% of the nitrogen present in wastewater. In quantitative terms, next to carbon compounds, nitrogen compounds constitute the most important wastewater components. Significant sources of nitrogen in wastewater from households, for example, are proteins contained in foodstuffs consumed by humans which enter wastewater, mainly in the form of urea. Besides, various other organic nitrogen compounds accumulate in wastewater. In the sewer system, urea is quickly converted into ammonium nitrogen. As a result of partial hydrolysis (ammonification) by certain bacteria, other organic nitrogen compounds are reduced to this nitrogen form as well [Bever et al. 1997].

An important indicator for determining wastewater susceptibility to biological treatment is the ratio of COD to BOD_5. For typical household or municipal wastewater, this ratio is usually from 1.7 to 2.0, and which indicates moderate wastewater biodegradability. If the ratio is less than 1.7, wastewater is assumed to be readily biodegradable. Wastewater with a COD/BOD_5 ratio above 5 is considered not susceptible to biodegradation [Sadecka 2010]. In the case of the tested wastewater, COD/BOD_5 value did not exceed 4.0 (except for rest area "A" - L) (Table 3). The concentrations of phosphorus and total suspended solids in the wastewater from the roadside rest areas in this study did not show any particular deviations from the composition of typical municipal wastewater.

Table 3. The results of analytical tests of raw wastewater at the roadside rest areas studied (own elaboration)*

No.	Indicative measure	Unit	Raw wastewater – average values (range of results)					
			Rest Area „A"		Rest Area „B"		Rest Area „C"	
			L	R	L	R	L	R
1	Reaction (PH)	-	7.9–8.0	7.8–7.9	8.6–8.8	8.2–8.4	8.5–8.6	8.5–8.8
2	Total alkalinity	mval/L	12.5	19.9	20.7	20.2	23.4	19.0
3	BOD_5	mgO_2/L	180 (176–184)	162 (155–169)	400 (393–407)	497 (480–514)	191 (189–193)	160 (153–167)
4	COD	mgO_2/L	771 (765–777)	629 (600–658)	1031 (950–1112)	1020 (978–1062)	349 (324–394)	384 (381–407)
5	COD/ BOD_5	-	4.3	3.9	2.6	2.1	1.8	2.4
6	BOD_5/N	mgO_2/mgN	1.5	0.8	1.5	1.7	0.8	0.7
7	Total Kjeldahl nitrogen	mgN/L	123	201	265	298	232	228
8	Ammoniacal nitrogen	mgN/L	103	167	253	252	194	206
9	Total phosphorus	mgP/L	17.4 (16.5–18.3)	15.6 (14.9–16.3)	15.3 (14.9–15.7)	32.2 (30.1–34.3)	18.1 (18.0–18.2)	17.1 (16.2–18.0)
10	Total suspended solids	mg/L	280	188	284	252	172	152

L/R – left/right side of the motorway
* The table shows the average values of the above parameters

The primary task of any treatment plant is first and foremost to ensure normative parameters for treated wastewater discharged to the environment.
In the case of on-site treatment plants established at roadside rest areas, the standards relate only to organic substances and are expressed as COD and BOD_5 indicative measures as well as the values for total suspended solids. Appropriate performance can be achieved in the case of single-stage biological treatment systems (based on activated sludge or biological bed bioreactors). However, when analysing the pertinent values for treated wastewater presented in Table 4, it can be concluded that the local treatment plants surveyed achieved generally poor performance, which was manifested by exceeded indicative values for COD and BOD_5 and total suspended solids. Especially in the wastewater treatment systems located at rest area "B", the treated wastewater was characterised by considerably elevated COD values. The values for COD at this rest area were 306 mgO_2/L and 463 mgO_2/L. The largest decrease in the COD values was observed at rest area "A". Here, one of the tested wastewater treatment plants showed an average COD value of 194 mgO_2/L, whereas at the second plant, COD permissible standard was not exceeded but fluctuated around the standard; COD value for this treatment plant was 145 mgO_2/L. In the case of the treatment plants at rest areas "B" and "C", the exceedances were observed for COD, BOD_5, and total suspended solids. Considerable exceedances in tested parameters were recorded for the treatment plants located at rest area "B". However, of the three facilities studied, the best results in wastewater treatment were obtained at the treatment plant at rest area "A".
Comparable conclusions were drawn by Londong and Meyer [2010] who carried out a detailed study on small treatment plants at roadside rest areas in Germany. In this case, the most often used treatment systems were: no-drain tanks connected to the reactors (with activated sludge), submerged and aerated biofilters, sand filters, the so-called "wetlands", and effluent ponds. The permissible values for organic matter indicators in the treated wastewater were exceeded by 5% for BOD_5 and 14% for COD.
Interesting data are provided in a study by Kiss et al. [Kiss et al. 2011] who showed the concentration of raw wastewater as being very different when compared to typical household wastewater. After over a six-month period of monitoring and analyses, the authors found that the average values of BOD_5, COD, total organic carbon (TOC), total N and total P were 880 mg/L , 4900 mg/L, 350 mg/L, 238 mg/L and 8 mg/L, respectively. The systems then assessed did not operate properly due to design errors as well as inadequate control settings and insufficient maintenance. To improve the performance of the wastewater treatment, the authors proposed and tested several modifications to the existing system. The most important modifications included the aeration and

Table 4. Analytical results for treated wastewater at the roadside rest areas studied (own elaboration)*

No.	Indicative measure	Unit	Treated wastewater – average values						Treated wastewater - the standard **
			Rest Area „A"		Rest Area „B"		Rest Area „C"		
			L	R	L	R	L	R	
			Average value; range of results; percentage of removal [%]						
1	Reaction (pH)	-	7.4–7.5	7.3–7.5	7.7–7.8	7.6–7.8	8.3–8.4	8.4–8.5	-
2	Total alkalinity	mval/L	4.4	3.4	8.3	5.2	22.0	18.4	-
3	BOD_5	mgO_2/L	13.8; 15.5–14.1; 92.3	16.0; 15.3–16.7; 90.1	72.0; 71.4–72.6; 82.0	81.0; 77–85; 83.7	40.0; 38.9–41.1; 79.0	86.0; 82.7–89.3; 46.0	40
4	COD total	mgO_2/L	145; 143–147; 81.2	194; 193–195; 69.2	306; 293–319; 70.3	463; 460–466; 54.6	173; 171–175; 50.4	208; 205–211; 45.7	150
5	COD dissolved	mgO_2/L	126	166	263	395	144	179	-
6	Total nitrogen	mgN/L	59.7	120	196	236	232	202	-
7	Kjeldahl nitrogen	mgN/L	38.0; 69.1	41.4; 79.4	138; 47.9	141; 52.7	249; -	195; 14.7	-
8	Nitrate nitrogen	$mgN-NO_3/L$	1.7	4.4	3.6	41.9	0.37	0.49	-
9	Nitrite nitrogen	$mgN-NO_2/L$	20.1	74.1	55.4	52.7	6.8	6.9	-
10	Ammoniacal nitrogen	mgN/L	24.9; 75.8	31.6; 81.1	132; 47.8	111; 56.0	162; 16.5	148; 28.2	-
11	Total phosphorus	mgP/L	11.0; 10.7–11.3; 36.6	12.5; 12.4–12.6; 19.8	16.6; 15.3–17.9; 44.5	18.8; 17.3–20.3; 41.6	20.1; 15.3–24.9; -	18.2; 18.1–18.3;	-
12	Total suspended solids	mg/L	29.0; 89.7	25.0, 86.7	23.0; 91.9	191.0; 24.2	63.0; 63.5	31.0; 79.3	50

L/R – left/right side of the motorway
* The table shows the average values of the above parameters
** Parameter limit value [Regulation...2019]

activated sludge recirculation systems. The aeration was adjusted to increase oxygen concentration from about 0.5 mgO_2/L to 4.0 mgO_2/L, which resulted in the improvement of the removal efficiency of COD, TOC, and total N from 4%, 24%, and unnoticeable levels, respectively, to 44%, 61%, and 19%, respectively. The activated sludge recirculation systems were modified by diverting the recirculate stream back into the aerobic chamber to increase biomass concentration. The authors concluded that the wastewater treatment systems described had to be designed for specific conditions and had to allow for easy changes in control settings during operation.

Then again, an interesting pattern was recorded for nitrogen compounds in the present study: elevated values of nitrite nitrogen concentration in treated wastewater at all the analysed facilities. The highest recorded values were 74.1 $mgN-NO_2/L$ for rest area "A" and 55.4 $mgN-NO_2/L$ for rest area "B". At the same time, high nitrate concentrations of 41.9 $mgN-NO_3/L$ were recorded for rest area "B". Such a distribution of concentrations of the analysed pollution indicators shows the incomplete course of the nitrification process. The facilities studied are not designed to remove nitrogen and phosphorus compounds; nevertheless, under favourable temperature conditions it is possible for the process to run spontaneously. This phenomenon also explains the decrease in the concentration of Kjeldahl nitrogen and ammonium nitrogen. The efficiency of removal of these compounds was observed at an average

of 74% and 50.5% for Kjeldahl nitrogen and 78.5% and 52% for ammonium nitrogen at rest areas "A" and "B" In the case of rest area "C" the level of nitrogen removal is low compared to the other treatment plants; the underlying causes for this are described later in this article. In terms of total phosphorus, a low removal efficiency was observed, which is only due to its incorporation into cellular biomass. In terms of total suspended solids, most rest areas met the legal requirements. Only at rest areas "B"- R and "C"- L were elevated values observed.

4. IDENTIFICATION AND DIAGNOSIS OF EXISTING PROBLEMS

The assessment of performance of the on-site treatment plants showed that their achieved effects were insufficient in terms of the standards defined by national law. As discussed in the Discussion and Results section, the level of wastewater treatment at the studied sites was inadequate, which was manifested by exceeded COD and BOD_5 indicators and total suspended solids. In the wastewater treatment systems located at MOP "A", the treated wastewater had an average COD value of 194 mgO_2/L, on one side; on the other, it oscillated around the permissible standard, 145 mgO_2/L. In the case of the treatment plants at roadside rest areas "B" and "C", exceedances were observed in terms of COD and BOD_5 indicators, as well as total suspended solids. Based on this rationale, the available documentation (treatment plant logbooks, equipment inspection reports, equipment operating instructions, etc.) of individual treatment plants was analysed and their operational practice was examined. The following issues can be considered as potential causes of the poor performance of the wastewater treatment plants studied:

– Design errors related to underestimating the number of people using the toilets at roadside rest areas, which translates into hydraulic overloading of the treatment plant (settling tank and SBR reactor) during peak travel periods. This problem is illustrated in Figure 3, showing the average daily flow through the wastewater treatment plant located at rest area "A" for the duration of the consecutive months of its operation. It can be seen that the designed load of the treatment plant was doubled during the summer months: in the period of increased holiday traffic. The plant inflow range went from 2.7 m^3/d to over 11 m^3/d. For the other two rest areas the inflow range was between 2.6–4.1 for rest area "B" and between 2.5–5.5 for rest area "C".
– Damage to the installation for pumping raw wastewater from the primary settling tank to the SBR-type bioreactor operating at rest area "A". The raw wastewater should have been pumped to the reactor in a cyclic manner by means of the air lift pump system.

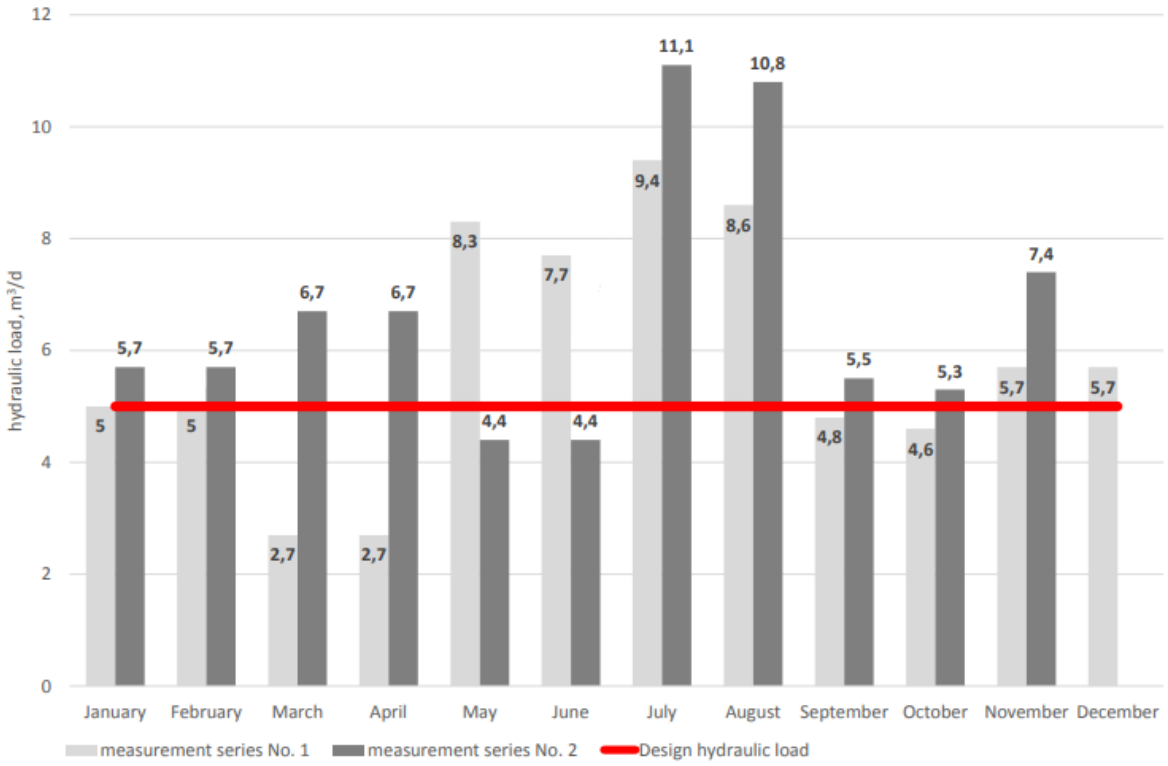


Figure 3. Average hydraulic load of the wastewater treatment plant at rest area "A" in consecutive months of operation (own elaboration)

The system failure was manifested in the continuous inflow of a small effluent stream, also during the phase of sedimentation and decantation of the treated effluent. As a result, the bioreactor discharged the effluent after the biological treatment mixed with raw wastewater, which flowed in at the at the end of the cycle.

– Failure of a device responsible for discharging excess sludge from the bioreactor (for sludge recirculation). In the solutions tested, a portion of activated sludge was pumped into the primary settling tank by means of an air lift pump, and then periodically discharged as surplus sludge. As a result of the failure, the amount of biomass increased in an uncontrolled manner, which could consequently result in a release of sludge with the treated effluent. This conclusion is confirmed by analytical results showing exceedances of the permissible standards for total suspended solids and COD at rest areas "B" and "C".
– Incorrect operation of the device responsible for discharging surplus sludge from the SBR reactor at rest area "A". The set point for the excess of sludge flow is constant throughout the year, although sludge accumulation varies throughout the year, as does the load of pollutants. The volume (period) of excess sludge removal during the treatment process should be adapted to the seasonal variability and the controlling device should be periodically and accordingly adjusted.
– Improper use and maintenance of the primary settling tank in all the cases analysed. The use should consist of periodic physical removals of the settling tank contents and transfers to another wastewater treatment plant. In particular, meticulous removal and disposal of wastewater scum is important, as it can cause failure of an air lift pump. A malfunctioning pump periodically causes contents of the primary settling tank to be mixed with air, and then wastewater with suspended solids and higher pollutant loads enters the biological process. As a consequence, after incomplete treatment, the pollutant load can penetrate the wastewater effluent.
– Incorrect aeration system settings, followed by insufficient oxygenation of the bioreactor contents at rest area "A". The observed oxygen concentration ranged from 0.2 mgO_2/L to 1.0 mgO_2/L, which favoured the occurrence of partial nitrification and resulted in nitrite accumulation. At rest area "C", on the other hand, over-intensive aeration of wastewater was identified (up to 7.5 mgO_2/L). Too much oxygen does not improve pollutant removal effects, but causes excessive wear and tear of aeration equipment and leads to increases in operating costs (Figure 4). For the observed plants oxygen concentration ranged

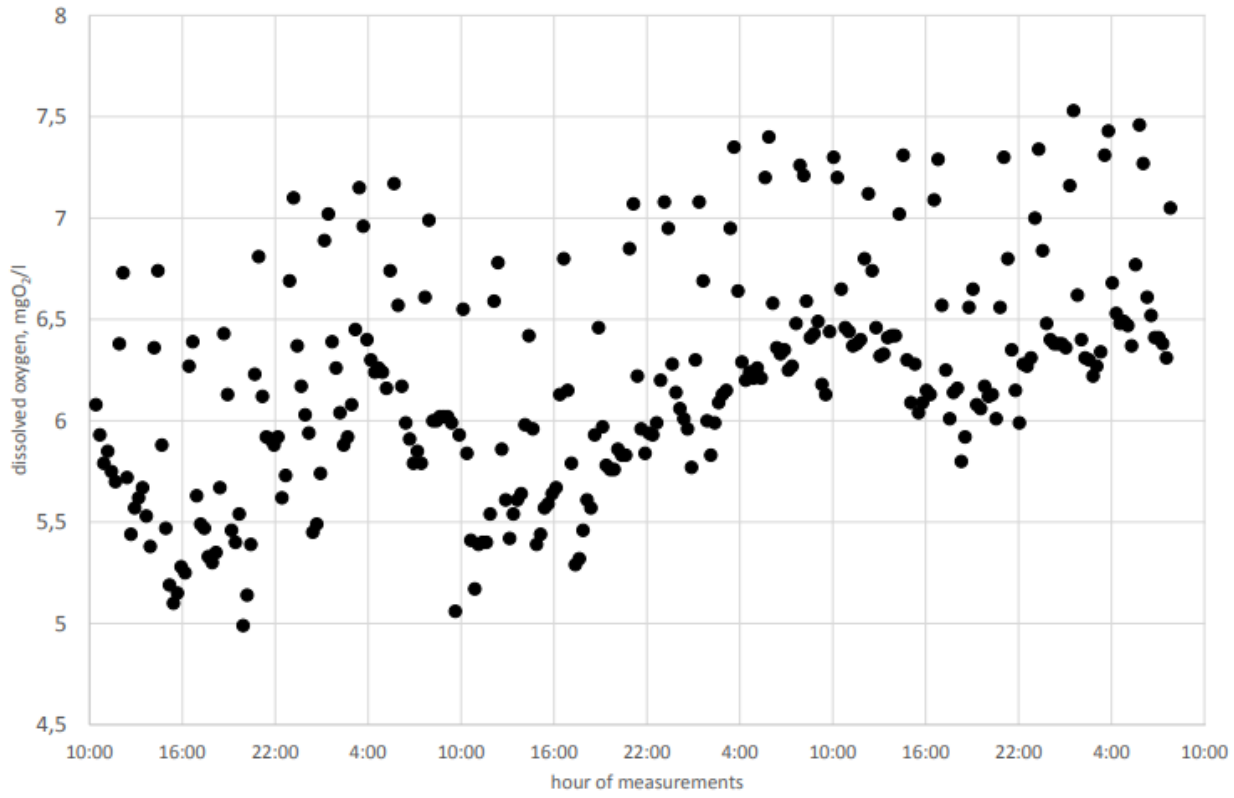


Figure 4. Distribution of dissolved oxygen concentration in the wastewater treatment plant at rest area "C" during successive hours of operation (own elaboration)

between 3.4–4.6 mgO_2/L for rest area "B" and from 5.0 to over 7.5 mgO_2/L for rest area "C".
– Too short operation time of a device used to flush the effluent filter (biomass separator) at the treatment plants located at rest areas "B" and "C". A clogged filter can cause suspended solids to escape with treated wastewater.

5. CONCLUSIONS

The main effect of on-site wastewater treatment plants at roadside rest areas should be normative standards for pollutant indicative measures in treated wastewater: COD, BOD_5, and total suspended solids. The results of the present study showed that the standards for these parameters were not met, and the assessment of the performance of the selected treatment plants indicated their insufficient operation. However, of the six facilities studied, the best results in wastewater treatment were obtained at the treatment plants at the rest area "A". The parameters of treated wastewater met the standards at treatment plant "A" (except for the value of total COD, which was slightly exceeded). The supervision of the plants tested was practically limited to visual determination of their operation – purely from a technical point of view, in other words, operatives just checked whether the equipment worked. Such a simplified evaluation of wastewater plant operation does not translate into appropriate technological management.

In terms of technical and technological aspects, attention should be drawn to improper operation of the primary settling tanks, which were not properly cleaned of sludge and scum, so that the biological reactor was overloaded with pollutant contents.

With regard to the operation of the biological reactor, attention should be drawn to the faulty operation of the system for discharge of excess sludge to the primary settling tanks and the ineffective operation of the final filter (separator). As a result of faulty settings and adjustments of the air management system, the activated sludge was over-mineralised and stripped from the bed bioreactors.

The main recommendation arising from the analysis of the wastewater plants under study is to strengthen the technological supervision in accordance with the guidelines set out in the operating instructions for such plants, especially with regard to the separation of activated sludge from treated wastewater and the effective recirculation of sludge from the biological reactor to the primary settling tank. It should be borne in mind that on-site wastewater treatment plants are not unmanned facilities and, as stated in their manuals, require regular inspections.

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[Regulation...2019] Rozporządzenie Ministra Gospodarki Morskiej i Żeglugi Śródlądowej z dnia 12 lipca 2019 r. w sprawie substancji szczególnie szkodliwych dla środowiska wodnego oraz warunków, jakie należy spełnić przy wprowadzaniu do wód lub do ziemi ścieków, a także przy odprowadzaniu wód opadowych lub roztopowych do wód lub do urządzeń wodnych (Dz. U. 2019 poz. 1311).