JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2021, 22(10), 141–151
https://doi.org/10.12911/22998993/142117
ISSN 2299–8993, License CC-BY 4.0

Received: 2021.08.15
Accepted: 2021.09.14
Published: 2021.10.01

Effectiveness of Dairy and Domestic Wastewater Treatment and Technological Reliability of the Wastewater Treatment Plant in Michów, Poland

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ABSTRACT

The study aimed to assess the operation of the mechanical and biological wastewater treatment plant in Michów (Poland) in terms of the effectiveness of removing contaminants from mixed wastewater (dairy and domestic) and technological reliability. The wastewater treatment plant is owned by the Dairy Cooperative "Michowianka." It is intended to treat mixed sewage, consisting of technological and sanitary sewage as well as part of rainwater from the plant, domestic wastewater supplied by a sewerage system from Michów, and wastewater delivered from septic tanks. In 2017 and in the first quarter of 2018, the permeate from the whey thickening process was also sent to the treatment plant. The period 2017–2021 was covered by the analysis. The analysis included the indicators from the fundamental group (TSS, BOD5, COD), biogenic indices (total phosphorus, total nitrogen, and ammonium nitrogen). The applied technology ensured the removal of total suspended solids, BOD5, and COD at the level of over 96%. Total phosphorus was removed with an average efficiency of 91%. Slightly lower effects were found in the elimination of total nitrogen – 78.5% on average, while the ammonium nitrogen removal rate was 88% on average. Due to the high efficiency of the facility, the values of the standard contamination indicators at the outflow, as a rule, met the requirements specified in the water permit. The technological reliability of the wastewater treatment plant in Michów, determined by the Weibull method, was at a high level, usually exceeding 90%. The reliability analysis shows that the facility in Michów has a high capacity to treat wastewater to the extent required for the wastewater receiver, and that the treated wastewater discharge does not cause negative changes in the environment. It indicates a high probability of obtaining the wastewater quality at the outflow from the treatment plant meeting the water permit requirements.

Keywords: domestic wastewater, dairy wastewater, wastewater treatment effectiveness, technological reliability

INTRODUCTION

The dairy industry is considered to be one of the largest branches of the food industry. At the same time, it is the most demanding in terms of the amount of produced wastewater [Bazrafshan et al. 2013; Karadag et al. 2015; Carvalho et al. 2013]. Production of wastewater in dairy plants is associated with high water consumption, ranging from 0.2 to 10 m^3 of water per 1 m^3 of milk produced [Bazrafshan et al. 2013; Vourch et al. 2008; Bharati, Shinkar 2013, Bortoluzzi et al. 2017]. Water is used at all stages of milk processing, including heating, cooling, cleaning and washing installations, process equipment, rooms, and cars [Sarkar et al. 2006; Brazzale et al. 2019; Bazrafshan et al. 2013].

The quantity and quality characteristics of wastewater depend on the plant size, its activity profile, and process requirements. Additionally, it is highly variable over time [Karadag et al. 2015; Slavov 2017; Janczukowicz et al. 2008]. Hourly and daily variations in the amount of wastewater are related to the organization of the production cycle of a given plant and sudden discharges as a result of the activities with a high degree of water consumption. Seasonal fluctuations can be attributed to a higher load on the dairy plant in summer than winter [Janczukowicz et al. 2008].

The dairy wastewater contains both organic and inorganic compounds. They include, among others, milk or milk products lost in technological cycles, starter cultures used in production, by-products of processing, and also contaminants from washing tanks, equipment, packaging, floor surfaces, agents used in the CIP (cleaning in place) procedures, or for sanitary purposes, contamination arising from cooling milk and milk products, as well as in the event of damage to equipment and operational problems [Tawfik et al. 2008; Watkins, Nash 2010; Kushwaha et al. 2011]. A characteristic feature of dairy wastewater is increased temperature, high pH fluctuations, high COD and BOD5 values, high concentrations of suspended solids as well as nitrogen and phosphorus compounds [Tawfik et al. 2008; Farizoglu et al. 2007; Bazrafshan et al. 2013; Karadag et al. 2015; Siping et al. 2020; Ashekuzzaman et al. 2019; Singh et al. 2019; Ji et al. 2020].

The dairy wastewater is generally treated using biological methods. These include oxygen methods, such as circulation ditches and sequencing batch reactors (SBR, SBBR) or spray filters [Heaven et al. 2011; Neczaj et al. 2008, Ozturk et al. 2019]. Among the anaerobic biological methods, one can distinguish, among others, anaerobic reactors, i.e., ABR, UASB, as well as combined forms using UASB and the AS system (activated sludge) [Miryahyaei et al. 2020; Charalambous et al. 2020].

Dairy wastewater treatment consists of several stages, including removing solids, oils, and fats by primary techniques, removing organic matter and nutrients in secondary processing, and finally treating by tertiary techniques [Kumar et al. 2015; Zinadini et al. 2015]. One of the most promising technologies of dairy wastewater treatment is membrane separation using micro- and nanofiltration and reverse osmosis [Struk-Sokołowska 2011; Andrade et al. 2014; Zinadini et al. 2015; Bortoluzzi et al. 2017].

The dairy wastewater is most often treated in on-site treatment plants. Due to the increasing requirements for the quality of treated sewage, it is necessary to optimize the treatment plant operation in terms of the quantity and composition of the raw sewage supplied. Due to high qualitative and quantitative variability of dairy wastewater, its treatment is a heavy burden for wastewater treatment plants [Demirel et al. 2005; Bortoluzzi et al. 2017]. The way to reduce this burden may be co-treatment of dairy sewage with municipal sewage. It allows equalizing the sewage inflow and pollutant load, thus increasing the effectiveness of biological treatment processes [Struk-Sokołowska 2011; Struk-Sokołowska, Ignatowicz 2013].

The study aimed to assess the operation of the mechanical and biological wastewater treatment plant in Michów (Poland) in terms of the effectiveness of removing contaminants from mixed wastewater (dairy and domestic) and technological reliability. The analysis included the indicators from the fundamental group (TSS, BOD5, COD) and biogenic indices (total phosphorus, total nitrogen, and ammonium nitrogen).

MATERIALS AND METHODS

Experimental facility

The research was carried out in the wastewater treatment plant in Michów, located in the Lublin Province (Poland), 51°31′47.4″ N, 22°18′38.1″ E (Figure 1).

The wastewater treatment plant is owned by the Dairy Cooperative "Michowianka" It is intended to treat mixed sewage, consisting of technological and sanitary sewage and part of rainwater from the plant, domestic sewage supplied by a vacuum sewage system from Michów, and the sewage delivered from septic tanks. The activity of the plant is focused on the production of cheese, cottage cheese, extra butter, and periodically whey mix. In 2017 and in the first quarter of 2018, the permeate from the whey thickening process was also sent to the treatment plant. The percentage share of individual types of sewage per year is presented in Table 1. The largest share, approximately 75% on average, was the plant sewage generated in the production process, including washing of machines, devices, tanks, pipelines, cars, production rooms as well as staff and living rooms. Additionally, part of the cooling water is discharged into the sewage system, the circuits of which are not closed. The share of domestic wastewater oscillated around 25% [Dairy Cooperative "Michowianka" 2017–2020].

The average capacity of the treatment plant is 765 m^3/d and is usually not exceeded in any

Figure 1. Localization of the town of Michów [https://pl.wikipedia.org]

period of the year. The treated wastewater is discharged to the tributary waters near Michów.

The treatment plant is mechanical and biological. The first device of the wastewater treatment plant is a vertical sand trap. Here, fine mineral impurities and sand are separated. Free of mineral suspensions, the wastewater is then directed *via* a siphon line to the bio-sorption tank. The first stage of purification, consisting of the biochemical decomposition of contaminants under aerobic conditions by the microorganisms of the activated sludge, occurs here. In addition to the removal of carbon compounds, the nitrification process also takes place here. The content of the bio-sorption tank is intensively mixed and aerated using turbine aerators, ROOT-type blowers, and aeration brushes. As a result of the continuous inflow of raw sewage, the contents of the bio-sorption tank flows through the internal trough to the bio-stabilization tank. Intensive mixing and aeration are used here as well. The final removal of organic contaminants from the wastewater and the mineralization of a significant part of the sludge occur in the bio-stabilization tank. Oxygen probes installed in both the bio-sorption and bio-stabilization tanks facilitate the control of the aeration devices. The treated sewage from the bio-stabilization tank flows into two multi-oil settling tanks, where the activated sludge is separated and retained. The sewage, free of sediment, cleaned and clarified, is discharged through troughs to the receiver. The regenerated sludge is returned to the first stage of treatment, and its excess is discharged to a belt press or a plot for sludge drying [Łoszak 2014].

Analytical methods

The assessment of the effectiveness and reliability of contaminant removal in the described treatment plant in Michów was based on the results of qualitative studies of raw (averaged) and treated wastewater collected in 2017–2021. The wastewater samples for analyses were collected

Table 1. Average annual share of particular types of wastewater [Dairy Cooperative “Michowianka” 2017–2020]

Year	Dairy Cooperative “Michowianka”		Permeate		Delivered wastewater		Domestic wastewater from sewerage	
	[m^3]	[%]	[m^3]	[%]	[m^3]	[%]	[m^3]	[%]
2017	155052	73.43	17337	8.21	481	0.23	38286	18.13
2018	147729	76.03	8013	4.12	410	0.21	38156	19.64
2019	130014	77.02	-	-	696	0.41	38100	22.57
2020	119568	73.97	-	-	1034	0.64	41045	25.39

according to the PN-ISO 5667–10:1997 standard, at regular intervals, with the frequency specified in the water permit. During the research period, a total of 29 measurement series were performed. All analyses were performed in an accredited laboratory following the reference methods specified in the applicable legal acts: *Regulation of the Minister of the Environment of November 18, 2014, on the conditions to be met when discharging sewage into water and soil and on substances particularly harmful to the aquatic environment* [No 2014, item 1800] and the *Regulation of the Minister of Maritime Economy and Inland Navigation on substances particularly harmful to the aquatic environment and the conditions to be met when discharging sewage into waters or soil, as well as when discharging rainwater and meltwater into waters or water devices* [No 2019, item 1311].

The following contamination indicators were determined in the wastewater samples:

- total suspended solids TSS (according to PN-EN 872: 2007 + Ap1: 2007);
- chemical oxygen demand COD (according to PN-ISO 6060:2006);
- biochemical oxygen demand BOD5 (according to PN-EN 1899–1:2002 and PN-EN ISO 5815–1:2019–12)
- total phosphorus (according to PN-EN ISO 6878:2006 + Ap1:2010 + Ap2:2010);
- ammonium nitrogen (according to PN-ISO 7150–1:2002);
- total nitrogen, expressed as the sum of:
  - nitrite nitrogen (according to PN-EN 26777:1999);
  - nitrate nitrogen (according to PN-82/C-04576.08);
  - Kjeldahl nitrogen (according to PN-EN 25663:2001);

Statistical analysis

The characteristic values of contamination indicators in raw and treated wastewater were determined based on the obtained results, including average, minimum and maximum values, medians, standard deviations, and coefficients of variation.

On the basis of the average values of contamination indicators in the inflowing (C_{in}) and discharged (C_{out}) wastewater, the average contamination removal efficiency was calculated according to equation 1:

$$\eta = 100\left(1 - \frac{C_{out}}{C_{in}}\right) \quad [\%] \qquad (1)$$

The evaluation of the technological reliability of the wastewater treatment plant in Michów was carried out for selected contamination indicators (BOD5, COD, total suspended solids, total nitrogen and total phosphorus, ammonium nitrogen) using elements of the Weibull reliability theory. The Weibull distribution is a good, general probability distribution, applicable in the reliability study and assessment of the risk of exceeding the permissible values of pollution indicators in treated wastewater [Bugajski et al. 2012; Bugajski 2014; Jóźwiakowski et al. 2018; Jucherski et al. 2017]. The following probability density function characterizes the Weibull distribution (equation 2):

$$f\,(x) = \frac{c}{b} \cdot \frac{x-\theta}{b}^{(c-1)} \cdot e^{-\frac{x-\theta}{b}^{c}} \qquad (2)$$

where: x – variable defining the concentration of a given contaminant indicator in treated wastewater,
b – scale parameter,
c – shape parameter,
θ – position parameter.
Assumptions: $\theta < x$, $b > 0$, $c > 0$.

The reliability analysis consisted in estimating the Weibull distribution parameters using the maximum likelihood method. The null hypothesis that the Weibull distribution can describe the analyzed variable was verified by the Hollander-Proschan test at the significance level of 0.05% [Bugajski et al. 2016]. The values of contamination indicators in the treated wastewater discharged to the receiving body were analyzed.

Reliability was determined from the distribution function in the diagrams, considering the maximum permissible values of the indicators specified in the water permit [Starosta of Lubartów District 2014]: BOD_5 – 25 mgO_2/L, COD – 125 mgO_2/L, total suspension – 35 mgO_2/L, total nitrogen – 30 mgO_2/L, total phosphorus – 2 mgO_2/L, ammonium nitrogen – 10 mgO_2/L. The analysis was carried out with the use of the Statistica 13 software. The determined values were related to the guidelines concerning the minimum level of reliability for wastewater treatment plants with a PE (Population Equivalent) in the range of 2,000–14,999 [Andraka, Dzienis 2003].

RESULTS AND DISCUSION

Quality of raw and treated wastewater

The starting point for assessing the effectiveness and reliability of the removal of contaminants in the Michów treatment plant involved the results of tests of mixed wastewater (dairy and domestic) supplied to the facility and sewage after biological treatment discharged to the receiving body. The characteristic values of individual contaminant indices are summarized in Table 2. The high content of total suspended solids and organic contaminants expressed by BOD_5 and COD indices is noteworthy in raw wastewater.

In the case of organic indicators, the content of proteins, lipids, and, above all, lactose play a decisive role. Sources indicate that in specific products related to milk processing, such as whey or whey permeate, lactose is responsible for up to 90% of the COD load [Slavov 2017]. The determined average values of the indicators mentioned above and those recorded in individual studies were in the lower part of the ranges given for typical dairy wastewater and specific sewage related to the type of production of the plant in Michów [Bartkiewicz 2006; Slavov 2017; Karthikeyan et al. 2015; Janczukowicz et al. 2008]. It is worth noting that the test covered a mixture of dairy sewage from the plant and domestic wastewater supplied to the treatment plant *via* the sewage system and delivered from the area of Michów. While the share of wastewater supplied during the study period can be considered trace (approximately 0.5%), the inflow of domestic sewage accounted for approximately 25% of the total volume of treated sewage (Table 1, Figure 2). The average ratio of BOD_5 to COD in the case of the analyzed raw wastewater was 0.58, and it was also consistent with the proportions of these indicators reported in the literature [Janczukowicz et al. 2008; Prazeres et al. 2012]. The research showed a significant differentiation of the results in individual series of tests, which may confirm the seasonal variability in the load of the dairy plant and the production volume. The coefficients of variation for BOD_5, COD, and ammonia in raw wastewater usually correspond to the high variability and are very high for total suspended solids [Mucha 1994]. The highest values of BOD_5, COD, and total suspended solids were recorded in 2017, indicating a possible effect of permeate drainage from the whey thickening process. This product is characterized by a specific composition, including a low pH and a very high content of organic impurities [Kroll, Budzyński 2001; Slavov 2017]. In 2017, its share in the total volume of wastewater exceeded 8%, and at the beginning of 2018 – 10.8% (Table 1, Figure 2). In the second quarter of 2018, the dairy plant Michowianka gave up the concentration of whey, which could have resulted in a reduction in the content of organic contaminants in the wastewater directed to the treatment plant. The concentrations of nitrogen compounds and total phosphorus in raw wastewater were at an average level. The total nitrogen content was about 7.4% BOD_5,

Table 2. Basic statistics for the indicator values in the treated wastewater (n = 29) [LSUM 2017–2021]

Parameters		Statistics indicators					
		Average	Median	Min	Max	SD	Cv
TSS [mg/L]	In	790.83	530.00	65	2880	959.84	121.4
	Out	22.53	23.0	7.6	55.0	9.23	40.9
BOD_5 [mg O_2/L]	In	1048.9	1080	51	1860	482.09	46.0
	Out	14.33	16.0	3.3	36.0	6.82	47.6
COD [mg O_2/L]	In	1807.8	1755	158	3807	884.71	48.9
	Out	68.9	65.0	17.0	193.0	36.42	52.9
Total phosphorus [mg/L]	In	22.29	23.55	10.00	35.90	8.73	39.2
	Out	2.00	1.73	1.07	6.52	1.09	54.2
Ammonium nitrogen [mg/L]	In	26.30	26.30	1.59	51.00	24.71	94.0
	Out	3.19	1.64	0.24	19.90	4.38	137.2
Total nitrogen [mg/L]	In	78.45	82.05	24.10	95.40	21.67	27.6
	Out	20.72	16.20	1.42	129.00	21.97	106.0

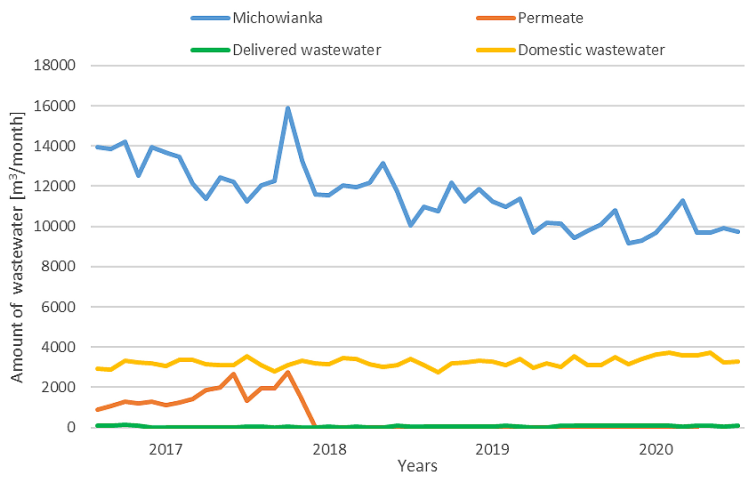

Figure 2. Monthly amounts of individual types of wastewater flowing to the wastewater treatment plant in Michów [Dairy Cooperative "Michowianka" 20217–2020]

and phosphorus – slightly more than 2%, and was slightly higher than the proportions reported in the literature for dairy wastewater [Slavov 2017].

The treated wastewater discharged from the Michów treatment plant was of good quality. The average values of all analyzed indicators decreased significantly compared to the wastewater directed to the treatment plant. The average BOD_5 value from the entire study period was 14.33 mg/L, and the mean value amounted to 16 mg/L (Table 2). In the case of COD, the average value was 68.90 mg/L, total suspended solids – 22.53 mg/L, total nitrogen – 16.85 mg/L, total phosphorus – 2 mg/L. The average values were lower than the limit values specified in the water permit [Starosta of Lubartów District 2014]. The analysis of extreme values of contaminants in the treated wastewater shows that the normative values of all the analyzed indicators were exceeded (Table 2).

Wastewater treatment efficiency

The treatment effects determined based on the average values of contamination indicators in raw and treated wastewater prove the correct operation of the wastewater treatment plant in Michów. The applied technology ensured the removal of total suspended solids, BOD_5, and COD at the level of over 96% (Figure 3). Total phosphorus was removed with an average efficiency of 91%. Slightly lower effects were found in the elimination of total nitrogen – 78.5% on average, while the ammonium nitrogen removal rate was 88% on average.

In comparison with the results presented in the literature, the efficiency of the wastewater treatment plant in Michów should be considered very high. In the biological part, the applied technological system, based on the two-phase activated sludge method, with medium-loaded active sludge in the first phase and low-loaded in the second phase of treatment, showed the effectiveness higher or comparable to other solutions used for dairy wastewater treatment in the analyzed period. However, attention should be paid to the individual working conditions of each installation due to the immense diversity of dairy plants producing wastewater. The effects of treatment plants based on oxygen flow reactors reported in the literature indicate over 90% removal of organic compounds expressed in COD from wastewater, approximately 65% removal of total nitrogen, and a maximum of 50% of total phosphorus [Slavov 2017]. Good effects of dairy wastewater treatment were demonstrated for sequencing batch reactors – up to 90% for COD, 80% for total nitrogen and 67% for total phosphorus [Neczaj et al. 2008; Ozturk et al. 2019], and sequential membrane bioreactors: BOD_5 – 97%, removal of total suspended solids, total nitrogen – 96%, total phosphorus 80% [Abdulgader et al. 2009; Bae et al. 2003]. The wastewater treatment plant in Michów ensured the degree of removal of organic contaminants similar to that recorded in anaerobic reactors, which are considered highly efficient in this respect. The efficiency of UASB reactors for BOD5 and COD ratios oscillates between 90–95% [Ince 1998]. However, the disadvantage of these solutions is a lower degree of elimination of nitrogen and phosphorus compounds. With the support of anaerobic reactors with the oxygen stage, it is possible to remove COD and BOD_5 at the level of 98–99% [Frigon et al. 2009; Tawfik et al. 2008].

Technological reliability

The technological reliability of a wastewater treatment plant, defined as its ability to neutralize sewage to the extent required for the sewage receiver, was determined using the Weibull method. It allows for a more in-depth analysis of qualitative data against the legal requirements imposed on the wastewater discharged into the environment. In the first step, the distribution parameters were estimated, and the null hypothesis was verified that the Weibull distribution could describe empirical data. The data sets were the values of the leading contamination indicators (BOD_5, COD, TSS, total phosphorus, total nitrogen, ammonium nitrogen) in the biologically treated wastewater discharged to the receiving body.

The null hypothesis has been positively verified. The results of fitting the distribution with the Hollander-Proschan test and the estimated parameters are summarized in Table 3.

A good fit of the obtained distributions was high and amounted to 74–96% at the significance level of $\alpha = 0.05$.

The technological reliability of the treatment plant was determined based on the distribution function, considering the limit values of the indicators specified in the water law permit granted to the Dairy Cooperative "Michowianka" to discharge treated wastewater into the environment [Starosta of Lubartów District 2014] (Figure 4).

The technological reliability of the wastewater treatment plant in Michów in terms of total suspended solids removal was 89% (Figure 3). According to the guidelines provided by Andraka and Dzienis [2003] the obtained value can be interpreted as a time in which the treated wastewater discharged from the facility meets the quality requirements specified for a given indicator. Taking the above into account, it can be stated that for 324 days a year, the concentration of total suspended solids in the treated wastewater from the treatment plant in Michów did not exceed the maximum allowable value specified in the water permit. According to the guidelines mentioned above, the minimum level of reliability for the treatment plants with the size of 2,000–14,999 PE should be 89.89%, which in turn means that if the plant operates improperly for 36 days a year, it still gives a 95% chance of successfully passing the control procedures [2003]. Therefore, the wastewater treatment plant in Michów ensured the level of reliability close to the required level, and the excessive concentration of total suspended solids may have a negative impact on the assessment of the wastewater treatment plant for five days a year.

The technological reliability in removing organic contaminants expressed by BOD_5 and COD indices was 93% and 92%, respectively. It means that the values of the indicators in the wastewater discharged from the Michów treatment plant exceed the normative values for the period of 26 and 30 days a year, respectively. Considering the guidelines of Andraka and Dzienis [2003] it can be concluded with a 95% probability that these exceedances do not affect the negative assessment of the facility operation.

The reliability of nutrient removal, compared to organic contaminants, was lower. The probability that the concentration of total phosphorus in treated wastewater will reach the most normative value (2 mg/l) was 53%, suggesting over-normal concentrations of total phosphorus in

Table 3. Parameters of the Weibull distribution and the Hollander-Proschan goodness-of-fit test (n=29)

Parameter	Parameters of Weibull distribution			Hollander-Proschan goodness-of-fit test	
	θ	*c*	*b*	stat	p
	(n = 29)				
TSS	2.6364	2.5397	25.3387	-0.0379	0.9697
BOD_5	1.3990	2.2568	16.1773	-0.0896	0.9285
COD	10.121	2.0018	77.9458	0.0645	0.9485
Total Phosphorus	1.0303	1.9801	2.2731	0.4205	0.6741
Ammonium nitrogen	0.2166	0.8922	2.9844	0.3192	0.7495
Total Nitrogen	-0.2000	2.1592	18.9536	-0.2606	0.9438

Symbols: stat – value of the test statistic, p – significance level of the test; when $p \le 0.05$ the distribution of data is not Weibull distribution

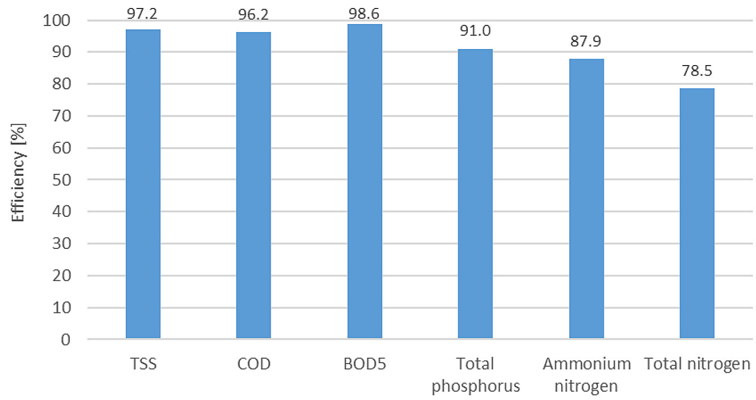

Figure 3. The mean efficiency of pollution removal during operation of the wastewater treatment plant (2017–2021)

treated wastewater for 172 days a year. Considering the permissible limit of 36 days of inappropriate work, it can be concluded that the excessive concentrations of total phosphorus in the treated wastewater may adversely affect the assessment of the facility for 136 days a year.

Higher technological reliability was determined in the case of total nitrogen – 93%. On this basis, it can be concluded that regarding the one-year reference period, the total nitrogen concentrations at the treatment plant outflow met the requirements of the water permit for 339 days. According to the guidelines of Andraka and Dzienis [2003] these exceedances did not affect the assessment of the wastewater treatment plant in Michów. Ammonium nitrogen is also a standard indicator in the water permit for the wastewater treatment plant in Michów. In its case, the technological reliability was 95%, so it can be concluded that exceeding the permissible level of the indicator in treated wastewater also did not affect the negative assessment of the treatment plant.

CONCLUSIONS

The high effects of removing contaminants from wastewater indicate the correct operation of the wastewater treatment plant in Michów. The technological system used, in the biological part, based on the two-phase activated sludge method, with medium-loaded active sludge in the first phase and low-loaded in the second phase of treatment, was characterized by higher or comparable efficiency to other solutions used for dairy wastewater treatment.

In the case of the facility in Michów, the quality of raw wastewater was characterized by slightly lower concentrations of contaminants than typical dairy wastewater, which is determined by the individual conditions under which the wastewater treatment plant operates. In addition to dairy wastewater, it accepts the domestic wastewater from the village area, which accounts for about 25% of the total volume of treated wastewater. The domestic wastewater inflow likely optimizes the hydraulic and contamination load of the wastewater treatment plant, which positively affects the efficiency of the biological treatment processes. At the beginning of the analyzed research period, the inflow of permeate contributed to an increase in the content of organic contaminants in the wastewater directed to the treatment plant. Still, it did not cause a significant deterioration in the quality of the wastewater discharged to the receiving body.

Due to the high efficiency of the facility, the values of the standard contamination indicators at the outflow, as a rule, met the requirements specified in the water permit and exceeded the limit values only in a few cases.

The technological reliability of the wastewater treatment plant in Michów, determined by the Weibull method, was at a high level, usually exceeding 90%. The determined levels of reliability were higher than the required level, which suggests that any exceeding of the permissible level of the indicator in treated wastewater did not affect the negative assessment of the treatment plant. The reliability analysis shows that the facility in Michów has a high capacity to treat wastewater to the extent required for the wastewater receiver, and that the treated wastewater discharge does not cause negative changes in the environment. It indicates a high probability of obtaining wastewater quality at the outflow from the treatment plant meeting the water permit requirements.

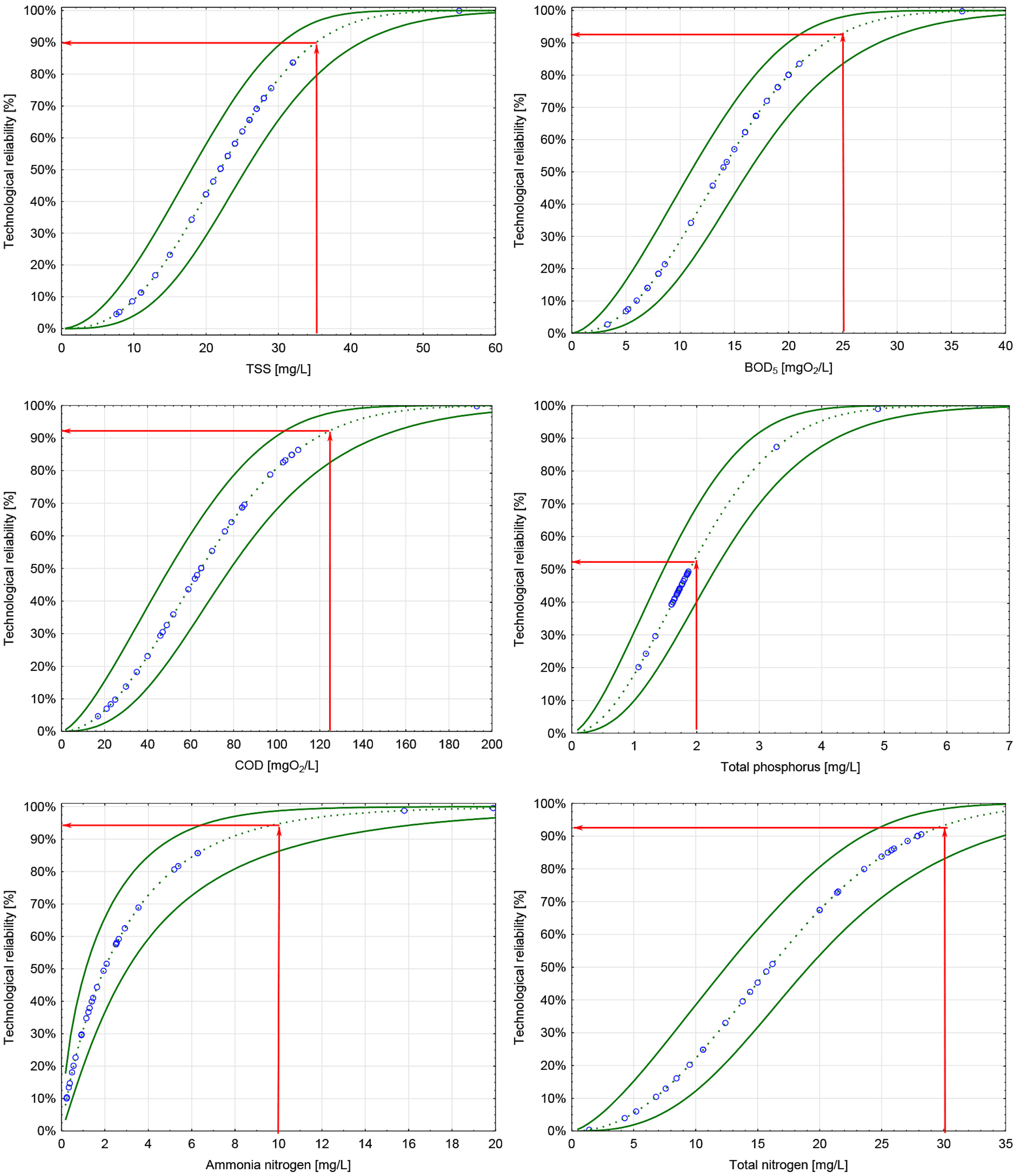

Figure 4. Weibull cumulative distribution functions and the technological reliabilities determined for each pollution parameter

Notation: dashed green line – reliability function, continuous green line – confidence intervals, red arrows – probability of achieving the indicators limit in the effluent

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