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Efficacy and reliability of wastewater treatment technology in small meat plants

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ABSTRACT

Due to the growing scale of food production, the volume of wastewater generated by the food industry has been increasing dramatically. This type of wastewater usually contains high loads of contaminants whose levels exceed several times the respective levels in domestic wastewater. The requirement of wastewater treatment is also imposed on the meat industry. Plants of a similar profile, dealing with slaughter, were selected for the study. Three plants were selected – abattoirs slaughtering poultry or pigs and cattle. Each of them is equipped with a wastewater treatment plant operating in two treatment stages: physicochemical and biological treatment. Analyses were conducted over 1 y on 12 samples collected from raw, pre-treated, and treated wastewater. Based on the results, treatment efficacy and biological treatability of the wastewater were assessed. Causes for exceedance of standard requirements applicable for treated wastewater were discussed. Reliability of wastewater treatment plant operations was analyzed using the Weibull distribution model. The efficiency of removing organic compounds expressed as biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) was determined in the range from 81% to 99%, and biogenic compounds from 37% to 79% (N_{tot}), and from 83% to 98% (P_{tot}). The operation of the tested wastewater treatment plants was found to be completely reliable in terms of removal of organic compounds such as BOD_5 and COD (100% for plants 1 and 2, and 80% and 91% for plants 3, respectively), phosphorus and suspended solids (100% for all plants). Nitrogen was removed with reliability of approximately 40%.

Keywords: Industrial wastewater; Meat industry; Biological treatability; Reliability

1. Introduction

The growing food consumption requires increasing production levels in food industry plants, including meat processing plants, which in turn results in higher wastewater volumes generated by the food industry. This type of industrial wastewater usually contains very high loads of contaminants, particularly organic ones. Consequently, it is necessary that its in-plant treatment be provided in order to meet conditions required for its discharge to the sewer system, to receiving waters, or to the ground [1].

In Poland, the consumption of meat, particularly poultry, has increased by approximately 9%, over the last 15 y, currently amounting to about 74 kg/cap/y [2]. In response to the growing consumer demand for meat, abattoirs tend to increase their production levels, consuming as a result greater amounts of water, and generating considerably more wastewater. Due to contaminant loads, this type of wastewater may not be directly discharged not only to receiving waters but even to the sewer system [3]. Operators of abattoirs and meat processing plants are obliged to select an appropriate industrial wastewater treatment technology to ensure an adequate level of environmental protection against such contamination [4].

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For this reason, many plants have their own wastewater treatment or pre-treatment systems. Most of them are equipped both with physicochemical and biological treatment installations based on the activated sludge process. Such operations generate costs; however, they considerably reduce contaminant loads introduced to the environment, particularly since industrial wastewater treatment plants are subject to comparable control means such as, for example, municipal wastewater treatment plants. They typically are mechanical and biological treatment systems that need to exhibit considerable reliability in order to meet specific requirements imposed on pollutant discharge. Due to the growing number of small meat industry plants and the need to neutralize the resultant wastewater, there is a need to carry out research into the applied treatment technologies. Literature does not provide much information on this subject, therefore, it was found that there is a need to assess not only the efficiency of the operation of devices but also the reliability of treatment systems, especially the multistage ones.

Production processes in abattoirs and meat processing plants generate a variety of types of wastewater. This is production wastewater resulting from animal meat processing, as well as water used to wash production installations and floor surfaces in production halls, yards, stockyards, and transportation vehicles, water used to cool products as well as sanitary wastewater. The unit volume of wastewater per one slaughter or processing unit varies greatly for individual plants and ranges from 1 up to 5 m^3/LU (livestock unit). The quality of production wastewater also varies considerably depending on the character of production and applied technology. Pollution indexes for meat processing wastewater are much higher than those for typical municipal wastewater. For example, changeability of 5 d biochemical oxygen demand (BOD_5) for such wastewater is usually in the range from 1,000 to 6,000 mg/L, chemical oxygen demand (COD) from 1,000 to 10,000 mg/L, total nitrogen from 140 to 580 mg N/L, while total phosphorus is in the range of 10–80 mgP/L. Unit contaminant loads depend on the specific character and volume of production of individual plants [5,6]. These amounts and loads in wastewater generated by meat processing plants may be reduced by rational water management and the application of advanced production technologies.

Due to its composition, production wastewater is treated using mechanical, physicochemical, and biological methods [7]. Mechanical methods include the use of grates, screens, and fat traps eliminating 50%–90% settleable solids and 10%–40% BOD_5. Physicochemical methods include, for example, flotation preceded by flocculation using chemical coagulants or electrocoagulation [8]. In turn, the biological treatment effectively uses the activated sludge process with an advanced removal of nitrogen and phosphorus [9] and anaerobic reactors [10]. Advanced methods based on adsorption or separation using filtration membranes can also be applied [11]. Good treatment results are also obtained using several combined methods [12,13].

Effluents discharged from industrial plants need to meet the requirements of the above-mentioned Regulation of 2019 on substances particularly harmful to the water environment and the Regulation of the Minister of Construction of 14 July 2006 on the execution of responsibilities imposed on industrial entities and conditions for wastewater discharge to sewage systems [14]. Additionally, the terms and conditions of contracts concluded between abattoirs and meat processing plants and wastewater treatment plant operators need to be met.

Depending on the adopted production technology, generated wastewater has varying biological treatability. It is assessed based on two calculated indexes [15,16]: COD/BOD_5 characterizing the content of readily digestible substrate (values < 1.8) or hardly digestible substrate (values > 2.5) and BOD_5/TKN, reflecting the rate of nitrifiability (values > 3 indicate low nitrifier content in the biomass).

Reliability of system operation is assessed based on the level of probability that the requirements are met within a specified time [17,18]. Indexes of reliability include treatment efficacy and technological efficiency. The Weibull model process is a suitable method to evaluate the reliability of a system in relation to the imposed requirements [19]. The Weibull probability distribution is based on the probability density function using three parameters [Eq. (1)]:

$$f(x) = \frac{c}{b} \times \left[\frac{(x-\theta)}{b} \right]^{c-1} \times e^{\left\{ -\left[\frac{x-\theta}{b} \right]^{c} \right\}} \quad (1)$$

where x is the value of the pollution index for treated wastewater, b is the scale parameter, c is the shape parameter, θ is the location parameter.

For the Weibull distribution, the complement of the cumulative distribution function to one is the reliability of distribution [Eq. (2)]:

$$F(x) = 1 - \exp\left\{ \left[\frac{(x-\theta)^{c}}{b} \right] \right\} \quad (2)$$

Parameters of the Weibull distribution are estimated using the maximum likelihood method, with the distribution fitted to empirical data using the Hollander–Proschan test [20,21].

The aim of this study was to determine the biological treatability of raw, as well as mechanically and physicochemical pre-treated wastewater, and to evaluate the efficacy of the applied treatment methods in view of the requirements imposed on treated wastewater. An important element of these investigations was related to the analysis of reliability for the discussed industrial wastewater treatment installations.

2. Methodology

Investigations were conducted in three wastewater treatment facilities for wastewater generated by meat processing plants. It was decided that these analyses would be performed in two poultry abattoirs and one pig and cattle abattoir. All these plants were equipped with physicochemical wastewater pre-treatment and biological wastewater treatment facilities. Individual treatment plants differed only in terms of their capacity. The physicochemical pre-treatment and biological treatment technologies in all these plants were identical. Raw, treated, and clarified wastewater were sampled once a month; a total of 12 samples were collected. Wastewater was analyzed using standard methods in plant laboratories. The determined parameters included the content of suspended solids, BOD_5, COD, total nitrogen, and total phosphorus contents as well as pH. Standard methods were used: for BOD_5, the respirometric method, for COD the bichromate method, for nitrogen and phosphorus – colorimetric methods, and the pH was measured with a microcomputer meter. Based on the recorded results, the efficiency of pollutant removal from wastewater in the mechanical and biological processes was determined, along with the mean values and standard deviations. In order to assess the biological treatability of wastewate, the COD/BOD_5 and BOD_5/Nog ratios were calculated. Since problems with nitrogen removal were reported in the investigated treatment plants, the formula proposed by Anthonisen et al. [22] was used to calculate the amount of free ammonia which may inhibit nitrification [Eq. (3)]:

$$S_{NH_3} = \frac{17}{14} \times \frac{S_{N-NH_4} \times 10^{pH}}{\exp(6,344/T) + 10^{pH}} \tag{3}$$

where S_{N-NH_4} is the concentration of ammonia nitrogen in wastewater, mg N/L; pH is the pH value in the reactor; and T is the temperature in the reactor, K.

For the first phase of nitrification, the limit of partial inhibition is the $N–NH_3$ concentration of 10 mg N/L and the limit of total inhibition is 150 mg N/L. For the second phase of nitrification, these limits are 0.1 and 1.0 mg N/L, respectively.

The conducted statistical analysis included calculating descriptive statistics parameters, while the normality of distribution for the set of results from the investigated treatment plants was verified for individual contamination indexes with the use of the Shapiro–Wilk test. Next, the analysis of variance (the Kruskal–Wallis test) was applied to test the hypothesis on the equality of distribution by comparing the results for individual pollution indexes from the three investigated facilities.

Then, the Weibull model was applied to assess the reliability of the analyzed treatment systems in terms of the imposed requirements. Statistical calculations were performed in the Statistica ver. 13.3 program (https://www.statsoft.pl/textbook/stathome.html).

3. Characteristics of investigated facilities

The facilities selected for analysis included poultry abattoirs in Kaliszkowice Ołobockie (plant 1) and in Lipce Reymontowskie (plant 2) and a pig and cattle abattoir in Kozia Góra (plant 3). The wastewater treatment plants operating in those abattoirs collect wastewater from production lines and domestic wastewater originating from sanitary facilities. Table 1 presents the volume of wastewater received by the treatment plants.

Fig. 1 presents design values of organic pollution indexes as well as concentrations of biogens in raw, mechanically, and physicochemically pre-treated and biologically treated effluents. Values of pollution indexes for treated effluents were found to be similar for all the plants (BOD_5 – 25 mg/L, COD – 125 mg/L, N_{og} – 30 mg N/L and P_{og} – 3 mg P/L, and TS – 35 mg/L). It follows that all the tested objects must achieve the same ecological effect.

The analyzed wastewater treatment plants consist of a mechanical treatment facility, a physicochemical treatment installation, a biological treatment facility, a strainer, and auxiliary devices (Table 2). All of the plants are equipped with screens in the mechanical treatment facility, only plant 2 has a separate grease trap. Physicochemical treatment consists of flotation induced with a coagulant, while an activated sludge reactor with increased nitrogen and phosphorus removal is located in the biological treatment section [23].

4. Results

Values of pollution indexes in raw wastewater exceeded, sometimes considerably, the design parameters (Fig. 2). In the wastewater treatment plant of abattoir 1, with the highest number of exceedances of the admissible pollutant load recorded in pre-treated wastewater in the course of this study, the reported BOD_5 and COD values in raw wastewater amounted to several dozen percent in relation to the mean (the ranges of 2,400–4,000 and 4,600–8,800 mg/L at the mean of 3,300 and 6,400 mg/L, respectively). A similar situation was observed in wastewater treatment plants for abattoirs 2 and 3 (values approximately 80% and 50% higher than the design parameters). Concentrations of nitrogen and phosphorus fell within the limits of the design values.

For this reason, after the physicochemical pre-treatment, the recorded values of pollution indexes also exceeded the design limits – in terms of organic compounds in the treatment plant for abattoir 1 it was the case of all of the tested samples, for plant 2 it was the case of approximately 50% samples, while for plant 3 – of approximately 30% samples. In the wastewater treatment plant for abattoir 3, nitrogen concentration was also increased. Since effluent treatment efficacy in the biological process (Fig. 3) was high (91% up to 99% for organic compounds and from 71% to 82% for nitrogen), in the treatment plants for abattoirs 1 and 2, the limits for organic pollutants were not exceeded in the effluent after biological treatment. In turn, in the treatment plant for abattoir 3, a total of 4 exceedances were recorded in 12 collected samples. A problem was observed for the efficacy of nitrogen removal. In each of the investigated wastewater treatment plants, an exceedance was recorded for total nitrogen concentration in the treated wastewater in 7 (abattoir 1) and 5 of the tested samples (abattoirs 2 and 3). Total phosphorus concentrations met the applicable requirements as a result of the assisted chemical treatment process. The concentration of total suspended solids

Table 1
Design flows of treated sewage

Sewage flow	Plant 1	Plant 2	Plant 3
Q_{dav}, m^3/d	150	565	300
Q_{max}, m^3/d	200	700	390
Q_{hav}, m^3/h	10	115	20

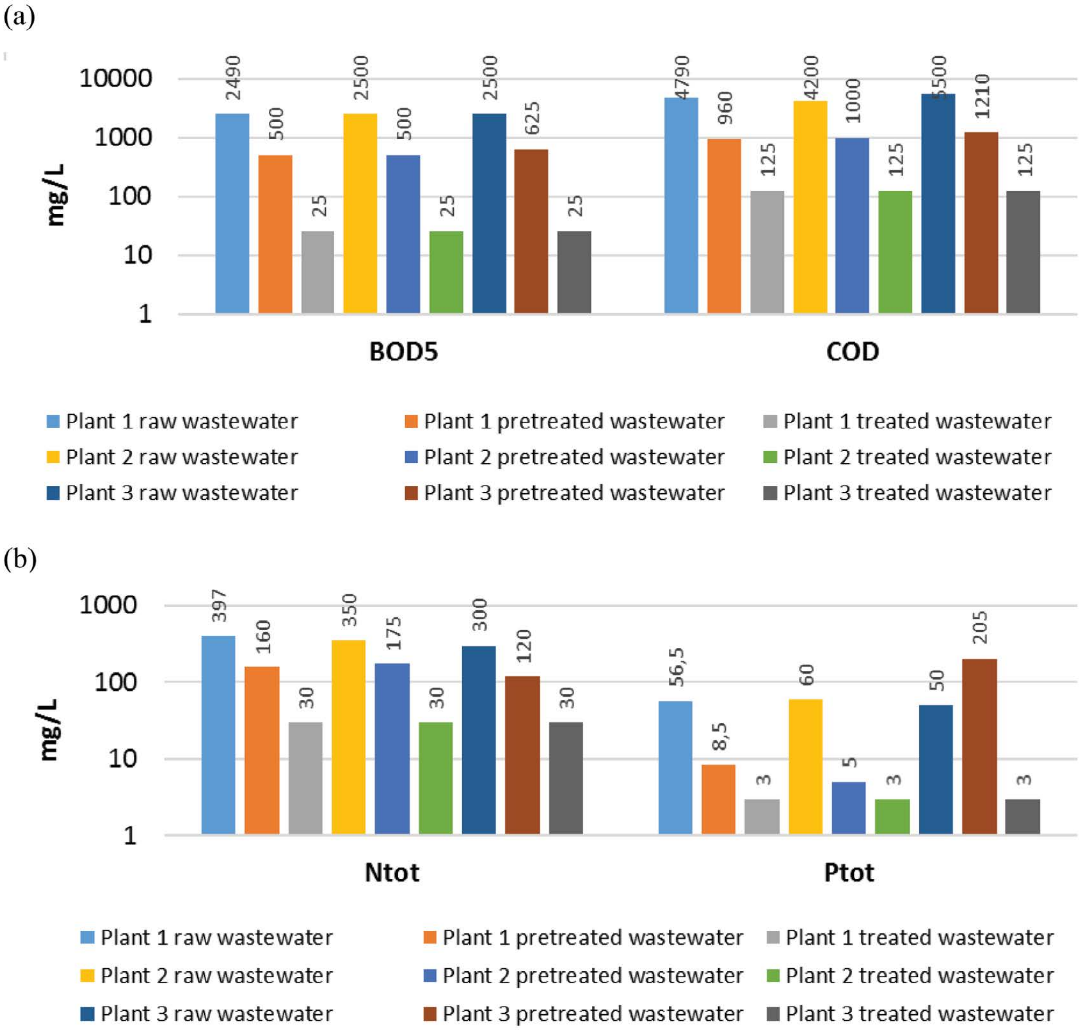

Fig. 1. Design pollution indexes for effluents from investigated treatment plants: (a) organic compounds and (b) biogenic compounds.

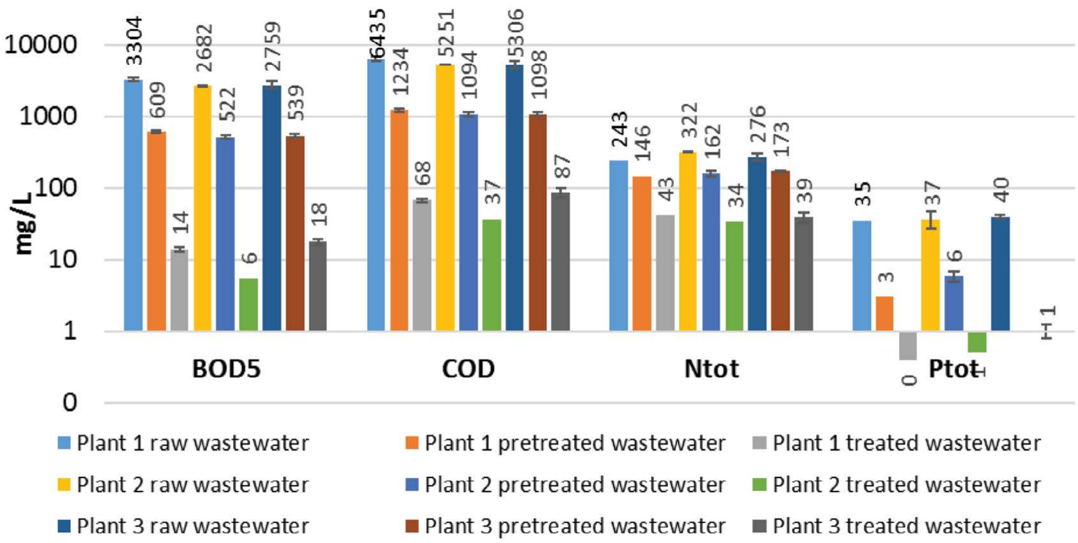

Fig. 2. Actual mean pollution indexes in effluents from investigated treatment plants.

Table 2
Components of investigated treatment plants

Cleaning level	Plant 1	Plant 2	Plant 3
Mechanical treatment	Pumping station I^0	Loop screen	Retention tank
	Spiral sieve		Strainer
	Retention tank	Grease trap	Loop screen
	Pumping station II^0		
Physico-chemical treatment	Pipe flocculator	Pipe flocculator	
	Coagulant feeder	Coagulant feeder	Coagulant feeder
	Neutraliser feeder	Neutraliser feeder	Neutraliser feeder
	Flocculator preparation station	Flocculator preparation station	Flocculator preparation station
	Pressure flotation tank	Pressure flotation tank	Pressure flotation tank
	Pumping station III^0	Pretreated effluent tank	Pretreated effluent tank
Biological treatment	Denitrification chamber	Denitrification chamber	Denitrification chamber
	Nitrification chamber	Nitrification chamber	Nitrification chamber
	Secondary settling tanks	Secondary settling tanks	Secondary settling tanks
	Blower	Blower	Blower
Sludge management	Sludge stabilization chamber	Sludge stabilization chamber	Sludge stabilization chamber
	Sludge dewatering station	Excess sludge pumping station	Post-flotation sludge tank
		Sludge dewatering station	Sludge dewatering station

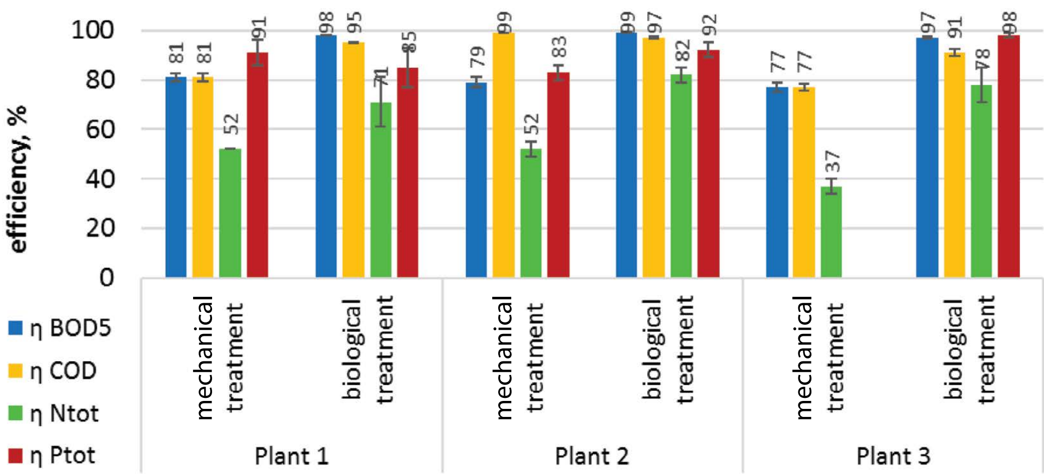

Fig. 3. Efficacy of pollutant removal from effluents in investigated treatment plants.

was tested only in the treated effluents and amounted on average to 12, 9, and 13 g/m^3 for abattoirs 1, 2, and 3, respectively. Values recorded in successive analyses for all of the plants fell below the applicable limit of 35 mg/L.

5. Analysis of results

Physicochemical treatment of wastewater in the investigated treatment plants involved straining and chemical coagulation. Efficacy of pollutant removal in that part of the treatment plants depended primarily on adequate doses of reagents and maintenance of the required process parameters. In turn, the results of biological treatment depended on the biological treatability of the effluents. In order to assess this treatability, COD/BOD_5, and BOD_5/N_{tot} values were calculated (Table 3).

Table 3
Biological treatability indexes

Index	Sewage	Plant 1	Plant 2	Plant 3
COD/BOD_5	Raw	1.94	1.97	1.96
	Pretreated	2.06	2.10	2.03
BOD_5/N_{tot}	Raw	13.50	8.30	10.00
	Pretreated	4.50	3.01	3.15

Similar COD/BOD_5 values were reported by Myra et al. [24] – from 1.04 to 1.61 for wastewater from meat processing, while Onet et al. [25] noted COD/BOD_5 values from 1.6 to 2.8 and BOD_5/N_{tot} from 2.4 to 11.2 for similar wastewater.

Based on the recorded results, it was observed that wastewater treated in the investigated treatment plants, both raw and pre-treated in the physicochemical process, is biologically treatable in terms of the removal of organic compounds. In turn, $BOD_5/N_{tot} > 3.0$ indicates low contents of nitrifiers, and thus low susceptibility to oxidation of ammonium nitrogen by biological processes. The product of this process is, in turn, the substrate for the denitrification process; however, in the investigated case it is restricted by too low amounts of organic compounds at the second stage of effluent treatment. Results obtained in abattoir 3 indicate that lower ambient temperatures in the winter period may have had some effect on nitrogen removal efficacy. In view of the high nitrogen content exceeding the design limit in raw wastewater and pre-treated effluents, it was decided that the potential inhibition of nitrification of undissociated ammonium nitrogen should be verified. Based on calculations conducted using Eq. (3) for the minimum and maximum temperatures of effluents in biological reactors, it was stated (Table 4) that – as reported by Anthonisen et al. [22] – in the course of wastewater treatment in the investigated plants, inhibition of substrate by ammonia occurred in the second stage of nitrification ($S_{NH_3} > 1.0$ mg/L). It may thus be assumed that nitrification–denitrification occurred only in the simplified process ($N–NH_4$ – $N–NO_2$ – N_2). In view of the high nitrogen concentration in raw wastewater, the low amount of nitrifiers, and the limited amounts of organic compounds following the chemical pre-treatment of effluents, the result of nitrogen removal was insufficient.

In the statistical analysis of the recorded results, the descriptive statistics were calculated, while the analysis of variance was applied to test the null hypothesis assuming no differences between the analyzed sets of data (i.e., the results of analyses for individual pollution indexes in treated effluents from the three investigated treatment plants). It was decided that a non-parametric alternative test of the simple Kruskal–Wallis classification should be applied since the Shapiro–Wilk distribution normality test for the analyzed data sets yielded a negative result (Table 5).

Based on the test, the null hypothesis was rejected or BOD_5, COD, and P_{tot}, while for N_{tot} and total suspended solids the null hypothesis was confirmed. Afterward, for the latter indexes, descriptive statistics were calculated for the results from all the investigated treatment plants collectively.

In the treatment of wastewater with heavy pollution loads, the reliability of treatment systems is particularly important. Reliability of the investigated treatment plants was evaluated using the above-mentioned Weibull model. In view of the analysis of variance, the Weibull model was applied for BOD_5, COD, and P_{tot} separately for each plant, whereas for N_{tot} and total suspended solids, the analysis of reliability was conducted for the results collected from all the plants collectively. Table 6 presents the distribution parameters and measures of goodness of fit of the model.

The figures below present reliability curves, and on their basis, the probability of exceedance of the mean values from the measurement period (annual mean values) in effluents following their biological treatment. It was determined

Table 4
Undissociated ammonium nitrogen in effluents from the investigated plants (mg N/L)

Treatment plant	pH		S_{NH_3} – temp. 15°C		S_{NH_3} – temp. 25°C	
	Raw sewage	Pretreated sewage	Raw sewage	Pretreated sewage	Raw sewage	Pretreated sewage
Plant 1	7.43	7.59	2.13	1.83	4.43	3.08
Plant 2	7.16	7.05	1.48	0.60	3.09	1.25
Plant 3	7.41	6.69	2.32	0.28	4.82	0.59

Table 5
Selected descriptive statistics and the Kruskal–Wallis test for treated effluents

Treatment plant	Statistic parameters	BOD_5, mg/L	COD, mg/L	N_{tot}, mg N/L	P_{tot}, mgP/L	TSS, mg/L
	Mean	14.17	67.60	42.93	0.40	11.53
Plant 1	Median	14.80	64.70	30.50	0.34	14.00
	Standard error	0.89	3.83	7.57	0.06	1.99
	Mean	5.61	37.13	34.38	0.52	8.75
Plant 2	Median	4.50	37.35	28.85	0.275	8.00
	Standard error	0.78	4.69	4.60	0.21	1.08
	Mean	17.81	87.16	38.33	1.02	12.67
Plant 3	Median	17.50	87.10	28.95	0.78	14.00
	Standard error	1.50	14.00	6.30	0.22	0.98
Results of the K–W test		$p < 0.05$	$p < 0.05$	$p > 0.05$	$p < 0.05$	$p > 0.05$
	Mean	–	–	38.55	–	10.98
Plants 1, 2, 3	Median	–	–	29.45	–	12.00
	Standard error	–	–	3.57	–	1.03

Table 6
Distribution parameters and fit measures for the Weibull model

Index	Plant	Distribution parameters			Hollander–Proschan test	
		Location	Shape	Scale	Test value	*p*
BOD_5	1	0.0000	6.5569	15.247	–0.326984	0.74368
	2	0.0000	2.3106	6.3643	0.340154	0.73374
	3	0.0000	3.8219	19.702	0.206188	0.83664
COD	1	0.0000	6.0404	72.963	0.124024	0.90130
	2	0.0000	2.6210	41.994	0.094626	0.92461
	3	0.0000	1.9945	98.834	0.082360	0.93436
P_{tot}	1	0.0000	2.2628	0.45559	0.254751	0.79892
	2	0.0000	1.0345	0.52606	0.336649	0.73638
	3	0.0000	1.5002	1.1348	0.188874	0.85019
N_{tot}	1, 2, 3	0.0000	1.9764	43.819	0.491134	0.62333
TSS	1, 2, 3	0.0000	0.88573	10.684	–1.52597	0.12702

for the indexes which met the requirements (blue line) or the values required for the indexes whose limits were exceeded (green line).

In the case of BOD_5, treated wastewater in plants 1 and 2 met the requirement of 25 mgO_2/L (Fig. 4). In plant 1, approximately 54% of treated wastewater samples contained organic compounds expressed in terms of BOD_5 at an amount greater than the annual mean, which corresponded to 197 d a year. The remaining values were lower than the annual mean. In plant 2, 48% of the values of this index exceeded the annual mean, which corresponded to 175 d a year. In plant 3, one value out of the 12 values

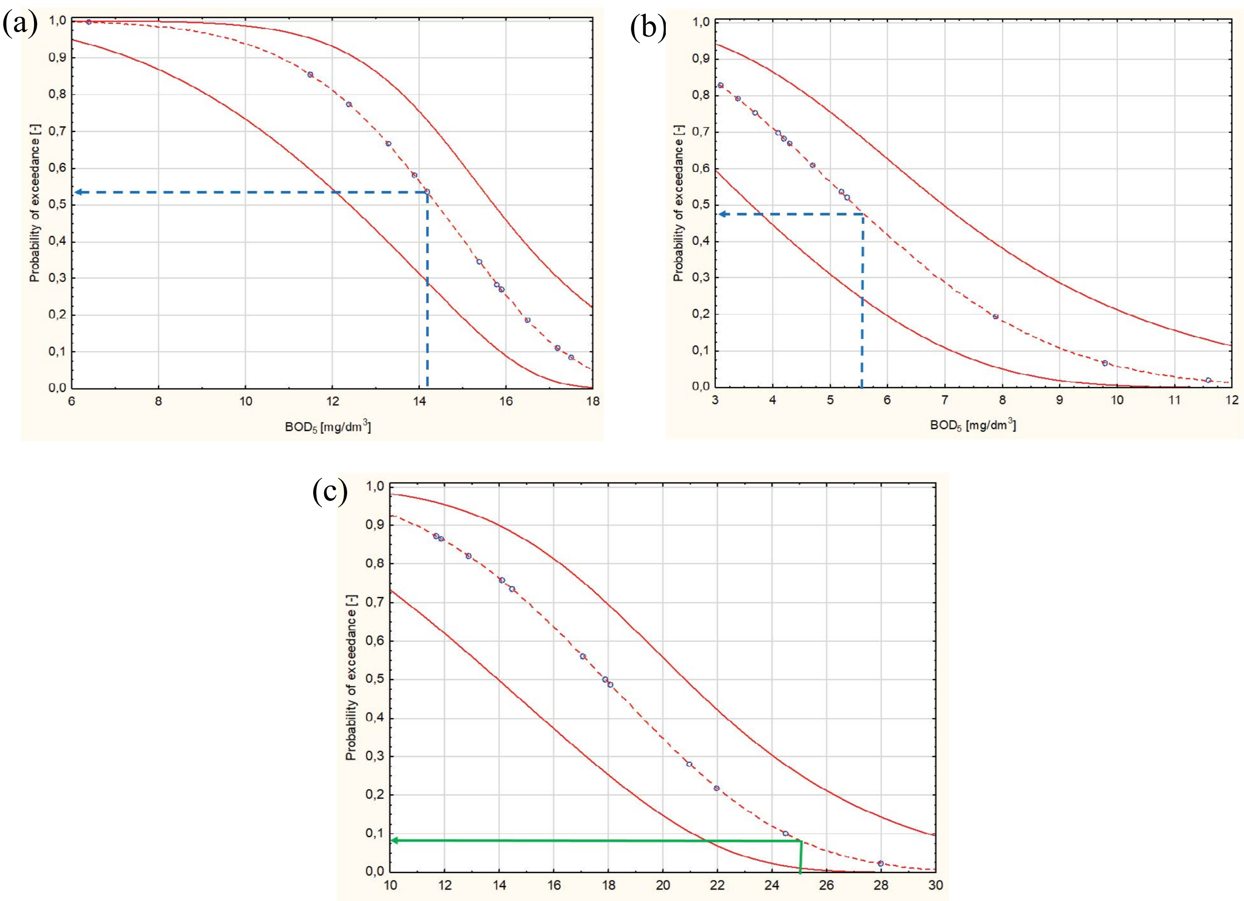

Fig. 4. Weibull reliability analysis for organic compounds expressed as BOD_5: (a) plant 1, (b) plant 2, and (c) plant 3.

recorded within a year exceeded the required threshold, which amounted to 9% and corresponded to 33 d a year.

In the case of COD, analogous findings were reported (Fig. 5). In plants 1 and 2, values of the index always met the requirements, while in plant 1 the mean was exceeded by 52% of the values (which corresponded to 190 d a year), while in plant 2, the mean was exceeded by 47% of the values (an equivalent of 172 d a year). In plant 3, a total of four COD exceedances were reported, while 20% of the results failed to meet the admissible limits, which corresponded to 73 d a year.

A similar pattern was observed in the case of total phosphorus (Fig. 6). In plants 1 and 2, the concentrations of phosphorus did not exceed the established threshold, while in plant 1, the mean was exceeded by 48% of the values, whereas in plant 2, the mean was exceeded for 35% of the values, corresponding to 175 and 128 d a year, respectively. In plant 3, one exceedance was recorded, which was equivalent to 2% of the results, corresponding to 7 d a year.

The reliability analysis for total nitrogen was conducted for all the objects collectively in view of the previous confirmation of the null hypothesis in the Kruskal–Wallis test. The results are presented in Fig. 7. Overall, 17 exceedances were reported for the required concentration of total nitrogen in treated wastewater, which corresponds to as much as 63% of all the results and is equivalent to 230 d a year. This result is consistent with an earlier analysis concerning the efficacy of nitrogen removal in the tested plants.

The reliability analysis for total suspended solids was also conducted collectively for all the plants (Fig. 8). It was found that all the treatment plants met the applicable requirements, with only 35% of the results exceeding the annual mean, which was equivalent to 128 d a year.

6. Conclusions

Based on the conducted studies and the analysis of the results, it was stated that effluents from the abattoirs, although characterized by high pollution indexes, were biodegradable.

- Efficacy of removal of organic compounds in the investigated treatment plants ranged from 97% to 99%, which in most cases was sufficient for the treated effluents to meet the admissible limits. Only in plant 3, a few exceedances were recorded for the admissible COD and – in the single case – BOD_5.
- Contents of total phosphorus (except for a slight exceedance in plant 3) and total suspended solids in treated effluents also fell within the required limits.

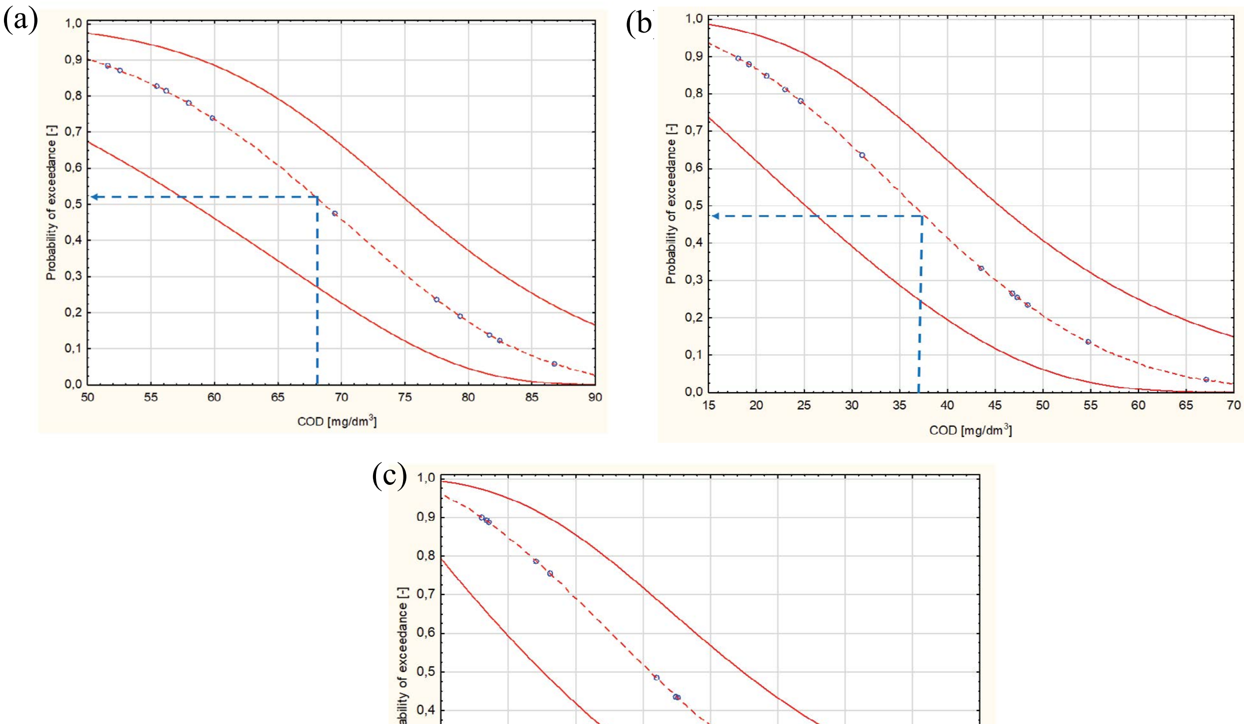

Fig. 5. Weibull reliability analysis for organic compounds expressed as COD: (a) plant 1, (b) plant 2, and (c) plant 3.

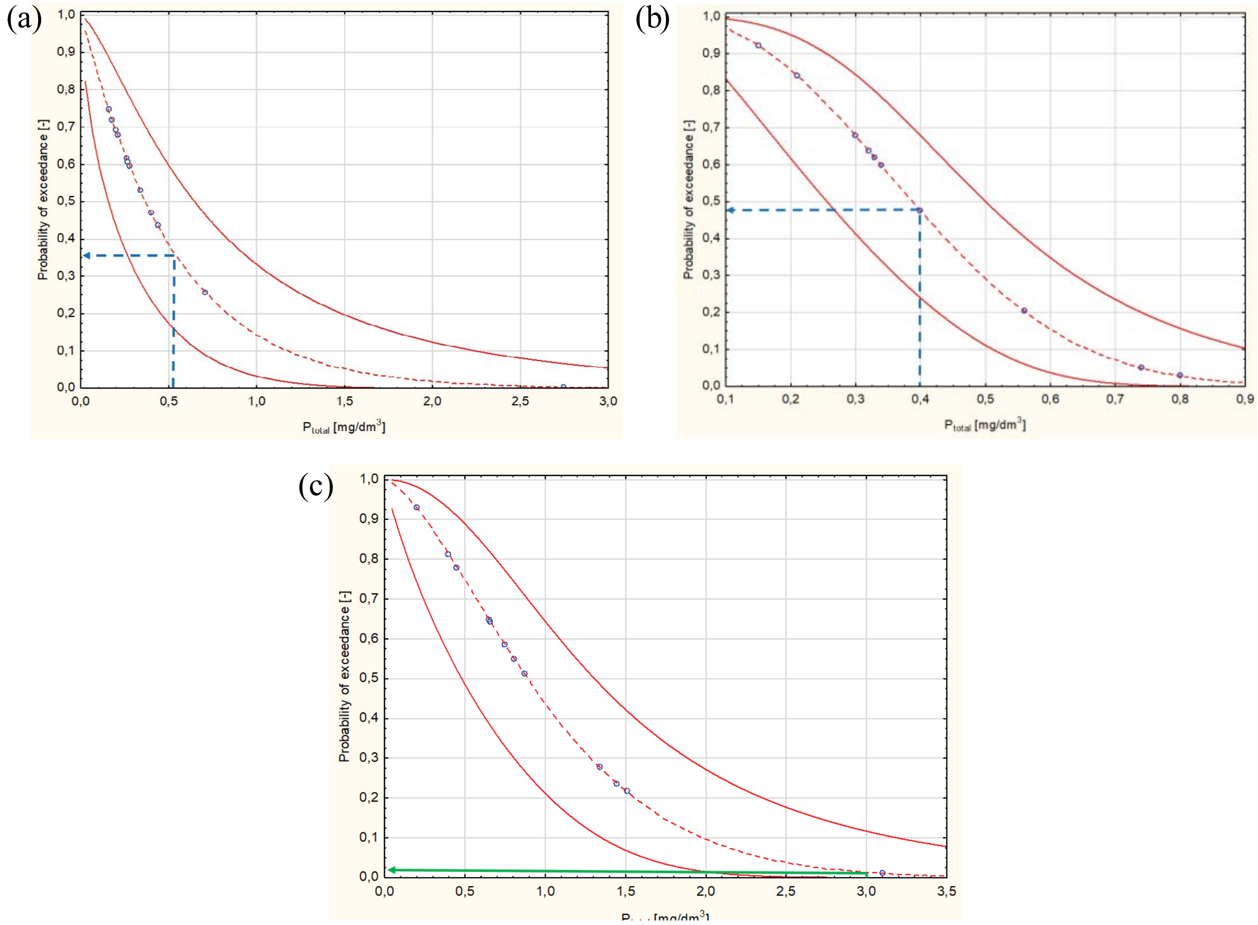

Fig. 6. Weibull reliability analysis for total phosphorus: (a) plant 1, (b) plant 2, and (c) plant 3.

- Good removal rates for organic compounds, suspended solids, and phosphorus were confirmed by the reliability analysis using the Weibull model.
- The treatment plants operating in abattoirs 1 and 2 proved to be completely reliable in terms of removal of organic compounds, with approximately 50% results falling below the annual mean. In abattoir 3, only 80% reliability was recorded for COD reduction and the related exceedance of the required values of this indicator for 73 d a year from literature recommendations [26] – 97.3 and 9 d, respectively.
- All the wastewater treatment plants were reliable in terms of the removal of solids and phosphorus compounds (exceedance of phosphorus limits in plant 3 at 2%, equivalent to 7 d a year).
- In all of the treatment plants, tthe applicable limits of total nitrogen were exceeded, with overall 63% values over the admissible threshold. As this study showed, this may have been caused by too low levels of nitrifiers, deficits of organic compounds following pre-treatment, or excessive ammonia nitrogen concentrations, resulting in the inhibition of the second phase of nitrification.
- According to literature sources, wastewater treatment plants in meat industry facilities operating in the two-stage system provide results comparable to, or slightly worse than those reported in research on the subject [7,27].

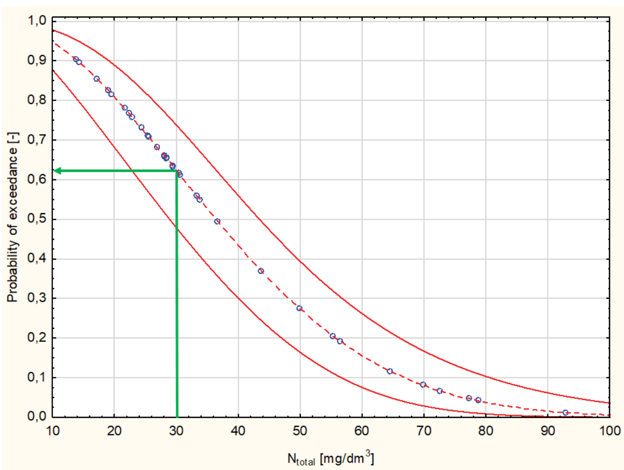

Fig. 7. Weibull reliability analysis for total nitrogen – plants 1, 2, and 3.

Lower values at the outflow are typically related to lower pollutant concentrations in raw wastewater.

- The effectiveness observed for the treatment of meat industry wastewater depends on the concentrations of pollutants in influents, on the proportions of individual

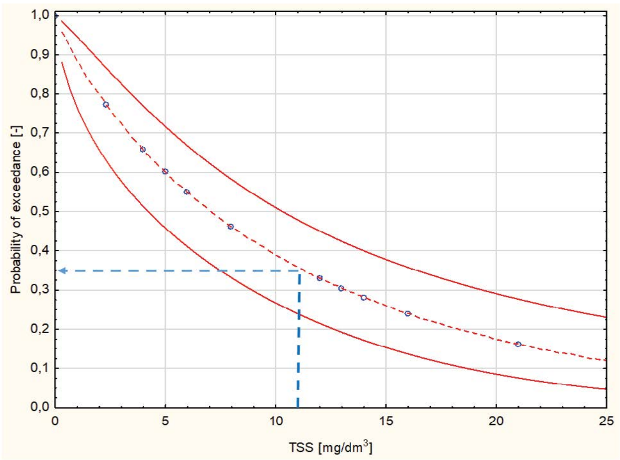

Fig. 8. Weibull reliability analysis for total suspended solids – plants 1, 2, and 3.

components, and on the applied treatment technology and proper installation operation.

This study demonstrated that treatment of specific wastewater, such as meat industry wastewater, may provide good or very good results; however, a problem may arise connected with effective removal of nitrogen compounds. The technology of meat processing wastewater treatment, including mechanical, biological, and chemical methods, used in the examined plants is effective and recommendable for this type of facilities, taking into account their specificity.

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