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A Weibull Analysis of the Reliability of a Wastewater Treatment Plant in Nowy Targ, Poland

Piotr Bugajski[*]*, Elwira Nowobilska-Majewska*
University of Agriculture in Krakow, Poland
[*]*corresponding author's e-mail: p.bugajski@urk.edu.pl*

1. Introduction

The technological reliability of a wastewater treatment plant (WWTP) can be defined as the probability that the facility will meet the requirements regarding the maximum permissible limits for pollution parameters in a given unit of time (Oliveira & Von Sperling 2008, Andraka & Dzienis 2003, Rak et al. 1989). In practice, the reliability of WWTPs is most often determined as a percentage reduction rate i.e. the difference between the values of pollution parameters in influent and effluent wastewater (Chmielowski & Ślizowski 2010, Młyński et al. 2016, Masłoń & Tomaszek 2013). Another, more advanced, method of reliability assessment used by many researchers in recent years is the method based on the three-dimensional Weibull distribution (Bugajski et al. 2012, Nastawny & Jucherski 2013, Bugajski 2014a, Bugajski et al. 2016, Marzec et al. 2018). In the case of WWTPs, the reliability obtained should be compared to the guidelines set out in the water quality permit, and if the facility turns out to be unreliable with respect to pollutant removal, measures should be taken to identify and then correct the deficiencies in the operation of the facility (Krzanowski & Wałęga 2006, Kuśnierz 2018). The technological reliability of treatment plants with a biological reactor with activated sludge in regard to pollution removal is affected by many factors, both dependent and independent of the operators of those facilities; the most important of these factors are the high variability in the quantity and quality of influent wastewater, its temperature, the ratio of organic carbon concentration to nitrogen and phosphorus concentrations, the content of toxic substances, and even the content of antibiotics in wastewater (Sadecka & Płuciennik-Koropczuk 2011, Takács 2008, Kaczor & Bugajski 2012, Vaiopoulou & Gikas 2012, Smyk et al. 2017). In Poland, one of the most important factors that have an adverse effect on the operation of WWTPs is the illegal discharge of stormwater into sewerage systems (Kaczor 2012, Pecher 1999). Stormwater, which is extraneous water, causes hydraulic overloads in wastewater treatment plants and leads to the cooling down of wastewater in winter (Kaczor et al. 2017, Michalska & Pecher 2000). To increase the reliability of WWTPs and thus reduce the risk of excessive amounts of pollutants being discharged into the environment, measures should be taken to eliminate the illegal discharge of meltwater and industrial wastewater into sewerage systems and to raise the ecological awareness of sewage system users (Kallas et al. 2015, Ren et al. 2018).

The aim of the present study was to assess the reliability of a wastewater treatment process with the use of a modified Weibull method. The experiments were conducted in a collective wastewater treatment plant in Nowy Targ, Poland. The obtained pollution removal reliabilities were compared to maximum permissible limit values specified in the water quality permit for this facility. Moreover, relative exceedance frequency values were determined for the individual parameters. The following parameters were analyzed: biochemical oxygen demand (BOD_5), chemical oxygen demand (COD_{cr}), total suspension (TS), chromium ions (Cr), total nitrogen (TN) and total phosphorus (TP).

2. Material and methods

2.1. Study site

The sewerage system in Nowy Targ has a length of 86.9 km, The system is divided into two water catchment areas: the Szaflary Axis and the Ludźmierz Axis. The sanitary network is built of stoneware (about 40%), concrete (about 10%) and reinforced concrete WIPRO pipes (about 10%) with diameters from DN 200 to 400 mm. At present the sewerage system is being modernized/recently the system has been modernized using new technologies, mainly PVC pipes as well as new generation stoneware and composite pipes made of fiberglass-reinforced plastic. Wastewater from the sanitary sewage network is drained to the WWTP mainly by gravity, but four sewage pumping stations are also used to support the gravity-driven flow. Currently, the sewerage system is used by 47 537 residents. Additionally, 60 legally operating fur companies are connected to the sewerage system. They discharge industrial wastewater. The household and industrial sewage flows into the collective mechanical and biological wastewater treatment plant with a designed flow capacity of $Q_{m.d..} = 21\ 000\ m^3 \cdot d^{-1}$ and a PE (population equivalent) = 116 000. The sanitary sewage system also receives illegal discharge of storm water, which, according to the data provided by the employees of the WWTP in Nowy Targ, represents 12% of the total amount of influent wastewater.

2.2. Characteristics of the wastewater treatment plant

The wastewater treatment plant in Nowy Targ was established in 1995 and is located at 49°29'N, 20°3'E. Sewage from the municipal sewerage network is conveyed via a collector with a diameter DN = 1.2 m to a pumping station. The main pumping station operates two pumps with a capacity of 1400 $m^3 \cdot h^{-1}$. The pumps lift sewage to a height of 7.5 m for easy gravity flow through the entire process line. The sewage flows from the pumping station to a screen room, where screenings are caught on two step-screens with a slot width of 3 mm and a rated power of 1.5 kW. Then, the wastewater flows into two sand traps, where mineral substances such as sand or gravel are sedimented. The sand separated by sedimentation is discharged into a sand scrubber separator, and after cleaning and dewatering, is fed into a container. The wastewater leaving the sand traps is conveyed by an 800 mm DN pipeline to two primary settling tanks. The horizontal-flow settling tanks are 42.0 m long, 6.0 m wide and 3.6 m high. Primary sludge is collected in sludge hoppers and cyclically removed to a gravity thickener. Biological treatment is performed using the sequencing batch reactor method. In the biological treatment section, three bioreactors are installed, which work in 8-hour cycles. Each of them is 70 m long, 23 m wide and 4.5 m deep. Treated wastewater, after decanting, is discharged through a 1000 mm DN collector pipe to the receiver, the Dunajec river.

The permissible limits (concentrations or minimum reduction rates) of pollutants for water leaving the wastewater treatment plant, as specified in the water quality permit for the Nowy Targ facility, are given below:

Maximum permissible limit in concentration units:

- BOD_5 – 15 $mg \cdot dm^{-3}$
- COD – 125 $mg \cdot dm^{-3}$
- Total suspension – 35 $mg \cdot dm^{-3}$
- Chromium – 0.5 $mg \cdot dm^{-3}$

Minimum reduction rate in percent:

- Total nitrogen – 70%
- Total phosphorus – 80%

2.3. Analytical and statistical methods

The study was conducted over two years (2016-2017). During this period, 87 samples of raw and treated wastewater each were collected and analyzed. Samples of influent wastewater were collected from the inlet channel using an autosampler programmed with respect to the wastewater flow rate. Effluent samples were taken from the outfall to the Dunajec river, which receives wastewater from the investigated treatment plant. Samples of wastewater were subjected to physical-chemical analysis in accordance with the reference methods set out in the applicable legal acts (Dz.U./2014/1800).

- BOD_5 – oxygen content was measured after 5 days of incubation at 20°C in OXI TOP – 197 WTW
- COD_{cr} – the dichromate test according to PN-ISO 6060:2006
- Total suspension – samples were filtered through GF/A glass fiber filters, dried for 1 hour at 105°C and weighed on a Santorius BA 210S analytical balance according to PN-EN 872:2007
- Chromium – Hach DR 2800 spectrophotometer using LCK 313 cuvette tests
- Total nitrogen (Kjeldahl) – according to PN-EN 25663:200
- Total phosphorus – Hach DR 2800 spectrophotometer using LCK 349 and LCK 350 cuvette tests.

The technological reliability of the WWTP in Nowy Targ was determined using the Weibull method. As Bugajski demonstrated in his previous studies (Bugajski et al. 2012, Bugajski 2014b), the Weibull distribution is a general probability distribution that can be successfully used to determine the technological reliability of WWTPs. The Weibull distribution can be used when the failure rate (in the case of a wastewater treatment plant, the exceedance rate) follows a monotonic trend. The Weibull distribution is characterized by the probability density function (1) with parameters b, c and θ (Bugajski et al. 2012):

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

where:
x – variable defining the concentration of a pollutant in treated wastewater,
b – scale parameter,
c – shape parameter,
θ – location parameter,
under the assumption that θ <x, b> 0, c> 0.

The reliability function R(x), as a complement to unity of the distribution function F(x), is given by the formula (Bugajski 2012):

$$R(x) = 1 - f(x) \tag{2}$$

where:

$$F(x) = 1 - exp\left[-\left(\frac{x-\theta}{b}\right)^{c}\right] \tag{3}$$

The Weibull distribution parameters were estimated using the maximum likelihood method. Goodness of fit of the Weibull distribution to empirical data was assessed with the Hollander-Proschan test. The results obtained in this part of the study were analyzed using STATISTICA 8 software.

In the analytical part of the study regarding the frequency of occurrence of characteristic values/concentrations of the analyzed parameters, the magnitudes and widths of class intervals were determined according to the guidelines provided by Jóźwiak & Podgórski (2001).

$$\mathbf{k = 5logn} \tag{4}$$

where:
k – number of class intervals ($5 < k < 20$),
n – sample size

The class intervals for the particular pollution parameters were selected so that the frequency distribution would provide a detailed and clear picture of the structure of the statistical set. The maximum permissible limits of the pollutant parameters were used as class boundaries.

3. Results and discussion

3.1. The quality of raw sewage

In the initial part of the analysis, the values of the investigated pollution parameters were determined in influent wastewater. The mean and median BOD_5, total nitrogen and total phosphorus values for the influent were similar to the typical values of these parameters in domestic wastewater, as given in the literature (Kaczor 2009, Gajewska 2015, Henze et al. 2010, Koutsou et al. 2018). In the case of COD and total suspension, the mean and median values exceeded the values typically reported for domestic wastewater (Kaczor 2009, Gajewska 2015, Henze et al. 2010, Koutsou et al. 2018, Abbassi et al. 2018, Stańko et al. 2016). As shown by previous studies on the characteristics of wastewater in the Nowy Targ WWTP, the increased values of some of the pollution parameters in raw sewage were due to the substantial share of industrial wastewater coming from fur companies

(Nowobilska-Majewska 2017, Bugajski et al. 2017). BOD_5, COD and TN values in the influent showed moderate variability according to the scale given by Wawrzynek (2007), with the coefficient of variation Cv ranging from 0.3 to 0.35. In the case of Total suspension, TP and chromium ions, a large variation (according to the Wawrzynek scale (2007)) was found, with Cv for these parameters ranging from 0.43 to 0.51. The statistics for the investigated pollution parameters of influent wastewater are given in Table 1.

Table 1. Descriptive statistics for the investigated pollution parameters of raw sewage

Parameter	Unit	Statistics					
		Average	Median	Min.	Max.	Standard deviation	Coefficient of variation
BOD_5	$mg \cdot dm^{-3}$	498.5	485.1	206.5	935.0	148.4	0.30
COD		1615.9	1559.0	552.0	3074.0	559.7	0.35
TS		1079.5	980.0	2650.0	2210.0	478.4	0.44
Cr		7.75	6.84	2.04	20.90	3.92	0.51
TN		106.6	104.2	44.2	209.3	31.5	0.30
TP		18.2	17.2	5.4	51.8	7.9	0.43

3.2. Technological reliability of the WWTP

The technological reliability of the wastewater treatment plant with regard to pollutant removal was determined using the Weibull distribution. A hypothesis was tested for the estimated distribution parameters that the Weibull distribution could be used to approximate the empirical data. An analysis of the p-value of the investigated parameters showed that the null hypothesis was true. The results of the Hollander-Proschan goodness-of-fit test along with scale, shape and location parameters are shown in Table 2.

The minimum (permissible) reliability limit adopted in this study was 93.72% (at the manufacturer's risk of $\alpha = 0.05$), a value established by Andraka and Dzienis (2003) for WWTPs of above 50.000 PE. According to those authors (2003), the permissible failure rate (exceedance rate) of a facility of this size is 22 days per year at a risk level $\alpha = 0.05$.

The technological reliability of BOD_5 reduction to the limit value of 15 $mg \cdot dm^{-3}$ was 72.5%, as shown in Fig. 1A. In other words, the probability of exceedance for BOD_5 in treated wastewater was 27.5%. A comparison to permissible reliability values shows that the BOD_5 removal reliability during the investigated period was 21.22% lower than required. A BOD_5 removal reliability of 72.5% means that the maximum permissible limit of this parameter in treated wastewater may be exceeded on nearly 100 days a year (365 days). The difference between the number of exceedances for BOD_5 and the allowable number of days on which the facility fails to operate properly, at $\alpha = 0.05$, was 78 days a year.

Table 2. Results of the estimation of the Weibull distribution parameters together with the measures of goodness of fit to empirical data

Parameter	Unit	distribution parameters			Hollander-Proschan test	
		b	c	θ	Test value	p
BOD_5	$mg \cdot dm^{-3}$	12.641	1.5330	3.3384	0.647505	0.51730
COD		97.315	2.9992	39.9490	0.569031	0.56934
TS		34.269	1.4892	3.5909	0.675626	0.49928
Cr		0.44481	2.3524	0.0000	0.372182	0.70976
TN	%	90.657	14.095	−5.0000	−1.34174	0.17968
TP		94.224	25.668	−10.0000	−0.624557	0.53226

COD removal reliability to the limit value of 125 $mg \cdot dm^{-3}$ was 88%, as shown in Figure 1B. The difference between the minimum required reliability (93.72%) and the measured reliability (88%) was 5.72%. This means that the treatment plant did not meet the requirements for effluent COD concentrations on about 44 days a year. When one subtracts from this number the number of allowable exceedances per year (22 days), it turns out that the maximum permissible COD concentration in treated wastewater was in excess of the standard on 22 days a year.

In the case of total suspension, the technological reliability of the plant relative to the permissible concentration of 35 $mg \cdot dm^{-3}$ was 65% (Fig. 2C). The number of exceedances per year was 128 days. Given that the allowable number of exceedances is 22 days, the plant exceeded the standards for total suspension on 106 days a year.

In the case of chromium (Cr), the removal reliability was 72.5% (Fig. 1D). This is the same level of reliability as in the case of BOD_5. The maximum permissible concentration of Cr in wastewater, which is 0.5 $mg \cdot dm^{-3}$, was exceeded on about 100 days a year. When one subtracts from this number the number of allowable exceedance days (22 days), it transpires that Cr concentration norms were exceeded at the study site on 72 days a year.

The coefficients of determination R^2 for the parameters whose reliabilities are described by the cumulative distribution functions in Figs. 1A, 1B, 1C and 1D are as follows: BOD_5 – 0.9884, COD – 0.9919, TS – 0.9421, Cr – 0.9327. These results show that the Weibull model of reliability described by the cumulative functions in Figs. 1A, 1B, 1C and 1D shows a very high goodness-of-fit.

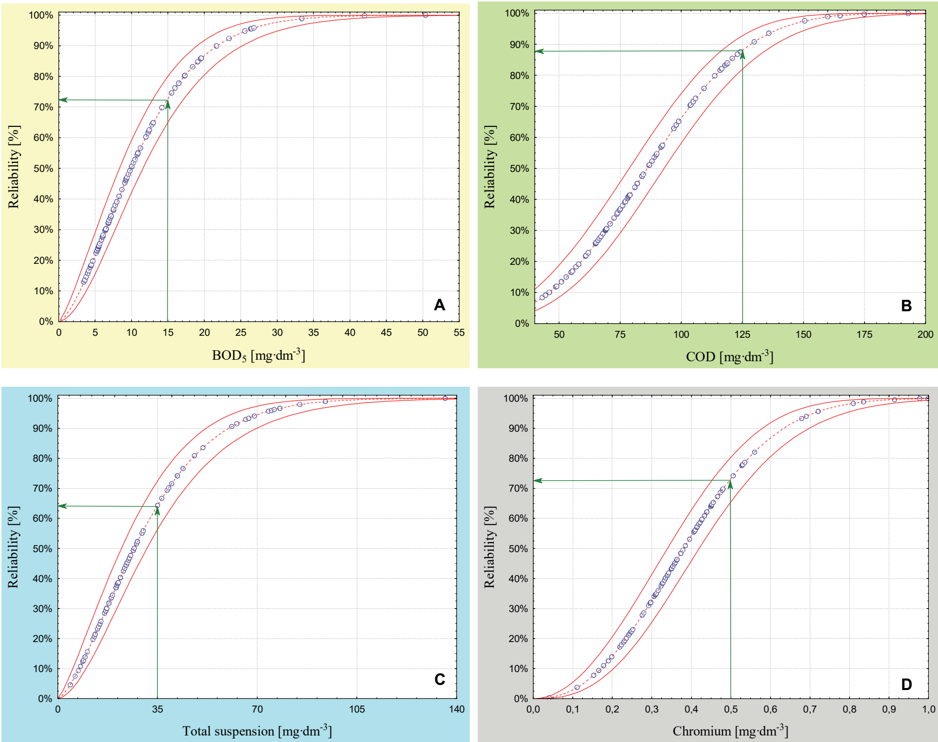

Fig. 1. Weibull cumulative distribution functions and the technological reliabilities determined for the pollution parameters expressed as a concentration

In the case of biogenic elements (TP and TN), for which permissible limits were defined as minimum reduction rates, the following reliabilities were obtained based on Weibull reliability analysis: 97.5% for total nitrogen removal to the minimum effluent discharge limit of 70% (Fig. 2A), and 98% for total phosphorus removal to the required minimum level of 80% (Fig. 2B). In both cases, the reliability values were higher than the minimum required removal reliability of 93.72%. It should be pointed out, however, that the reliability data also show that total nitrogen and total phosphorus reduction rates were lower than the required minimum on 9 and nearly 7 days a year, respectively.

The coefficients of determination R^2 for the biogenic elements were: TN – 0.8521 and TP – 0.7986, which shows that the Weibull model of TN and TP removal reliabilities described by the cumulative distribution functions in Figs. 2A and 2B had a high goodness-of-fit, which was, however, lower than in the case of the four previously analyzed parameters.

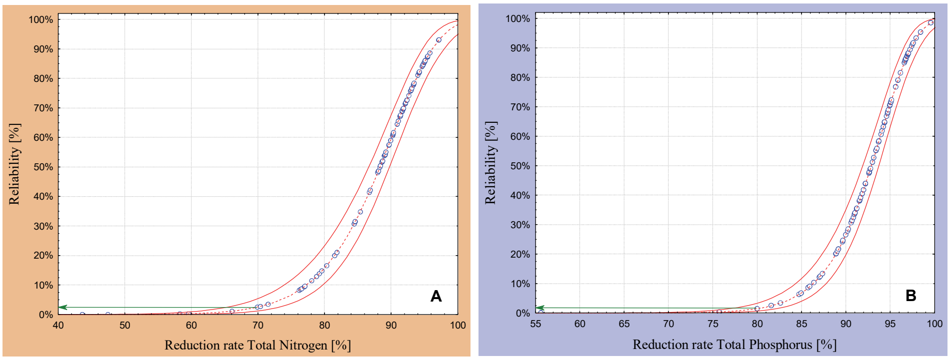

Fig. 2. Weibull cumulative distribution functions and the technological reliabilities determined for the pollution parameters whose limit values are expressed in percent

The analysis of the technological reliability of the WWTP in Nowy Targ performed using the Weibull model confirms literature reports that the Weibull method aptly describes the reliability of various technologies used in wastewater treatment plants (Bugajski et al. 2012, Nastawny & Jucherski 2013, Bugajski 2016, Jóźwiakowski et al. 2018, Marzec 2017, Marzec et al. 2018). The removal reliabilities for Total suspension, BOD_5 and COD of 65%, 72.5% and 88%, respectively, are lower than those described by Marzec et al. (2018) and Nastawy & Jucherski (2013). In the case of biogenic parameters, the reliability of the investigated facility is comparable to that reported by Bugajski (2014) and Jóźwiakowski et al. (2018).

3.3. Relative exceedance frequency

According to the literature, valuable information for purposes of maintenance and potential modernization of wastewater treatment systems can be obtained by determining exceedance frequency values for pollution parameters of effluent wastewater (Henze et al. 2010, Kaczor 2001). Frequency analysis is a very useful statistical tool for the interpretation of results of regularly and irregularly performed measurements.

In this part of the study, the frequency of occurrence of specific concentrations/reduction rates and exceedance frequencies of the analyzed pollution parameters were determined in treated wastewater. This allowed us to determine the relative exceedance frequencies (%) for the investigated pollution parameters. Also, based on this analysis, we were able to identify the modal class intervals (ones with the highest frequency of observations) for the individual effluent parameters. After calculating the frequency of occurrence of the values of the particular pollution parameters, the number of frequency distribution classes was determined for each parameter. Five interval classes were adopted for BOD_5, with a class width of 5 mg·dm^{-3} (Fig. 3A). Also five classes were delimited for COD, but class width was 25 mg·dm^{-3} (Fig. 3B). In the case of COD, the lowest interval class was 0 to 75 mg·dm^{-3}, as COD concentrations lower than 50 mg·dm^{-3} were not recorded in this study. The same number of classes (five) was established for Total suspension, and the class width was calculated at 17.5 mg·dm^{-3} (Fig. 3C). For chromium ions, four classes with a width of 0.25 mg·dm^{-3} (Fig. 3D) were considered. In the case of biogenic parameters, measured as a reduction rate, six classes with a width of 10% were established for total nitrogen (Fig. 4A) and five classes with a width of 10% were adopted for total phosphorus (Fig. 4B). For all the investigated parameters, class limits were defined so that the permissible limit or the minimum reduction rate should constitute a closed limit of the class interval. This allowed us to determine the relative frequency as percentage of the number of exceedances of a given parameter in relation to its permissible limit.

For BOD_5, the percentage of observations (samples) in the classes from 15 to 20 mg·dm^{-3} and above 20 mg·dm^{-3} was 12.6% and 10.3%, respectively (Fig. 3A). In total, 23.0% of all wastewater samples fell in these two intervals. The analysis of the relative exceedance frequency for BOD_5 showed that the largest number of observations for this parameter were in the interval from 5 to 10 mg·dm^{-3}. For COD, the frequency of occurrence in the two class intervals above the limit of 125 mg·dm^{-3} totaled 8.0% of all wastewater samples (Fig. 3B). No modal interval was observed for effluent COD, which indicated that COD removal processes in the investigated treatment plant were unstable. The frequency of occurrence of Total suspension concentrations from 35 to above 70 mg·dm^{-3} (Fig. 3C) in sewage samples was 25.3%. The modal class interval for Total suspension was the interval from 17.5 to 35.0 mg·dm^{-3}, which contained 48.3% of all observations. Concentrations of chromium ions in treated wastewater in excess of the permissible limit were observed in 16.1% of cases, i.e. all observations in the intervals from 0.5 to 1.0 mg·dm^{-3} (Fig. 3D). The modal class interval for Cr was 0.25 to 0.50 mg·dm^{-3}, which contained 64.4% of all effluent chromium ion concentrations.

An analysis of the frequency of occurrence of biogenic parameters, whose levels are expressed as a reduction rate, showed that TN and TP reduction rates below the adopted minimum limits (70% and 80%, respectively) constituted 6.9% and 2.2% of all events, respectively (Figs 4A and 4B). In the case of TN, the largest number of events (52% of all observations) was recorded in the interval above 90%. Similar results were obtained for TP, for which 78.2% of all observations fell in the interval above 90%. These findings show that the reduction rates of total nitrogen and total phosphorus were high. Nevertheless, cases of a low reduction rate should be identified and measures should be taken to increase the rate of removal of biogenic waste.

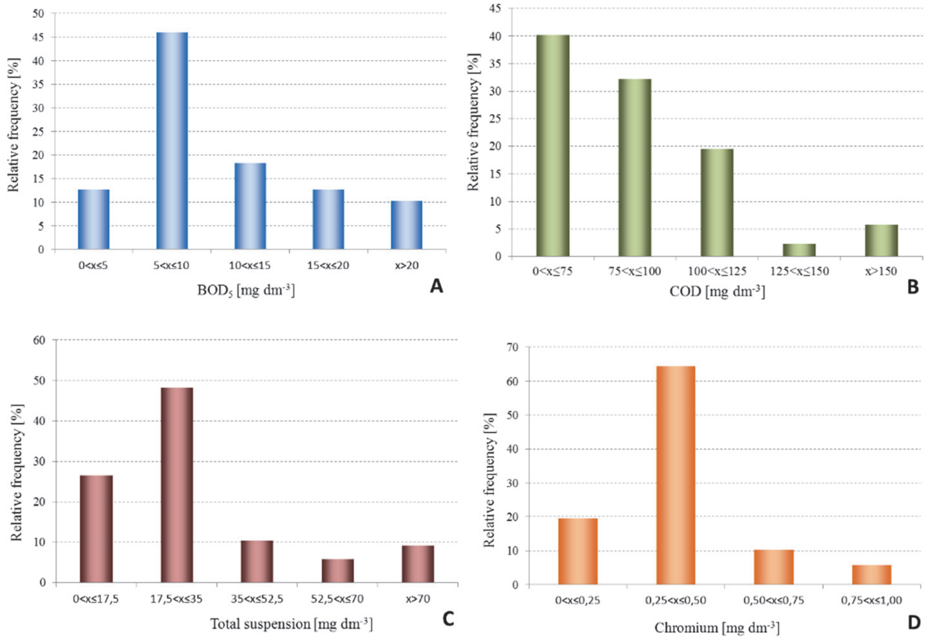

Fig. 3. Histograms of relative frequency for the pollution parameters measured in concentration units (mg·dm^{-3}) – BOD_5, COD, TS, Cr

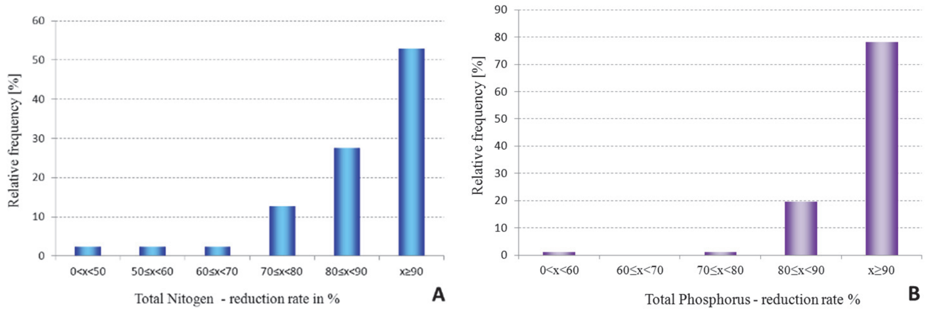

Fig. 4. Histograms of relative frequency of TN and TP reduction rates (%)

As a last step of the analysis of the results obtained in this study, we determined the number of exceedances for the analyzed parameters in relation to the permissible number of exceedances laid down in the applicable legal provisions. In accordance with the Regulation of 18 November 2014 (Dz.U./ 2014/1800) Annex 7, current Polish legislation specifies the number of sewage samples collected during the year which are allowed not meet the specific water quality permit requirements. This can be defined as the "tolerance limit". Given that we collected 43 wastewater samples in 2016 and another 44 samples in 2017, according to the provisions of Annex 7 (line 6) to the abovementioned Regulation, the allowable number of exceedances which did not adversely affect the operation of the treatment plant was five. The exceedance frequency data show that in each research year the permissible limits were exceeded on 84 days for BOD_5, 29 days for COD, 92 days for Total suspension, 59 days for Cr, 25 days for TN and 8 days for TP. This means that the tolerance limit of five exceedance events was exceeded for all the analyzed parameters.

4. Conclusions

The Weibull analysis of the technological reliability of the wastewater treatment plant in Nowy Targ demonstrated that the facility was the most reliable with regard to the removal of the biogenic components: total nitrogen and total phosphorus. The plant was 97.5% reliable in achieving the minimum TN reduction rate of 70% and 98.0% reliable in achieving the minimum TP reduction rate of 80%. The reliabilities obtained for the parameters measured as concentrations were as follows: 72.5% for BOD_5, 88% for COD, 65% for Total suspension and 72.5% for chromium ions. The relative exceedance frequency values for these parameters were 23%, 8%, 25.3% and 16.1% of all analyzed wastewater samples, respectively. For the biogenic parameters, whose permissible limit values are expressed as minimum reduction rates, values lower than the required minimum were found in 2.5% of all observations for total nitrogen and in 2% of all observations for total phosphorus. The number of exceedances per year for all the investigated parameters was larger than the "tolerance limit" of five days laid down in the legal provisions in force in Poland. When analyzing the causes of the malfunction of the investigated WWTP in Nowy Targ, which is part of a combined sewerage system, it is first necessary to determine which of those causes are the result of improper operation of the plant and which are independent of the operator. Then appropriate corrective actions should be taken.

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Abstract

In the study, the Weibull method was used to determine the technological reliability of a collective wastewater treatment plant in Nowy Targ in Poland in regard of its ability to meet effluent discharge standards for selected pollution parameters. In addition, relative exceedance frequencies were calculated for this facility. The experiments were conducted in 2016 and 2017. During this period, 87 samples of influent and effluent wastewater were collected and analyzed. The parameters investigated in the study included BOD_5, COD, Total suspension and chromium Cr, for which the maximum permissible limits specified in the water quality permit are expressed as concentrations, and TN and TP, for which limit values are defined as minimum reduction rates (%). The technological reliability values for the parameters measured in concentration units were 72.5% for BOD_5, 88% for COD, 65% for Total suspension, and 72.5% for Cr. The relative exceedance frequency was 23% of all measurement series for BOD_5, 8% for COD, 25.3% for Total suspension, 16.1% for Cr, 2.5% for TN, and 2.0% for TP. It was found that the number of exceedances per year for all the investigated parameters was larger than the "tolerance limit" of five days laid down in the legal provisions in force in Poland relating to the quality of wastewater discharged to a reservoir. The results show that measures should be taken to identify the causes of the observed deficiencies in the reduction of the analyzed pollution parameters in the technological line of the treatment plant and that corrective action should be pursued.

Keywords:
wastewater, wastewater treatment plant, technological reliability,
frequency of occurrence

Analiza niezawodności funkcjonowania oczyszczalni ścieków w Nowym Targu (Polska) z zastosowaniem metody Weibulla

Streszczenie

Celem pracy jest wykorzystanie metody Weibulla w celu określenia niezawodności technologicznej odnośnie uzyskania wartości normatywnych w ściekach oczyszczonych dla wybranych wskaźników zanieczyszczeń w zbiorczej oczyszczalni ścieków w Nowym Targu. Ponadto w pracy określono częstość względną występowania ponadnormatywnych wartości analizowanych wskaźników. Badania prowadzono w latach

2016 i 2017, gdzie w tym okresie pobrano i poddano analizie po 87 próbek ścieków dopływających i odpływających. W pracy uwzględniono wskaźniki, dla których wymagania w pozwoleniu wodno-prawnym podano jednostce wagowej i są to: BZT_5, ChZT, zawiesina ogólna i chrom Cr oraz wskaźniki, dla których wymagania określono, jako minimalny stopnień redukcji (%) i są to: azot ogólny oraz fosfor ogólny. Niezawodność technologiczna dla wskaźników, których miarą jest jednostka wagowa wynosi dla BZT_5 – 72.5%, dla ChZT – 88% dla zawiesiny ogólnej – 65% i dla chromu Cr – 72.5%. Częstość względna występowania ponadnormatywnych wartości lub stopnia redukcji dla analizowanych wskaźników wynosi dla BZT_5 – 23%, dla ChZT – 8%, dla zawiesiny ogólnej – 25.3%, dla jonów chromu Cr – 16.1%, dla azotu ogólnego – 2.5% i dla fosforu ogólnego – 2.0% przypadków w stosunku do wszystkich serii pomiarowych. Stwierdzono, że liczba dni w roku, w których występują wartości ponadnormatywne dla badanych parametrów przekracza liczbę 5 dni, czyli „granicę tolerancji" wskazaną w obowiązującym w Polsce akcie prawnym dotyczącym jakości ścieków odprowadzanych do odbiornika. Na terenie analizowanego systemu kanalizacyjnego zaleca się podjąć działania w celu identyfikacji przyczyn występujących nieprawidłowości unieszkodliwiania analizowanych wskaźników w ciągu technologicznym oczyszczalni i podjąć działania naprawcze.

Słowa kluczowe:
ścieki, oczyszczalnia ścieków, niezawodność technologiczna, częstość występowania