DOI: 10.1515/jwld-2017-0078

JOURNAL OF WATER AND LAND DEVELOPMENT
2017, No. 35 (X–XII): 141–148
PL ISSN 1429–7426

Available (PDF): http://www.itp.edu.pl/wydawnictwo/journal; http://www.degruyter.com/view/j/jwld

Received 31.10.2017
Reviewed 08.11.2017
Accepted 15.11.2017

A – study design
B – data collection
C – statistical analysis
D – data interpretation
E – manuscript preparation
F – literature search

Reliability of removal of selected pollutants in different technological solutions of household wastewater treatment plants

Michał MARZEC ABCDEF ✉

University of Life Sciences in Lublin, Faculty of Production Engineering, Department of Environmental Engineering and Geodesy, ul. Leszczyńskiego 7, 20-069 Lublin, Poland; e-mail: michal.marzec@up.lublin.pl

For citation: Marzec M. 2017. Reliability of removal of selected pollutants in different technological solutions of household wastewater treatment plants. Journal of Water and Land Development. No. 35 p. 141–148. DOI: 10.1515/jwld-2017-0078.

Abstract

The reliability of removal of selected contaminants in three technological solutions of the household sewage treatment plants was analysed in this paper. The reliability of the sewage treatment plant with activated sludge, sprinkled biological deposit and hybrid reactor (activated sludge and immersed trickling filter) was analyzed. The analysis was performed using the Weibull method for basic indicators of impurities, BOD_5, COD and total suspended solids. The technological reliability of the active sludge treatment plant was 70% for BOD_5, 87% for COD and 66% for total suspended solids. In the sewage treatment plant with a biological deposit, the reliability values determined were: 30% (BOD_5), 60% (COD) and 67% (total suspended solids). In a treatment plant with a hybrid reactor, 30% of the BOD_5 and COD limit values were exceeded, while 30% of the total suspended solids were exceeded. The reliability levels are significantly lower than the acceptable levels proposed in the literature, which means that the wastewater discharged from the analysed wastewater treatment plants often exceeds the limit values of indicators specified in currently valid in Poland Regulation of the Minister of Environment for object to 2000 population equivalent.

Key words: *BOD_5, COD, household wastewater treatment plants, technological reliability, total suspended solids*

INTRODUCTION

Household wastewater treatment plants have in recent years become a common element of sanitary infrastructure in rural areas, especially in their part, where the development of a traditional sewage system is not justified for economic or technical reasons [BŁAŻEJEWSKI 2005; OBARSKA-PEMPKOWIAK *et al.* 2015; PAWEŁEK, BUGAJSKI 2017; PIASECKI, JURASZ 2015; ŚWIERK 2016]. They are a good alternative to the hitherto used septic tanks, the exploitation of which is connected with many problems, mainly of an economic and ecological nature [KAROLINCZAK *et al.* 2015]. As a result, the number of septic tanks has been steadily decreasing, with a simultaneous increase in the number of household wastewater treatment plants. According to the Central Statistical Office (Pol. Główny Urząd Statystyczny – GUS) data [2016] the number of non-return tanks in 2015 amounted to 2 136 thousand, which means a decrease by 2.6% compared to 2014. In the same period, the number of household wastewater treatment plants increased by 11.9%, to ca. 203,000 [GUS 2016]. Among the many solutions offered on the market of household wastewater treatment plants we can mention systems with infiltration drainage, sand filters, constructed wetland treatment plants and technological systems using conventional methods of sewage treatment – biological deposits, activated sludge and treatment plants with hybrid reactor [BŁAŻEJEWSKI 2005; HEIDRICH *et al.* 2008; 2013; IGNATOWICZ, PUCHLIK 2015; SKRZYPIEC *et al.* 2017].

Usually, the amount of wastewater flowing out of household sewage treatment plants is small, however, objects of this type do not always ensure high efficiency of operation, so that the sewage flowing from them is often characterized by poor quality, especially in terms of nutrient content [BUGAJSKI 2014b; HEIDRICH 1998; JÓŹWIAKOWSKI, MARZEC 2011; MARZEC, JÓŹWIAKOWSKI 2006; 2007]. The reason for this is, first of all, the failure to respect the legal requirements concerning the quality of wastewater discharged from household treatment plants and the lack of instruments allowing for real control over their functioning, especially outside the agglomeration [BUGAJSKI 2014b; JAWECKI *et al*. 2017]. Taking into account the number of existing residential facilities and the prospect of strong growth in the coming years, we should strive to introduce such regulations that would force domestic wastewater treatment plants to achieve high effects of removing pollution, and thus prefer technological solutions that meet the highest standards of treatment. Analyses taking into account different criteria for assessing the operation of domestic wastewater treatment plants, including reliability criteria [ANDRAKA, DZIENIS 2013; BUGAJSKI 2014b; BUGAJSKI *et al*. 2012; JÓŹWIAKOWSKI *et al*. 2015; JUCHERSKI *et al*. 2017; OLIVEIRA, VON SPERLING 2007; 2008].

The aim of the study is to assess the reliability of organic pollutants removal expressed in BOD_5, COD and total suspended solids in various technological solutions of household wastewater treatment plants.

MATERIALS AND METHODS

The study covered 3 household wastewater treatment plants, differentiated due to the applied technology of pollutants removing from wastewater: 1) a treatment plant with activated sludge, 2) a treatment plant with biological deposit, 3) a treatment plant with hybrid reactor (activated sludge and biological deposit).

Object No. 1. The household wastewater treatment plant with activated sludge type BIOPAN operates in Branica Radzyńska and has a flow capacity of 0.9 $m^3 \cdot d^{-1}$. The population equivalent for this object is 6. It is made of PEHD polyethylene panels. It consists of a 1.34 m diameter cylinder with a depth of 1.55 m and a sealed bottom, divided into four chambers with vertical and inclined walls and covered with a tightly sealed cover (Fig. 1). The domestic wastewater flowing out of the residential building is fed directly into the I chamber of the wastewater treatment plant (no classical septic tank) where the thicker contaminants (grills) are separated. They then flow into the second anaerobic chamber, where under oxidized conditions a denitrification process takes place, and then they flow into the III chamber with activated sludge, in which the nitrification process takes place due to intensive mixing and aeration. After a certain time of contact, the mixture of old and newly formed microbial cells flows with the wastewater to the IV chamber – a secondary settling tank, where the sediment is separated from the treated sewage. Purified wastewater is discharged to the ground by drainage system [PASTUSZAK 2004].

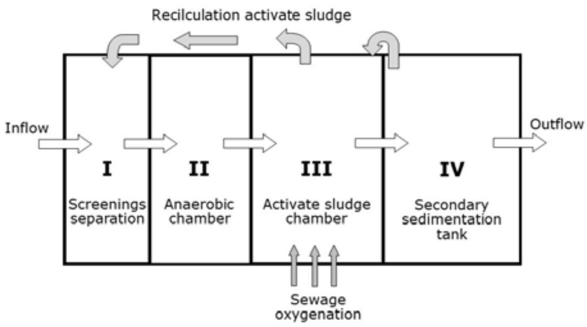

Fig. 1. Technological scheme of household wastewater treatment plant with activated sludge; own elaboration based on PASTUSZAK [2004]

Object No. 2. The household wastewater treatment plant with biological deposit is located in Brzeziny, in the municipality of Siedliszcze near Chełm. The task of the treatment plant is to neutralize domestic wastewater from a multi-family residential building. The hydraulic load of the treatment plant is about 4.5 $m^3 \cdot d^{-1}$. The population equivalent calculated on the basis of the average of BOD_5 load in raw wastewater is 50. The facility consists of a primary settling tank and biological deposit integrated with the secondary settling tank. The system uses a natural process of biological oxidation of contaminants on the sprinkled bed for wastewater treatment. After mechanical treatment in the precipitator, gravitational wastewater flows to the pumping zone in the bottom well under the biological deposit, from where they are lifted and flattened on the surface of the deposit by the sprinkler system. The deposit is filled with plastic fittings with high hydraulic permeability and a highly developed active surface. During periods of low flow, some treated wastewater can be recirculated, thus improving the efficiency of the deposit [MARZEC, JÓŹWIAKOWSKI 2006]. The treated wastewater is discharged to the drainage ditch.

Object No. 3. Wastewater treatment plant with hybrid reactor is located in Dys (lubelskie province). It is used for treatment of domestic wastewater from two houses inhabited by five people. The maximum throughput capacity of the treatment plant amounts to 1.0 $m^3 \cdot d^{-1}$. The population equivalent for this object is 6 [JÓŹWIAKOWSKI *et al*. 2012; MARZEC 2016].

The tank of the wastewater treatment plant is made of concrete. It consists of four chambers with the total active capacity of 5.57 m^3 [JÓŹWIAKOWSKI *et al*. 2012]. The first two chambers are primary settling tanks (V_{cz} = 3.36 m^3), the third chamber (V_{cz} = 1.57 m^3) is the hybrid reactor operating based on activated sludge and immersed trickling filter system, and the fourth chamber (V_{cz} = 0.64 m^3) contains a secondary settling tank (Fig. 2). In the primary settling tank solids are separated and the accumulated sludge is initially fermented. From the second chamber of the primary settling tank wastewater flows into the hybrid reactor where it is cleaned by means of the biological activated sludge method (suspended biomass) and immersed trickling filter (settled biomass). Suspended

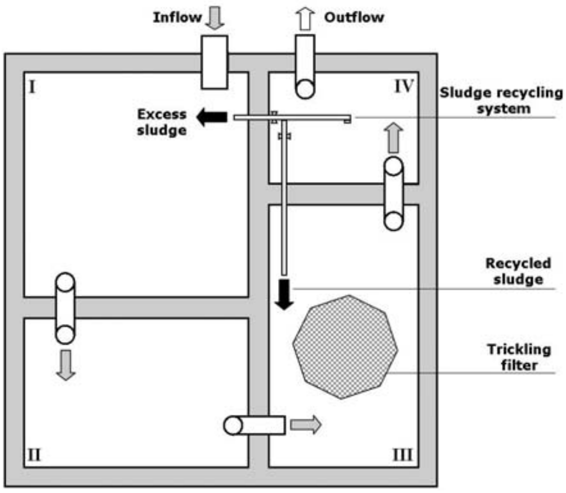

Fig. 2. Schematic of a household wastewater treatment plant with a hybrid reactor (horizontal section): I, II – chambers of the primary settling tank, III – hybrid reactor (activated sludge and trickling filter), IV – secondary settling tank; own elaboration based on JÓŹWIAKOWSKI *et al.* [2012]

and settled biomass is supplied with oxygen by means of a diaphragm blower and a disc diffuser. The last element of the plant is a secondary settling tank from which cleaned wastewater flows to the drainage system. Some sludge retained inside the secondary tank is from time to time recycled into the reactor by means of an airlift pump to ensure a fixed concentration of biomass. The rest is discharged into the first chamber of the primary settling tank [JÓŹWIAKOWSKI *et al.* 2012].

The assessment of the reliability of household wastewater treatment plants operation was based on the results of five-year studies. Wastewater samples for laboratory analyses were collected seasonally on the inflow to the treatment plants (raw raw) and on the outflow (treated wastewater). In total, 20 samples of raw and treated wastewater from each objects were analyzed. The size of BOD_5, COD and total suspended solids (TSS) content according to commonly used and recommended methods [HERMANOWICZ *et al.* 1999; Rozporządzenie MŚ… 2014].

The reliability of pollutants removal was evaluated using elements of the Weibull reliability theory [BUGAJSKI 2014a; BUGAJSKI *et al.* 2012]. Estimation of Weibull distribution parameters was done using the most reliable method. The quality of fit of the Weibull distribution to empirical data was assessed by Hollander–Proschan test for the significant level of 0.05. The reliability function $R(x)$ was calculated as a complement to the cumulative distribution function using the Equation 1 [BUGAJSKI *et al.* 2012; JUCHERSKI *et al.* 2017]:

$$R(x) = 1 - F(x) \qquad (1)$$

where: x = indicator of the concentration of pollutants in treated wastewater.

The analysis has been carried out using Statistica 13.1. Reliability was determined from cumulative distribution plots, taking into the limit values of indicators for wastewater treatment plants of <2000 p.e. [Rozporządzenie MŚ… 2014]. The results have been interpreted on the basis of the guidelines proposed by ANDRAKA and DZIENIS [2003].

RESULTS AND DISCUSION

Raw wastewater flowing into particular objects included in the assessment showed quite large differences in terms of physico-chemical properties. The lowest content of organic pollutants and total suspended solids was recorded in object No. 3 (treatment plant with hybrid reactor). During the whole research period the mean value of basic indicators was: for BOD_5 – 393 mg $O_2 \cdot dm^{-3}$, COD – 724 mg $O_2 \cdot dm^{-3}$, and for total suspended solids – 140 mg$\cdot dm^{-3}$. In object No. 1 (treatment plant with activated sludge) the values of parameters in raw wastewater were at a slightly higher level: BOD_5 – 521 mg $O_2 \cdot dm^{-3}$, COD – 780 mg $O_2 \cdot dm^{-3}$, total suspended solids – 427 mg$\cdot dm^{-3}$. In the described cases, the composition of treated wastewater did not differ significantly from the composition of typical domestic wastewater [HEIDRICH 1998; HEIDRICH *et al.* 2008]. Values significantly deviating from typical values were found in wastewater treated in a treatment plant with biological deposit (object No. 2). The average size of BOD_5 was 666 mg $O_2 \cdot dm^{-3}$, COD – 1017 mg $O_2 \cdot dm^{-3}$, and total suspended solids – 563 mg$\cdot dm^{-3}$. The household equipment with water and wastewater systems, inhabitants habits and their material situation have a decisive influence on the quality of raw wastewater flowing to particular facilities. Objects No. 1 and 3 serve individual households, while object No. 2 operates in a communal building, inhabited mainly by unemployed persons, which may significantly affect the level of water consumption and thus the concentration of pollutants in wastewater.

In order to assess the reliability of operation of selected types of WWTPs, the results of tests of treated wastewater discharged from these facilities into the environment were used. The basic statistical parameters characterising their quality are listed in Table 1. In all cases, the average values of indicators are close to the levels specified in the Regulation of the Minister of Environment [Rozporządzenie MŚ… 2014] as acceptable. In a treatment plant with a biological deposit, the average BOD_5 value at the outflow was more than twice the normative value (Tab. 1).

In addition, the data presented can be used to conclude that the results are very varied and vary widely between their sets. Basic statistical analysis may indicate the occurrence of disturbances in the operation of the investigated objects and their instability.

Further analysis included a verification of the hypothesis that empirical data could be described by the Weibull distribution. The results of the Hollander–Proschan test with the estimated parameters are presented in Table 2.

Table 1. Basic statistics for the indicator values in the treated wastewater

Parameter	Number of samples	Mean	Median	Minimum	Maximum	Standard deviation	Coefficient of variation
		mg·dm^{-3}					%
Object No. 1							
BOD_5	20	31.8	26.0	4.7	95.0	23.1	72.4
COD	20	108.2	107.0	29.0	200.0	37.6	34.7
TSS	20	51.5	26.0	2.0	227.0	64.6	125.4
Object No. 2							
BOD_5	20	86.2	56.3	33.0	398.0	88.6	102.7
COD	20	135.6	125.0	35.0	350.0	66.1	48.8
TSS	20	41.2	28.0	5.0	111.0	29.2	70.8
Object No. 3							
BOD_5	20	34.6	27.5	4.0	90.0	27.0	78.0
COD	20	128.5	103.0	28.0	350.0	88.9	69.2
TSS	20	37.8	26.2	2.0	103.0	33.8	89.3

Source: own study.

Table 2. Parameters of the Weibull distribution and the Hollander–Proschan goodness-of-fit test

Parameter	Parameters of Weibull distribution			Hollander–Proschan goodness-of-fit test	
	location	shape	scale	stat	*p*
Object No. 1					
BOD_5	1.2222	1.5557	35.7110	0.2797	0.7796
COD	–5.0000	3.1435	120.6442	0.0488	0.9610
TSS	1.1667	0.8266	46.1486	0.1913	0.8482
Object No. 2					
BOD_5	32.5760	1.2539	93.9970	0.4527	0.6703
COD	5.0000	2.1978	153.0813	0.1345	0.8929
TSS	1.2576	1.5195	45.9229	0.1774	0.8591
Object No. 3					
BOD_5	2.9343	1.3027	37.5350	0.0706	0.9436
COD	22.2220	1.5749	143.9030	0.1919	0.8477
TSS	0.0757	1.0621	38.7208	0.0319	0.9745

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.
Source: own study.

Reliability analysis was performed separately for each facility and wastewater quality indicator. The results of the analysis are shown in Figures 3–5.

In the wastewater treatment plant with activated sludge (object No. 1) it was found that the permissible BOD_5 size was exceeded in 30% of the samples (Fig. 3). On this basis, it can be estimated that in 110 days of the year, wastewater with an above-normative concentration of organic pollutants, expressed as BOD_5. In the case of COD, the reliability level found was 87%, which means that for 48 days per year the rate in treated wastewater exceeded the acceptable level. Reliability of the wastewater treatment plant with activated sludge for total suspended solids removal was 66%. The limit value was exceeded in 34% of the wastewater samples, which corresponds to 124 days a year. BUGAJSKI *et al.* [2012] in his study of the wastewater treatment plant with active sludge Biocompact BCT S-12 determined its process reliability

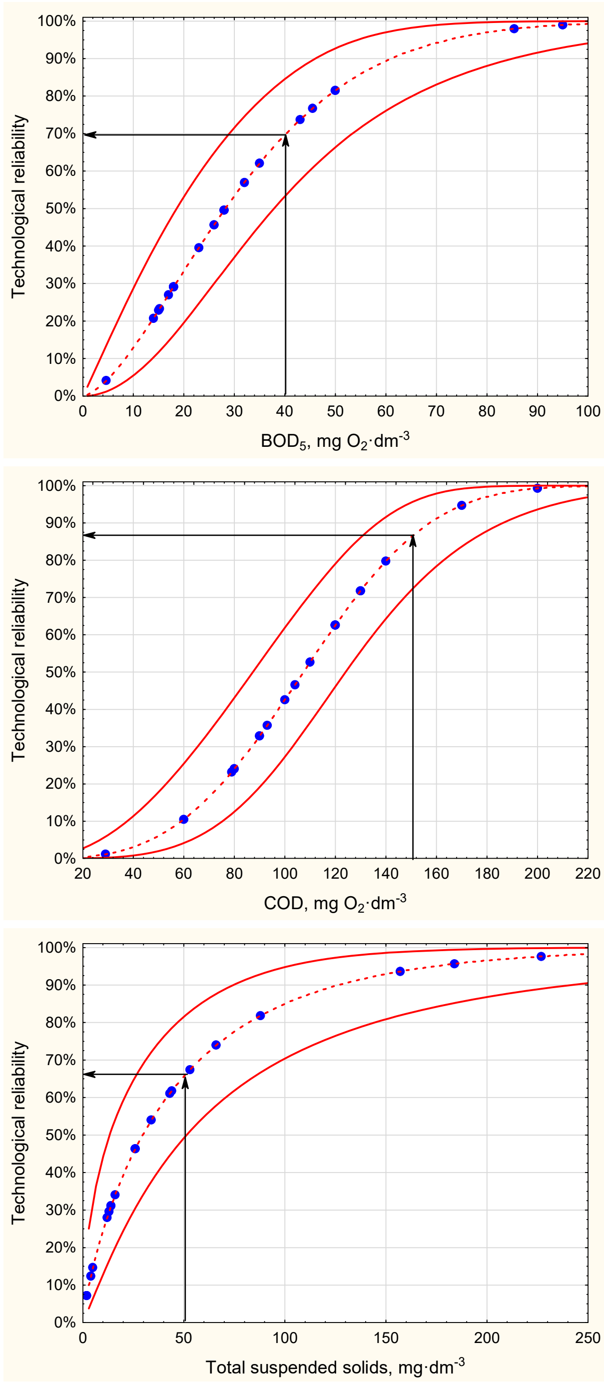

Fig. 3. Weibull cumulative distribution functions and the technological reliabilities determined for each pollution parameter in object No. 1; source: own study

at 68% for BOD_5, 88% for COD and 62% for total suspended solids.

The analysis shows that the treatment plant with activated sludge operates at a very low level of reliability and does not guarantee stable results and quality of treated wastewater in accordance with the applicable regulations. According to the guidelines proposed by ANDRAKA and DZIENIS [2003] the minimum level of reliability for wastewater treatment plants with an p.e. < 2000 should be 97.27%, with the operator's risk of the treatment plant at a level of $\alpha = 0.05$. Therefore,

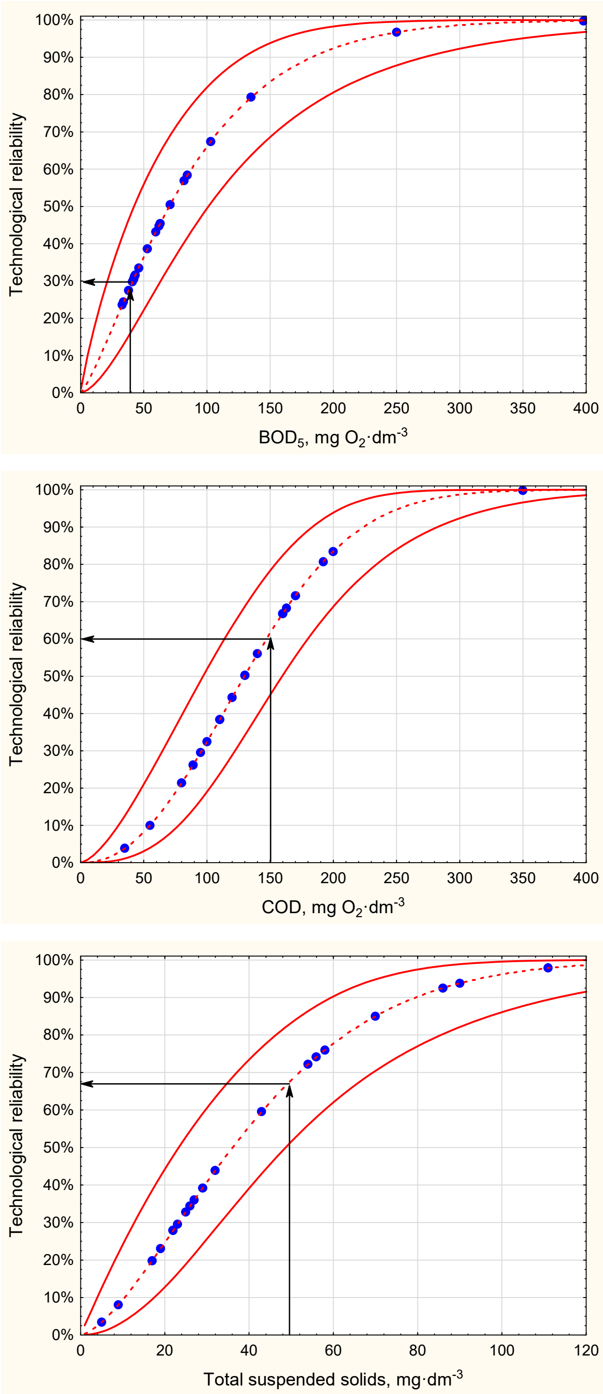

Fig. 4. Weibull cumulative distribution functions and the technological reliabilities determined for each pollution parameter in object No. 2; source: own study

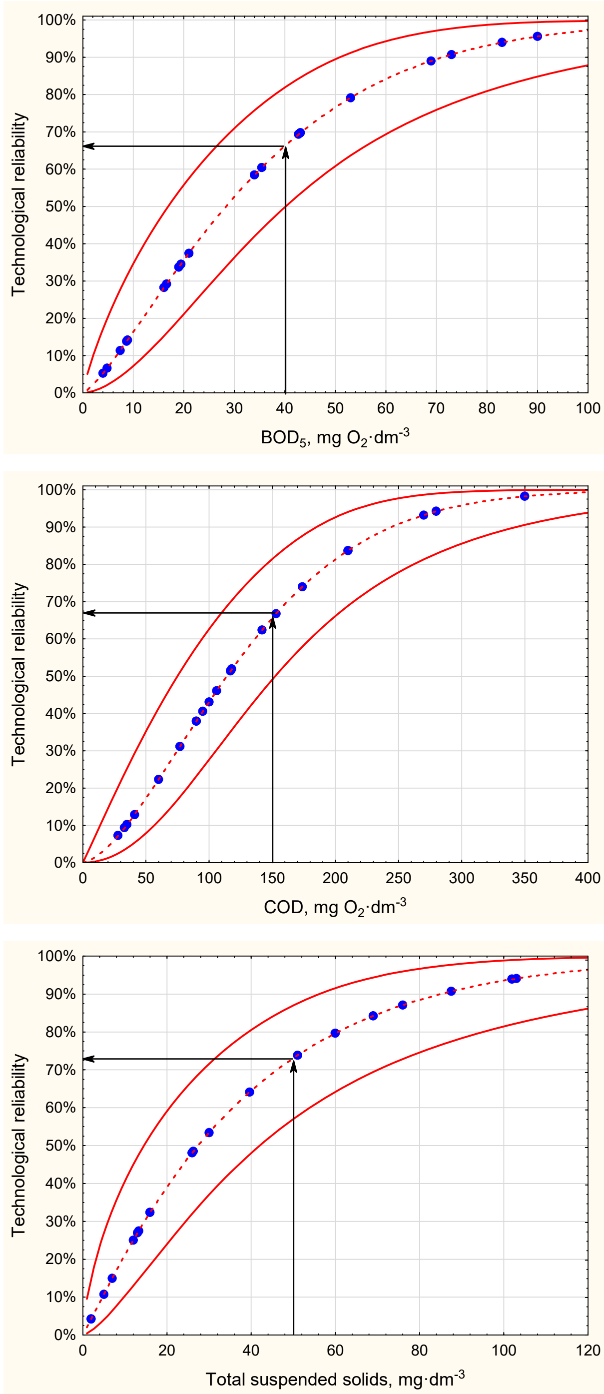

Fig. 5. Weibull cumulative distribution functions and the technological reliabilities determined for each pollution parameter in object No. 3; source: own study

the permissible value of indicators in 9 days per year can be exceeded.

In wastewater treatment plant with a biological deposit, 70% of the BOD_5 limit value was found to be exceeded. It follows that the period of faulty operation of the treatment plant for disposal of BOD_5 was 256 days per year. In 40% of the wastewater samples treated, the amount of COD exceeded 150 mg·dm^{-3} normalized value (Fig. 4). This means that 146 days of the year did not meet the requirements specified for this indicator in the Regulation of the Minister of the Environment [Rozporządzenie MŚ… 2014]. Reliability of the sewage treatment plant in the scope of total suspended solids removal was about 67%. As in the case of other indicators, it is much lower than the value proposed by ANDRAKA and DZIENIS [2003]. For comparison, the reliability wastewater treatment plant type of RetroFAST (with aerated biological filter) was 85% (BOD_5), 89% (COD) and 92% (total suspended solids) respectively [WAŁĘGA *et al*. 2008].

In a wastewater treatment plant with a hybrid reactor, the limit values BOD_5 and COD were exceeded in 33% of the treated wastewater samples (Fig. 5). It follows that for around 121 days a year, the effluents flowing from object No. 3 did not meet the legal requirements for these indicators. The reliability of the total suspended solids removal in a treatment plant with a hybrid reactor was 72%, which means that the limit in 28% of cases was exceeded (Fig. 5). As a general rule, it can be concluded that in 103 days a year, the total suspended solids content in treated wastewater exceeded the limit value.

Summing up the research results, it can be concluded that the reliability of the wastewater treatment plants included in the tests for organic pollutants and suspended solids removal was very low. The reliability levels based on the limit values of pollution indicators differ significantly from those indicated in the literature [ANDRAKA, DZIENIS 2003]. It is worth noting that the analysed objects achieved in the research period quite high effectiveness of removing contaminants. For most of the indicators, the average effects were around 90%, but this did not ensure a stable quality of treated wastewater, in accordance with the national regulations. Many factors can affect this, including with the characteristics of raw wastewater, as well as the specificity of the analysed technological solutions. They are based on conventional methods of contaminant removal (activated sludge, biological deposit), which require the provision and maintenance of specific parameters and technological conditions. Fulfilling this in the case of household wastewater treatment plants can be difficult, as it requires users to constantly check the facilities, to identify disturbances and faults and to correct them. Moreover, in the event of a failure, a certain amount of time is needed to restore the wastewater treatment plant to normal operation. As an alternative to this type of solution, systems using semi-natural wastewater treatment methods can be used. They are simpler to operate and provide high efficiency and reliability. Studies by JUCHERSKI *et al.* [2017] indicate that the reliability of hybrid constructed wetland wastewater treatment plant can reach up to 100% for BOD_5 and COD and 92% for total suspended solids.

CONCLUSIONS

1. The reliability of BOD_5, COD and total suspended solids removal in all wastewater treatment plants under analysis was very low, usually within the range of 60 to 70%.

2. Low reliability of analysed objects is the result of many cases of exceeding the limit value of the tested indicators of pollutions.

3. The reliability levels set were significantly lower than those proposed in the literature.

4. Low reliability of pollutants removal in household wastewater treatment plants with activated sludge, biological deposit and hybrid reactor may be associated with the sensitivity of these systems to sudden changes in technological conditions and their inability to maintain them during operation.

Acknowledgement

WFOŚiGW w Lublinie

Dofinansowano ze środków Wojewódzkiego Funduszu Ochrony Środowiska i Gospodarki Wodnej w Lublinie
Cofinanced by Voivodeship Fund for Environmental Protection and Water Management in Lublin

REFERENCES

ANDRAKA D., DZIENIS L. 2003. Wymagany poziom niezawodności oczyszczalni ścieków w świetle przepisów polskich i europejskich [Required reliability level of wastewater treatment plants according to European and Polish regulations]. Zeszyty Naukowe Politechniki Białostockiej. Ser. Inżynieria Środowiska. Nr 16 p. 24–28.

ANDRAKA D., DZIENIS L. 2013. Modelowanie ryzyka w eksploatacji oczyszczalni ścieków [Modeling of risk in the operation of wastewater treatment plants]. Rocznik Ochrona Środowiska. Nr 15 p. 1111–1125.

BŁAŻEJEWSKI R. 2005. Aktualny status przydomowych oczyszczalni ścieków i perspektywy ich rozwoju [Current legal status of haousehold wastewater treatment plants and development perspectives]. Wodociągi i Kanalizacja. Nr 1 (10) p. 24–25.

BUGAJSKI P. 2014a. Analiza niezawodności funkcjonowania oczyszczalni Bioblok PS-50 z zastosowaniem metody Weibulla [Analysis of reliability of the treatment plant Bioblok PS-50 using the method of Weibull]. Infrastruktura i Ekologia Terenów Wiejskich. Nr 2 (3) p. 667–677.

BUGAJSKI P. 2014b. Ocena niezawodności usuwania związków biogennych w oczyszczalni ścieków metodą Weibulla [Assessment of nutrient removal reliability in a sewage treatment plant using the Weibell method]. Zeszyty Problemowe Postępów Nauk Rolniczych. Z. 576 p. 13–21.

BUGAJSKI P., WAŁĘGA A., KACZOR G. 2012. Zastosowanie metody Weibulla do analizy niezawodności działania przydomowej oczyszczalni ścieków [Application of the Weibull reliability analysis of haousehold sewage treatment plant]. Gaz, Woda i Technika Sanitarna. Nr 2 p. 56–58.

GUS 2016. Infrastruktura komunalna w 2015 r. [Municipal infrastructure in 2015]. Warszawa. Główny Urząd Statystyczny pp. 36.

HEIDRICH Z. 1998. Przydomowe oczyszczalnie ścieków. Poradnik [Household wastewater treatment plants. A guide]. Warszawa. Centralny Ośrodek Informacji Budownictwa. ISBN 83-85393-55-2 pp. 220.

HEIDRICH Z., KALENIK M., PODEDWORNA J., STAŃKO G. 2008. Sanitacja wsi [Rural sanitation]. Warszawa. Seidel-Przywecki. ISBN 978-83-60956-04-5 pp. 374.

HEIDRICH Z., STAŃKO G., WARĘŻAK T., GOLEŃ M., ZAWADZKI A. 2013. Leksykon przydomowych oczyszczalni ścieków. Poradnik inwestora [Lexicon of domestic treatment plants. Investors guide]. Ed. 2. Warszawa.

Seidel-Przywecki Sp. z o.o. ISBN 978-83-60956-39-7 pp. 174.

HERMANOWICZ W., DOJLIDO W., DOŻAŃSKA W., KOZIOROWSKI B., ZERBE J. 1999. Fizyko-chemiczne badanie wody i ścieków [Physical-chemical testing of water and wastewater]. Warszawa. Arkady. ISBN 978-83-213-4067-8 pp. 558.

IGNATOWICZ K., PUCHLIK M. 2015. Ekologiczne rozwiązania oczyszczania małych ilości ścieków bytowych [Ecological solutions for treatment of domestic wastewater]. Rynek Instalacyjny. Nr 5 p. 80–85.

JAWECKI B., PAWĘSKA K., SOBOTA M. 2017. Operating household wastewater treatment plants in the light of binding quality standards for wastewater discharged to water bodies or to soil. Journal of Water and Land Development. No. 32 p. 31–39. DOI 10.1515/jwld-2017-0004.

JÓŹWIAKOWSKI K., MARZEC M. 2011. Skuteczność usuwania zanieczyszczeń w różnych rozwiązaniach technologicznych przydomowych oczyszczalni ścieków [Effeciency of pollution removal in different technological solutions of household wastewater treatment plants]. Zeszyty Problemowe Postępów Nauk Rolniczych. Z. 561 p. 53–63.

JÓŹWIAKOWSKI K., MARZEC M., PYTKA A., GIZIŃSKA M., GORAL R. 2012. Dokumentacja techniczna budowy przydomowej hybrydowej oczyszczalni ścieków w miejscowości Dys [Technical documentation for the construction of wastewater treatment plant in Dys]. Lublin pp. 24.

JÓŹWIAKOWSKI K., MUCHA Z., GENEROWICZ A., BARAN S., BIELIŃSKA J. 2015. The use of multi-criteria analysis for selection of technology for a household WWTP compatible with sustainable development. Archives of Environmental Protection. No. 41 p. 76–82.

JUCHERSKI A., NASTAWNY M., WALCZOWSKI A., JÓŹWIAKOWSKI K., GAJEWSKA M. 2017. Assessment of the technological reliability of a hybrid constructed wetland for wastewater treatment in a mountain eco-tourist farm in Poland. Water Science and Technology. No. 75 p. 2649–2658.

KAROLINCZAK B., MIŁASZEWSKI R., SZTUK A. 2015. Analiza efektywności kosztowej różnych wariantów technologicznych przydomowych oczyszczalni ścieków [Cost-effectiveness analysis of different technological variants of single-house sewage treatment plants]. Rocznik Ochrona Środowiska. No. 17 p. 726–746.

MARZEC M. 2016. Efficiency of removing organic pollutants from wastewater in a household wastewater treatment plant with a hybrid reactor. Journal of Ecological Engineering. No. 17(5) p. 240–246.

MARZEC M., JÓŹWIAKOWSKI K. 2006. Wstępna analiza funkcjonowania małej oczyszczalni ścieków ze złożem biologicznym [Preliminary analysis of the operation of a small wastewater treatment plant with a biological deposit]. Zeszyty Naukowe AR w Krakowie. Inżynieria Środowiska. Nr 28 p. 123–130.

MARZEC M., JÓŹWIAKOWSKI K. 2007. Operational and environmental problems of the functioning of mini-sewage treatment plant with activated sludge. Polish Journal of Environmental Studies. Vol. 16. No. 2A p. 525–529.

OBARSKA-PEMPKOWIAK H., KOŁECKA K., GAJEWSKA M., WOJCIECHOWSKA E., OSTOJSKI A. 2015. Zrównoważone gospodarowanie ściekami na przykładzie obszarów wiejskich [Sustainable wastewater management on the example of rural areas]. Rocznik Ochrona Środowiska. Nr 17 p. 585–602.

OLIVIERA S.C., VON SPERLING M. 2007. Reliability analysis of stabilization pond systems. Water Scienes and Technology. Vol. 55. No. 11 p. 127–134.

OLIVIERA S.C., VON SPERLING M. 2008. Reliability analysis of wastewater treatment plant. Water Research. Vol. 42 p. 1182–1194.

PASTUSZAK M. 2004. Projekt budowlany przyzagrodowych, przydomowych oczyszczalni ścieków na terenie gminy Radzyń Podlaski [Construction project of wastewater treatment plant in Radzyń Podlaski commune]. Lublin. PW „IN-BUD" s.c. pp. 45.

PAWEŁEK J., BUGAJSKI P. 2017. Rozwój przydomowych oczyszczalni ścieków w Polsce – zalety i wady [The development of household wastewater treatment plants in Poland – advantages and disadvantages]. Acta Scientiarum Polonorum. Formatio Circumiectus. Nr 16 (2) p. 3–14.

PIASECKI A., JURASZ J. 2015. Urbanizacja a stan gospodarki wodno-ściekowej na przykładzie obszaru podmiejskiego Torunia [Urbanization and the status of water management and sewage disposal – a Toruń suburban example]. Woda-Środowisko-Obszary Wiejskie. T. 15. Z. 4 (52) p. 19–28.

Rozporządzenie Ministra Środowiska z dnia 18 listopada 2014 r. w sprawie warunków, jakie należy spełnić przy wprowadzaniu ścieków do wód lub do ziemi, oraz w sprawie substancji szczególnie szkodliwych dla środowiska wodnego [Regulation of the Minister of Environment of November 18, 2014 laying down conditions for the introduction of sewage into water or soil and substances particularly harmful to the aquatic environments]. Dz.U. 2014 poz. 1800.

SKRZYPIEC K., BEJNAROWICZ A., GAJEWSKA M. 2017. Rozwiązania gospodarki wodno-ściekowej na obszarach niezurbanizowanych. Małe oczyszczalnie ścieków zgodne z zasadami zrównoważonego rozwoju [Wastewater treatment and management solutions for non-urban areas. Small wastewater treatment plans in accordance with the principles of sustainable development]. Rynek Instalacyjny. Nr 4 p. 85–89.

ŚWIERK W. 2016. Gospodarka wodno-ściekowa w gminie Raba Wyżna [Water and sewage management in the Raba Wyżna commune]. Woda-Środowisko-Obszary Wiejskie. T. 16. Z. 4 (56) p. 97–123.

WAŁĘGA A., MIERNIK W., KOZIEŃ T. 2008. The efficiency of a domestic sewage treatment plant type RetroFAST. Przemysł Chemiczny. Nr 87 (5) p. 210–212.

Michał MARZEC

Niezawodność usuwania wybranych zanieczyszczeń w różnych rozwiązaniach technologicznych przydomowych oczyszczalni ścieków

STRESZCZENIE

W pracy przeanalizowano niezawodność usuwania wybranych zanieczyszczeń w trzech rozwiązaniach technologicznych przydomowych oczyszczalni ścieków: oczyszczalni z osadem czynnym, ze złożem biologicznym zraszanym oraz reaktorem hybrydowym (osad czynny i złoże biologiczne zanurzone). Analizę wykonano z wykorzystaniem metody Weibula w odniesieniu do podstawowych wskaźników zanieczyszczeń: BZT_5, ChZT i zawiesiny ogólnej. Niezawodność technologiczna oczyszczalni z osadem czynnym kształtowała się na poziomie 70% w przypadku BZT_5, 87% – ChZT i 66% – zawiesiny ogólnej. W oczyszczalni ścieków ze złożem biologicznym zraszanym wyznaczone wartości niezawodności wyniosły: 30% (BZT_5), 60% (ChZT) i 67% (zawiesina ogólna). W oczyszczalni z reaktorem hybrydowym przekroczenie dopuszczalnej wartości BZT_5 i ChZT miało miejsce w 30% przypadków, a zawiesiny ogólnej w 28%. Wyznaczone poziomy niezawodności są wyraźnie niższe od poziomów dopuszczalnych proponowanych w literaturze, co oznacza, że w ściekach oczyszczonych odpływających z analizowanych oczyszczalni często pojawiają się przekroczenia wartości granicznych wskaźników, określonych w aktualnie obowiązującym Rozporządzeniu Ministra Środowiska dla obiektów o wielkości poniżej 2000 RLM.

Słowa kluczowe: *BZT_5, ChZT, niezawodność technologiczna, przydomowe oczyszczalnie ścieków, zawiesina ogólna*