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Research Article

THE EFFICIENCY OF POLLUTION REMOVAL FROM DOMESTIC WASTEWATER IN CONSTRUCTED WETLAND SYSTEMS WITH VERTICAL FLOW WITH COMMON REED AND GLYCERIA MAXIMA

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ABSTRACT
The paper presents the results of research on the effects of removing pollution from domestic wastewater in two beds of constructed wetland systems with vertical flow. Bed I was planted with common reed *(Phragmites australis Cav. Trin. Ex Steud.)*, whereas bed II with Glyceria maxima *(Glyceria aquatica L.)*. The surface of each of the beds amounted to 30 m^2, and the hydraulic load of each of them amounted to 0.033 $m^3 \cdot m^{-2} \cdot d^{-1}$. The study showed very good results in the removal of most of the analyzed indicators of contamination, which were similar in both analyzed beds. They were, respectively: 91 and 93% – for total suspended solids, 96 and 98% – for BOD_5, 96 and 94% – for COD_{Cr}, 88 and 86% – for ammonia nitrogen and 87 and 88% – for total phosphorus. Much smaller effects were reported with regard to total nitrogen removal – 55% in bed I with common reed and 54% in bed II with Glyceria maxima. The tested beds also eliminated the number of *coliform* bacteria and faecal *coliform* bacteria quite effectively. Average effects of the removal of *coliform* bacteria in bed I and II were 99.74%, in the case of faecal *coliform* 98.06% and 97.94% respectively. Values of basic indicators of contamination (total suspended solids, BOD_5 and COD_{Cr}) in the wastewater discharged from the analyzed beds met the requirements of the Regulation of the Minister of the Environment of 2014. The test results obtained in the first year of operation of the analyzed beds show that neither of the applied plants significantly improves the results of contaminant removal.

Keywords: constructed wetland, vertical flow, domestic wastewater, common reed, Glyceria maxima.

INTRODUCTION

For treating a small amount of wastewater produced in households and service facilities, located in areas without access to sewer collective, one currently uses a variety of construction systems and technology, called household sewage treatment systems [Pawęska et al. 2011]. This type of objects includes also wetlands, among which we can mention constructed wetland systems with surface sewage flow (FWS – „*free water surface*") and constructed wetland systems with submerged sewage flow (VSB – „*vegetated submerged bed*") [Vymazal 2008].

In recent years in Poland and around the world, constructed wetland systems are increasingly popular due to high efficiency of contaminant removal. Currently, the most commonly used systems are constructed wetland with vertical (VF – *vertical flow*) or horizontal (HF – *horizontal flow*) sewage flow. This type is characterized by easy and simple operation, tolerance for uneven flow of wastewater, and their construction cost is competitive, compared to using other household sewage or septic tank – "cesspool". In addition, their natural appearance enables easy integration into the existing landscape [Jóźwiakowski 2012]. Constructed wetlands systems are used for wastewater treatment throughout the year, also in winter conditions.

For many years, beds of vertical flow of wastewater are mainly used worldwide, which, thanks to favorable aerobic conditions, provide a very efficient nitrification and mineralization of organic matter. Vertical sewage flow beds in Poland are most commonly planted with common reed *(Phragmites australis Cav. Trin. Ex Steud.)* [Obarska-Pempkowiak et al. 2010]. In recent years there have also been attempts to use the facilities of this kind with Glyceria maxima [Jucherski, Walczowski 2012], as well as energy plants, e.g. Giant miscanthus [Gizińska et al. 2013] and other marsh plants, for example Typha, Bulrush, Iris, Sweet flag, Common club-rush [Tomczuk, Ochrymiuk 2012].

The study of Jucherski and Walczowski [2012] shows that vertical flow bed with Glyceria maxima is characterized by long-term average of wastewater treatment efficiency than a bed with common reed, also in biogenic ingredients removal. According to these authors, a vertical flow bed with Glyceria maxima provides a result of total nitrogen removal at the level of 92,9%, total phosphorus – 87.4% and BOD_5 – 90.6% and COD_{Cr} – 87.9%. These authors also found that the common reed *„due to the excessive expansion of the root, creates the danger of compaction and displacement of the beds' minerals"*.

The aim of this study was to compare the results of research on the effects of pollution removal from domestic sewage in two beds of constructed wetland systems with vertical flow (VF) of common reed and Glyceria maxima in the first year of their operation.

MATERIALS AND METHODS

The study was conducted in constructed wetland wastewater treatment plant located in the village of Popkowice in the municipality of Urzędów in Lubelskie province in Poland. The first element of the analyzed object is a three-chamber primary settling tank of working capacity of 8.5 m^3, then the wastewater after mechanical cleaning is administered in pulses by means of a pump once a day to two parallel of constructed wetland beds: I – bed of common reed (*Phragmites australis* (Cav.) Trin. ex Steud.), II – bed of Glyceria maxima (*Glyceria aquatica L.).* Around 0.5 $m^3 \cdot d^{-1}$ of wastewater flows into each of the beds, and the hydraulic load is 0.033 $m^3 \cdot m^{-2} \cdot d^{-1}$ each. Both beds have the same dimensions: depth – 0.8 m, length – 6 m, width – 5 m, and the surface of each of the beds is 30 m^2 (Figure 1). Coarse sand with a diameter of 1–2 mm was used to fill the beds. After cleaning in the I and II bed the sewage flows into the bed of Virginia mallow with horizontal flow, and are then discharged into a drainage ditch, which flows into the Urzędówka river. In the paper we analyzed the effects of removing impurities in only two fields of the vertical flow of waste water (Figure 1).

The research was carried out in June, August and November 2014 and in January 2015. 4 series of analyzes were performed, during which 12 samples of wastewater were examined. Samples of wastewater for physico-chemical ana-

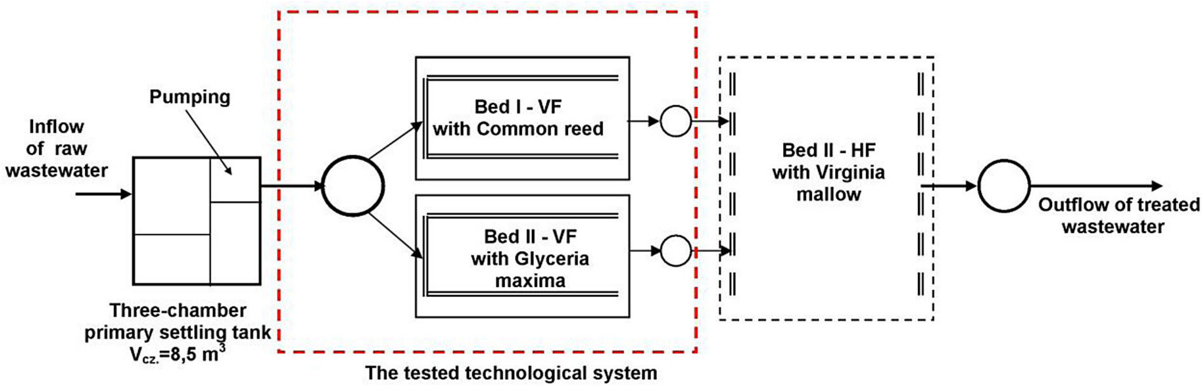

Figure 1. Flow diagram of the tested constructed wetland wastewater treatment plant

Phot. 1. Bed I with vertical flow with common reed (*Phragmites australis* (Cav.) Trin. ex Steud.), phot. K. Jóźwiakowski

Phot. 2. Bed II with vertical flow with Glyceria maxima (*Glyceria aquatica L.),* phot. K. Jóźwiakowski

lyzes were collected according to the Polish norm PN-74/C-04620/00 from a pumping station - after mechanical purification and biological treatment in beds I and II. The analyzes were performed by reference methodologies of analysis of wastewater samples specified in the Regulation of the Minister of the Environment of 2014.

The sample analyzes included the determination of:

- total suspended solids – by direct gravimetric method with paper points,
- BOD_5 – by dilution (oxygen content was determined using oxygen meter WTW Oxi 538),
- COD_{Cr} – by bichromate method (COD determination was performed with WTW MPM 2010 photometer, after prior oxidation of the test sample in a thermoreactor at 148 °C),
- total nitrogen – with AQUALYTIC PCspectro spectrophotometer, after prior oxidation of the test sample in a thermoreactor at 100 °C,
- ammonia – with AQUALYTIC PCspectro spectrophotometer,
- total phosphorus – with WTW MPM 2010 photometer after prior oxidation of the test sample in a thermoreactor at 120 °C.

The study also collected wastewater samples for microbiological analysis. The number of *coliform* bacteria and faecal *coliform* bacteria was determined in the collected samples. Microbiological testing was performed by Polish standards (PN-C-04615-05:1975P, PN-C-04615-07:1977P). The minimum, maximum, mean and standard deviation were identified based on the results of studies (Table 1). The efficiency of removing impurities in the analyzed beds was determined on the basis of the average values of the analyzed indicators of contamination in wastewater flowing in (C_d) and out (C_o) of the beds according to formula 1:

$$Ŋ = (1 - C_o/C_d) \times 100, \% \quad (1)$$

The results were compared with the requirements of the Regulation of the Minister of Environment from 2014.

RESULTS AND DISCUSSION

The study showed very good results in the removal of the analyzed indicators of contamination, which were similar in both analyzed beds of constructed wetland. Table 1 shows physical and chemical composition of the wastewater treated in the studied beds, and Figure 2 shows the average efficiency of wastewater treatment. Table 2 and Figure 3 show the number of *coliform* bacteria and faecal *coliform* bacteria in the studied wastewater and the effects of their removal.

Total suspended solids

The average removal efficiency of total suspended solids in the studied constructed wetland systems was comparable: 91.2% in bed I with common reed and 93.0% in bed II with Glyceria maxima (Figure 2). It was found that the concentration of total suspended solids in wastewater flowing from bed I ranged from 12.00 to 47.00 $mg \cdot dm^{-3}$, and the average was 27.50 $mg \cdot dm^{-3}$. In contrast, in the wastewater discharged from bed II the concentration of total suspended solids ranged from 10.80 to 30.00 $mg \cdot dm^{-3}$, and the average was 21.70 $mg \cdot dm^{-3}$ (Table 1). Average concentrations of total suspended solids in the treated wastewater discharged from the tested beds were lower than the limit value (50 $mg \cdot dm^{-3}$) defined in the Regulation [2014].

Table 1. Physical and chemical composition of the wastewater treated in tested constructed wetland systems with vertical flow with common reed and Glyceria maxima

Parameters		Wastewater after the mechanical treatment	Wastewater after bed I with common reed	Wastewater after bed II with Glyceria maxima
Total suspended solids [$mg \cdot dm^{-3}$]	min	82.00	12.00	10.80
	max	229.00	47.00	30.00
	x	**142.25**	**27.50**	**21.70**
	σ	62.37	14.53	7.98
BOD_5 [$mg\ O_2 \cdot dm^{-3}$]	min	286.50	4.30	2.35
	max	637.00	55.20	20.40
	x	**420.75**	**17.80**	**8.54**
	σ	159.06	24.95	8.42
COD_{Cr} [$mg\ O_2 \cdot dm^{-3}$]	min	420.00	13.00	12.00
	max	1366.00	97.00	160.00
	x	**759.00**	**37.75**	**52.50**
	σ	417.03	40.01	71.91
Ammonium [$mg\ N\text{-}NH_4 \cdot dm^{-3}$]	min	29.00	0.83	0.36
	max	114.00	16.60	14.70
	x	**68.50**	**9.41**	**10.50**
	σ	35.73	6.91	6.79
Total nitrogen [$mg \cdot dm^{-3}$]	min	38.00	34.00	25.00
	max	115.00	55.00	64.00
	x	**77.00**	**42.00**	**43.75**
	σ	35.24	9.13	16.68
Total phosphorus [$mg \cdot dm^{-3}$]	min	4.70	0.63	0.40
	max	38.00	5.32	4.61
	x	**17.35**	**2.41**	**2.11**
	σ	14.59	2.23	1.99

Comments: min – minimum value, max – maximum value, x – average value, σ – standard deviation.

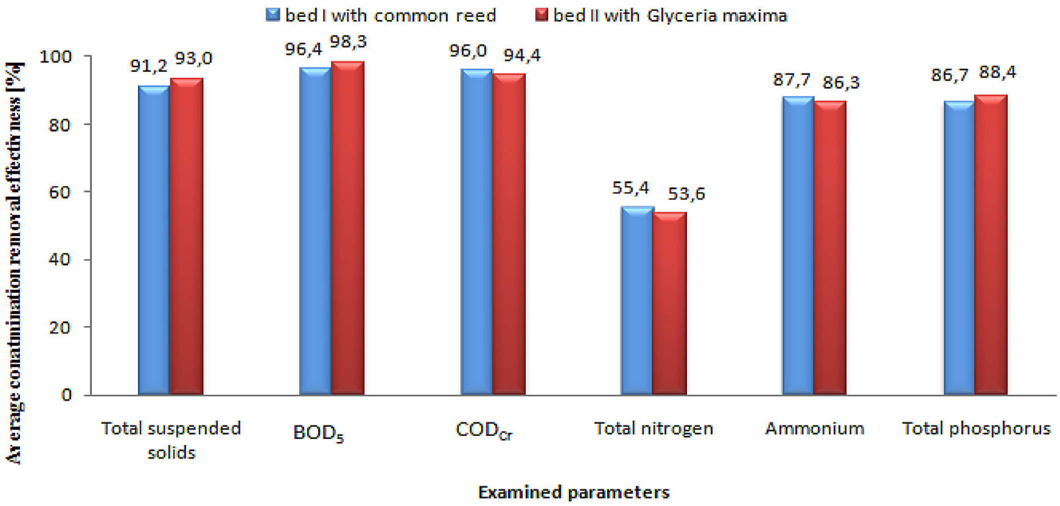

Figure 2. Average contamination removal efficiency in tested constructed wetland systems with vertical flow with common reed and Glyceria maxima

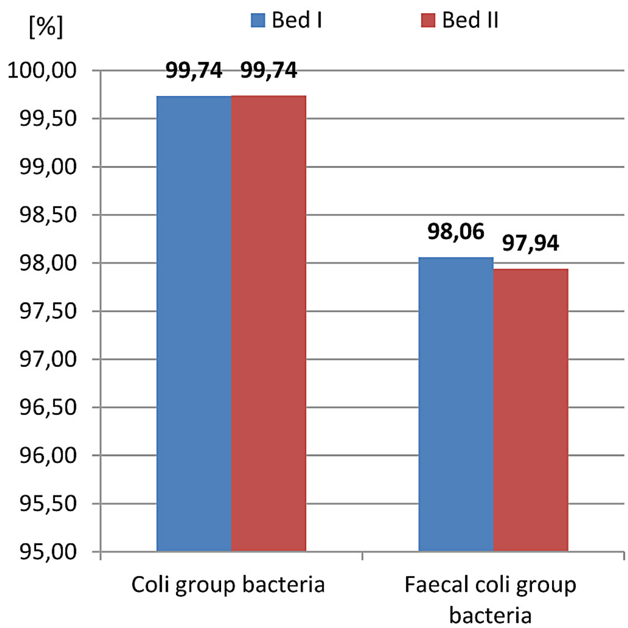

Figure 3. The average removal efficiency of microbial contamination in the tested constructed wetland systems with vertical flow with common reed and Glyceria maxima

In studies by Gizińska et al. [2013] the total suspended solids removal efficiency in the bed with vertical flow with common reed was lower than in the studied beds and was 78%, and the average concentration of total suspended solids was 24 mg·dm^{-3}. Past experience indicates worldwide that total suspended solids removal efficiency in systems with vertical flow with common reed ranges from 65–90% [Hablerl et al. 1995; Chen et al. 2008; Vymazal 2010; Jóźwiakowski 2012]. The total suspended solids removal efficiency in the studied beds is slightly higher than that obtained in the similar objects around the world.

BOD_5

The study showed a very high efficiency of wastewater treatment of organic matter. In bed I with common reed the average efficiency of the elimination of BOD_5 was 96.4%, and in bed II with Glyceria maxima 98.3% (Figure 2). It was found that the value of BOD_5 in the wastewater flowing from bed I ranged from 4.30 to 55.20 mg O_2·dm^{-3} and the average was 17.80 mg O_2·dm^{-3}. However, in the wastewater discharged from bed II the BOD_5 value ranged from 2.35 to 20.40 mg O_2·dm^{-3}, and the average was 8.54 mg O_2·dm^{-3} (Table 1). The average values of BOD_5 in treated

Table 2. Numbers of *coliform* bacteria and of faecal *coliform* bacteria in wastewater treated in the tested constructed wetland systems with vertical flow with common reed and Glyceria maxima

Investigated microbiological indicators	Kind of sewage	Range	Mean
Mean numbers of *coliform* bacteria in MPN×100cm^{-3} (incubation at 37°C)	Outflow from septic tank	7.0×10^5 – 7.0×10^8	2.5×10^8
	Outflow from bed I	2.0×10^3 – 2.4×10^6	6.6×10^5
	Outflow from bed II	5.0×10^2 – 2.4×10^6	6.6×10^5
Numbers of faecal *coliform* bacteria in MPN×100cm^{-3} (incubation at 44°C)	Outflow from septic tank	2.3×10^5 – 2.4×10^7	9.4×10^6
	Outflow from bed I	6.2×10^2 – 7.0×10^5	1.8×10^5
	Outflow from bed II	2.4×10^2 – 7.0×10^5	1.9×10^5

wastewater discharged from the tested beds were lower than the limit value (40 mg $O_2 \cdot dm^{-3}$) defined in the Regulation [2014]. Only the maximum value obtained in the wastewater discharged from bed I with common reed (55.20 mg $O_2 \cdot dm^{-3}$) was higher than the limit value defined in the above mentioned regulation.

Research carried out by Gizińska et al. [2013] shows that the efficiency of BOD_5 removal from wastewater in a bed of vertical flow with common reed was similar to that obtained in the examined beds and amounted to 97%, and the average BOD_5 value in the bed outflow amounted to 14.2 mg $O_2 \cdot dm^{-3}$.

The efficiency of the tested object was significantly higher, than that found by Jucherski and Walczowski [2012] in slope constructed wetland beds with common reed and Glyceria maxima. These authors' studies show that the effectiveness of the elimination of BOD_5 in the bed with vertical flow with common reed was 59.7%, and in bed with Glyceria maxima 60.8%.

Past experience indicates worldwide, that the BOD_5 efficiency reduction in vertical flow systems with common reed ranges from 84 to 96% [Haberl et al. 1995; Chen et al. 2008; Vymazal 2010; Jóźwiakowski 2012].

COD_{Cr}

In bed I with common reed the efficiency of COD_{Cr} removal was 96,0%, and in bed II with Glyceria maxima 94,4% (Figure 2). It was found that the COD_{Cr} value in the wastewater flowing from bed I ranged from 13.00 to 97.00 mg $O_2 \cdot dm^{-3}$, and the average was 37.75 mg $O_2 \cdot dm^{-3}$. And in the wastewater flowing from bed II the COD_{Cr} value ranged from 12.00 to 160.00 mg $O_2 \cdot dm^{-3}$, and the average was 52.50 mg $O_2 \cdot dm^{-3}$ (Table 1).

The average COD_{Cr} values in the treated wastewater discharged from the studied beds were lower than limit value (150 mg $O_2 \cdot dm^{-3}$) defined in Regulation of the Minister of the Environment of 2014. Only the maximum value obtained in the wastewater discharged from bed II with Glyceria maxima (160.00 mg $O_2 \cdot dm^{-3}$) was lower than the limit value defined in the Regulation [2014].

Research carried out by Gizińska et al. [2013] shows, that the efficiency of removal of COD_{Cr} from wastewater in a bed of vertical flow with common reed was similar to that obtained in the examined beds and amounted to 95%, and the average COD_{Cr} value in the discharged wastewater was 31.5 mg O $\cdot dm^{-3}$.

In similar facilities worldwide, there was not so high COD_{Cr} lowering effects. In systems with vertical flow of common reed COD_{Cr} reduction effectiveness ranged from 78 to 82% [Haberl et al. 1995; Chen et al. 2008; Jóźwiakowski 2012]. Also, in a study conducted by Tomczuk i Ochrymiuk [2012] and Ávila [2015] the effectiveness of removal of organic compounds expressed by the COD_{Cr} was 83%.

Ammonium

In the studied beds, there were found very high effects of ammonium nitrogen removal – on average 87.7% – in bed I with common reed and 86.3% – in bed II with Glyceria maxima (Figure 2). The content of ammonia nitrogen in the wastewater discharged from the bed with common reed ranged from 0.83–16.60 mg $N\text{-}NH_4 \cdot dm^{-3}$, and the average was 9.41 $N\text{-}NH_4 \cdot dm^{-3}$. In the wastewater discharged from bed with Glyceria maxima ranged from 0.36 to 14.70 mg $N\text{-}NH_4 \cdot dm^{-3}$ and the average was 10.50 $N\text{-}NH_4 \cdot dm^{-3}$.

Based on the study by Tomczuk and Ochrymiuk [2012] in a bed with vertical wastewater flow it was determined, that the average ammonium removal effectiveness was 78%. And the study carried out by Gizińska et al. [2013] showed, that ammonium removal effectiveness from wastewater in the bed with vertical flow with common reed was significantly higher in the examined beds and amounted to 98%, and the average concentration of ammonium nitrogen was 13.9 mg $N\text{-}NH_4 \cdot dm^{-3}$. High effectiveness of ammonia nitrogen removal in VF type deposits VF are the evidence of a good bed oxygenation, which allows for a proper conduct of nitrification.

Total nitrogen

The average effectiveness of total nitrogen removal in the examined constructed wetland beds was similar and amounted to 55.4% in bed I with common reed and 53.6% in bed II with Glyceria maxima (Figure 2). The concentration of total nitrogen in the effluent from bed I ranged from 34.00 to 55.00 $mg \cdot dm^{-3}$, and the average was 42.00 $mg \cdot dm^{-3}$. And in the effluent from bed II the total nitrogen concentration ranged from 25.00 to 64.00 $mg \cdot dm^{-3}$, and the average was 43.75 $mg \cdot dm^{-3}$ (Table 1).

The Regulation [2014] defines (with Equivalent Number of Residents under 2000) the maximum concentration of total nitrogen – 30 $mg \cdot dm^{-3}$, but only in the case of discharging sewage into lakes and their tributaries and directly to reservoirs located on the flowing waters. For the object analyzed in this work such requirements were not specified.

Research carried out by Gizińska et al. [2013] shows, that total nitrogen removal effectiveness from wastewater in the bed with vertical flow with common reed was lower than in the examined beds and amounted to 29.5%, and the average concentration of total nitrogen in the effluent was 73 $mg \cdot dm^{-3}$. Significantly better results of total nitrogen removal, than in the examined facility, were found by Jucherski and Walczowski in beds with common reed and Glyceria maxima [2012]. According to these authors, removal efficiency of total nitrogen in the bed of vertical flow of wastewater with common reed was 75%, while in the bed of Glyceria maxima it was significantly higher and amounted to 93%.

Past experience indicates that the removal efficiency of total nitrogen in vertical flow systems with common reed ranges from 24 to 43% [Hablerl et al. 1995; Vymazal et al. 2010; Jóźwiakowski 2012]. Total nitrogen removal efficiency in the studied beds is much higher than that achieved in similar establishments in the world.

Experience shows that the effectiveness of the overall nitrogen removal in the beds of vertical flow of wastewater does not give satisfactory results, because such objects provide only nitrification process, i.e. the conversion of ammonium to nitrate nitrogen [Luederitz et al. 2001]. In such systems, there is generally no denitrification, which makes it possible to remove total nitrogen in a much greater extent. It was shown that favorable conditions for the decomposition of organic matter and for denitrification is provided by beds with a horizontal flow of effluent (HF) [Obarska-Pempkowiak et al. 2010, Jóźwiakowski 2012]

In order to enhance the effects of removing contamination in recent years hybrid systems are more and more popular They consist of two or three VF and HF type beds which provide better conditions for biological treatment of wastewater [Obarska-Pempkowiak, Gajewska 2005, Jóźwiakowski 2012].

Total phosphorus

The average total phosphorus removal efficiency in the studied constructed wetland beds was similar and amounted to 86,7% in bed I with common reed and 88.4% in bed II with Glyceria maxima (Figure 2). The concentration of phosphorus in the effluent flowing from bed I ranged from 0.63 to 5.32 $mg \cdot dm^{-3}$ and the average was 2.41 $mg \cdot dm^{-3}$. And in the effluent flowing from bed II the concentration of total phosphorus ranged from 0.40 to 4.61 $mg \cdot dm^{-3}$, and the average was 2.11 $mg \cdot dm^{-3}$ (Tabela 1). The Regulation [2014] defines (as in the case of total nitrogen) maximum permissible value of total phosphorus only in the case of discharging sewage into lakes and their tributaries and directly to reservoirs located on the flowing waters, which is 5 $mg \cdot dm^{-3}$. For an object analyzed in this work such requirements were not specified.

In the research carried out by Gizińska et al. [2013] total phosphorus removal effectiveness from wastewater in the bed with vertical flow with common reed was lower than in the examined beds and amounted to 68%, and the average total phosphorus concentration was 9,8 $mg \cdot dm^{-3}$. Studies by Jucherski and Walczowski [2012] showed that the effectiveness of a vertical flow bed with Glyceria maxima (87%) in removing total phosphorus was significantly higher than the bed with common reed (58%).

Past experience indicates that the removal efficiency of total phosphorus in vertical flow systems with common reed ranges from 43–99% [Hablerl et al. 1995; Chen et al. 2008; Vymazal

2010; Jóźwiakowski 2012]. However, a study by Warężak et al. [2013] shows that the removal efficiency of total phosphorus in vertical flow systems ranges from 55 to 84%.

Microbiological factors

The study shows that the sewage flowing into the analyzed constructed wetland beds contained very large numbers of *coliform bacteria* ($2.5 \cdot 10^8$ MPN·100 cm^{-3}) and faecal *coliform* bacteria ($9.4 \cdot 10^6$ MPN ·100 cm^{-3}) (Table 2). Slightly lower numbers of *coliform* bacteria ($8.3 \cdot 10^6$ to $1.4 \cdot 10^7$ MPN ·100 cm^{-3}) and faecal *coliform* bacteria ($2.1 \cdot 10^6$ to $3.3 \cdot 10^6$ MPN ·100 cm^{-3}) were recorded in the wastewater fed to other constructed wetland facilities with reed and willow [Jóźwiakowski et al. 2009; Jóźwiakowski 2012]. On the other hand, in the wastewater flowing into the soil cane filter in the municipal sewage treatment plant in Wielka Nieszawka, in Torun county, the number of *coliform* bacteria ranged from $4.3 \cdot 10^4$ to $4.3 \cdot 10^5$ MPN ·100 cm^{-3}, and faecal *coliform* bacteria from $3.0 \cdot 10^3$ to $3.9 \cdot 10^4$ MPN·100 cm^{-3} [Lalke-Porczyk et al. 2010].

Based on the results presented in table 2, the average effects of removal of *coliform* bacteria and faecal *coliform* bacteria in the analyzed beds were calculated (Figure 3). The obtained data shows that both examined beds are highly effective in removal of *coliform* bacteria (99.74%) and less effective in elimination of faecal *coliform* (97.94–98.06%). Similar effects of elimination of the analyzed bacteria groups (98.09–99.88%) were reported in VF and HF constructed wetland bed types with reed and willow in the Lublin province in Poland [Jóźwiakowski et al. 2009; Jóźwiakowski 2012] and in a reed bed in England (96,6–98,9%) [Decamp, Warren 2000]. While in Tanzania in systems of that type with reed and typha the effects of the elimination of *coliform* bacteria and faecal *coliform* bacteria were only 43–72% [Kaseva 2004]. In contrast, other studies carried out by Lalke-Porczyk et al. [2010] in beds of reeds and willow near Torun in Poland showed an average elimination of *coliform* bacteria and faecal *coliform* bacteria at the level of 94.51–94.71% and 92.07–94.95% respectively.

It was found that the number of *coliform* bacteria in sewage flowing out of the surveyed beds no. I and II was on average $6.6 \cdot 10^5$ MPN·100 cm^{-3}, and the number of faecal *coliform* bacteria was $1.8 \cdot 10^5$ and $1.9 \cdot 10^5$ MPN ·100 cm^{-3} respectively and despite the high efficiency of their removal remained high. Significantly lower numbers of these indicator bacteria ($8.2 \cdot 10^3$–$8.1 \cdot 10^4$ MPN ·100 cm^{-3}) were recorded in the wastewater discharged from constructed wetland beds of VF and HF type with reed and willow in Lublin province in Poland after several years of operation [Jóźwiakowski et al. 2009; Jóźwiakowski 2012]. And in wastewater flowing from constructed wetland beds with reed and willow near Torun the number of *coliform* bacteria ranged from $1.0 \cdot 10^2$ to $1.2 \cdot 10^4$ MPN ·100 cm^{-3} and of faecal *coliform* bacteria from $1.0 \cdot 10^1$ to $1.0 \cdot 10^3$ MPN ·100 cm^{-3} [Lalke-Porczyk et al. 2010].

CONCLUSIONS

1. Both studies constructed wetland beds with vertical flow with common reed and Glyceria maxima provided very good results in removing pollutants from domestic sewage.
2. The effectiveness of removing pollution in bed I and II was 91.2 and 93.0% respectively – for total suspended solids, 96.4 and 98.3% – for BOD_5, 96.0 and 94.4% – for COD_{Cr}, 87.7 and 86.3% – for ammonium and 86.7 and 88.4% – for total phosphorus. Only the average total nitrogen removal efficiency in the studied beds was lower and amounted to 55.4% in bed I with common reed and 53.6% in bed II with Glyceria maxima.
3. It was found that the efficiency of removing microbiological indicators in bed I and II was on average 99.74% – in the case of *coliform* bacteria and 98.06 and 97.94% respectively – in the case of faecal *coliform*.
4. Concentrations of basic indicators of pollution (TSS, BOD_5 and COD_{Cr}) in the wastewater discharged from the analyzed beds meet the requirements defined in the Regulation [2014].

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