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Research Article

APPLICATION OF CONSTRUCTED WETLANDS FOR TREATMENT OF WASTEWATER FROM FRUIT AND VEGETABLE INDUSTRY

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ABSTRACT

About 2000 plants are involved in fruit and vegetable processing in Poland, they are mostly located in non-urbanized areas and without any access to sewerage and sewage treatment facilities. In 2014, they produced more than 10 hm^3 of wastewater requiring treatment, which was discharged directly into surface waters or into the ground. The aim of the study was to evaluate the efficiency of the constructed wetland for treating the sewage from fruit and vegetable industry. The analyzed constructed wetland with vertical flow reveled a reduction in the value of BOD_5 to 68.2%, and COD_{Cr} to 79.3%. The model was characterized by 60.2% efficiency of total phosphorus removal.

Keywords: constructed wetland, fruit and vegetable industry, organic matter.

CHARACTERISTICS OF WASTEWATER FROM FRUIT AND VEGETABLE INDUSTRY

Fruit and vegetable processing industry is characterized by temporal production that falls mainly on the period from June to October [2]. Activities related to the processing and preservation of fruits and vegetables are dealt with by 88% of entities, while the remaining 12% is involved in the production of juices and beverages [1]. Due to the nature and diversity of the processed material, wastewaters from fruit and vegetable industry are difficult to characterize [3].

According to Nawirska [2007], sewage generated from fruit and vegetable facilities is characterized by high content of carbohydrates and minerals and variable composition depending on the processed raw material or the season [3]. Their composition is also influenced by processes of washing and disinfecting production lines. The washing process moves solid, colloidal, and dissolved impurities to the wastewater, depending on the type of raw material processed and the technological process used. At the same time, cleaning and disinfecting components at the amounts difficult to determine, penetrate the wastewater. Depending on the site, wastewaters are generated. One can distinguish: raw material washing, cleaning, peeling, blanching, cooling (water after cooling), filling. The composition and the amount of sewage also depends on the type, quality, setting, and size of dishwashers, as well as type and origin of the material [4, 5].

Wastewater generated during the production of fruit concentrates has a pH in the range from 5.8 to 9.4 and the COD value from 1030 to 5630 mg O_2/dm^3 [6]. In plants producing varied assortment, e.g. salads, puree, or pickles, the pH range can be from 4.9 to 7.7, and the COD value from 5260 to 270 mg O_2/dm^3. These values depend on production technology and currently processed assortment [6]. Wastewater from fruit and vegetable processing is poor in nitrogen and their main contaminant is organic matter. According to literature, the BOD_5 value was from 500 to 5000 mg O_2/dm^3, and during the production peak, it even exceeds 5000 mg O_2/dm^3 [2, 7, 8, 9]. These values are higher than in household wastewater [2, 10]. The seasonal oscillations in the quantity and quality of sewage composition originating from fruit-vegetable processing became a problem for many conventional wastewater treatment plants to where they are discharged.

WAYS TO TREAT THE WASTEWATER FROM FRUIT AND VEGETABLE INDUSTRY

In case of insufficient place for building the treatment plant, it is plausible to precise separation of more contaminated wastewater after washing and blanching from less loaded cooling and condensation water. At first, sewage is purified on grates and sieves, then it is chemically purified, mainly by liming combined with iron and aluminum salts. Chemical wastewater treatment and sedimentation reduces the BOD_5 value by about 50% [11].

Preliminarily purified sewage can be supplied to biological beds along with household one. However, the difficulty of their common purification may arise from the fact of seasonality and variable composition of wastewater from fruit-vegetable production [12].

Problems associated with treatment of sewage from small fruit and vegetable processing facilities that have no access to the sewerage, made to undertake the attempt of its purification using the constructed wetlands. The functioning of constructed wetlands is based on the application of the same physical, chemical, and biological processes that occur in natural marsh ecosystems in cooperation with various microorganisms and properly selected plant species [13].

Removal of impurities in constructed wetlands is mainly associated with biological membrane formed during wastewater flow through the bed [14].

MATERIALS AND METHODS

The tests were carried out on laboratory scale applying constructed wetland. The installation included the bed of 0.11 m^2 surface area and 0.65 m filling thickness. The bed was supplied with wastewater from a small processing plant that were generated since October till December during washing, sorting, and production of fruit and vegetable juices. The hydraulic load of the bed was 0.1 m^3/m^2d.

The bed consists of four filling layers (from top): layer I (sand 0–2 mm, 0.15 m), layer II (gravel 2–8 mm, 0.15 m), layer III (sand 8–20 mm, 0.20 m), layer IV (stones 20–80 mm, 0.15 m), onto which the common reed (*Phragmites australis*) was grown. The scheme of the constructed wetland is presented in Figure 1. The following items were determined in collected wastewater samples in accordance with obligatory procedures:

- COD_{Cr} – dichromate method according to PN-74/C-04578.03,
- BOD_5 – manometric method using Oxi-Top Standard system,
- $N\text{-}NH_4^+$ – spectroscopy according to PN-ISO 7150-1:2002,
- $N\text{-}NO_3$ – spectrometry according to PN-82/C-04576/08,
- PO_4^{3-} – spectrometry according to PN-EN ISO 6878:2006.
- Pog. – spectrometry according to PN-EN ISO 6878:2006
- Nog. – spectrometry applying spectrometer UV-VIS Pharo 300

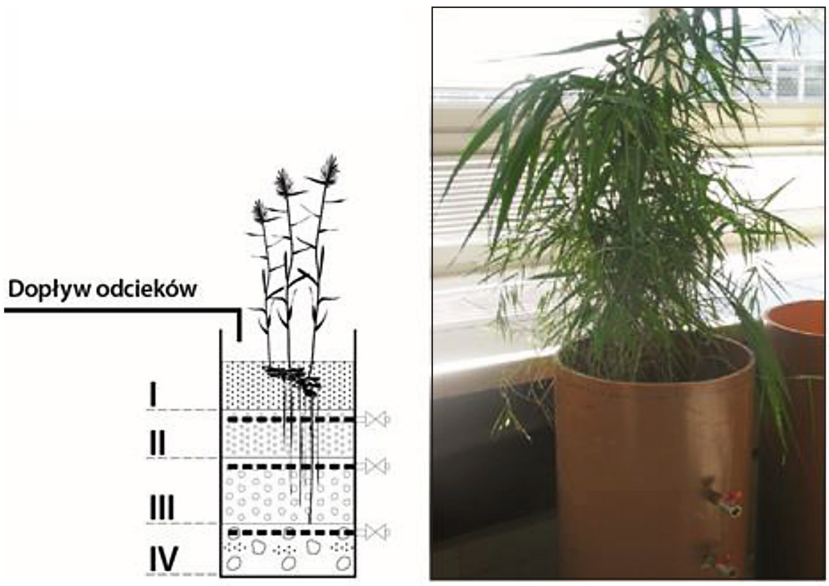

Figure 1. Constructed wetland with vertical flow [15]

RESULTS AND DISCUSSION

Wastewater from small fruit-vegetable treatment plant purified in constructed wetland (Table 1) was characterized, as compared with typical sewage from rural sewerage [16], by many times higher values of BOD_5 and COD_{Cr} and much lower concentration of total nitrogen. Therefore, the main issue became to reach an appropriately high degree of organic matter removal on the tested bed. The ratio of COD to BOD_5 for raw wastewater is larger than 2 indicating that this sewage is hardly bio-degradable. The purification effect on the bed for BOD_5 was 68.2% (Figure 2). The removed load of contaminants for BOD_5 was 1.0 $g/m^2 \cdot d$. Organic matter removal effect expressed in BOD_5 and COD indicated a proper process of organic substances removal. Wastewater purified on the bed had pH from 4.5 to 6.7, thus ammonia in 95–100% occurred in ionized form of NH_4^+. The raw sewage from fruit and vegetable industry contains biologically non-decomposable organic nitrogen in the amount of about 16.4 mg N/m^3 [18]. In treated sewage, it amounted to 7.5 mg N/m^3 (Table 1). Organic nitrogen compounds are ammonified just during supplying onto the bed. In the opinion of Krzanowski and Wałęga [19], such a large quantity of organic nitrogen is typical for food processing facilities. Convenient conditions for nitrification process (good aeration of wastewater, pH close to 7) during sewage flow through the constructed wetland contributed to the removal of ammonia nitrogen in 68.7% (Figure 3). Due to microorganisms that can assimilate nitrogen only in an inorganic form, and ammonia is readily available form for them, concentration of NH_4^+ in wastewater outflowing to the receiver was 0.5 mg N/dm^3 (Table 1). The activity of *Nitrosomonas* and *Nitrobacter* bacteria is proved by reduction in ammonia nitrogen content in outflowing sewage. When comparing the achieved values and taking into account the fact that heterotrophic bacteria compete with nitrifying bacteria during fight for substrates, it can be assumed that prominent part of organic load was removed on constructed wetland.

The tested raw wastewater revealed an average total phosphorus level of 12.1 mg P/dm^3, while in the treated ones – 5.0 mg P/dm^3 (Table 1). The complete effect of phosphates removal from wastewater during the research reached 55.5%, and the complete effect of total phosphorus removal was 60.2%. The load of contamination removal for total phosphorus was 0.7 $g/m^2 \cdot d$ (Figure 3). Part of phosphorus compounds was assimilated by bacteria and plants, whose growing root system is an environment abundant in aerobic and anaerobic bacteria [20]. According to Sadecka [21], since the third to fifth year of the treatment plant operation, a

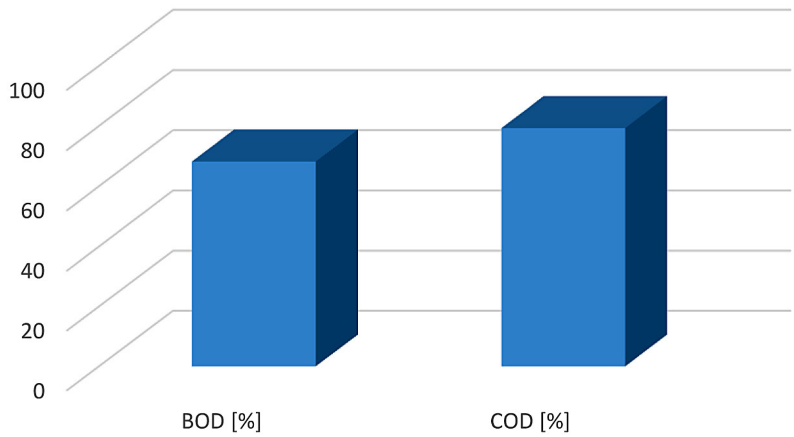

Figure 2. Total efficiency COD and BOD_5 [%] on constructed wetland

Table 1. Average values of parameters for raw and treated wastewater from fruit and vegetable industry on constructed wetland

Factor / Sample	BOD [mg O_2/dm^3]	COD [mg O_2/dm^3]	$N\text{-}NH_4^+$ [mg N/dm^3]	$N\text{-}NO_3^-$ [mg N/dm^3]	Nog. [mg N/dm^3]	Pog. [mg P/dm^3]	$P\text{-}PO_4^{3-}$ [mg P/dm^3]
Raw wastewater (1)	550	1602	1.6	<0.1	18.0	12.1	3.2
Treated wastewater (2)	175	331	<0.5	<0.1	8.0	5.0	0.8

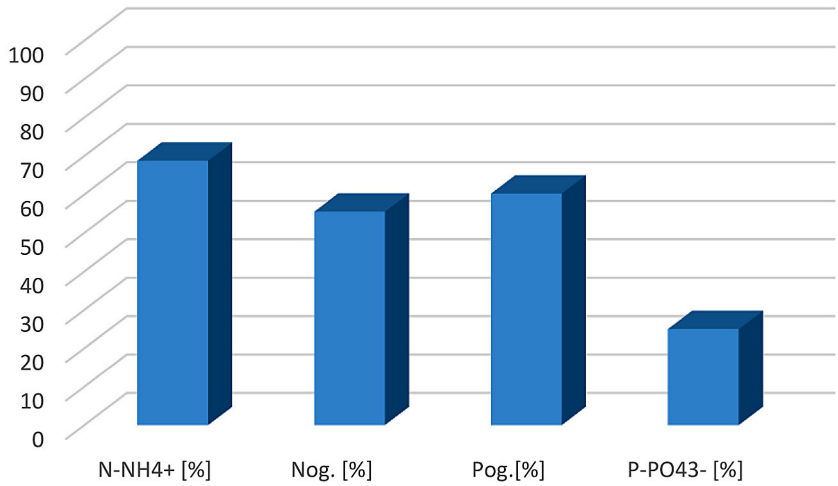

Figure 3. Total efficiency of nitrogen and phosphorus forms [%] on constructed wetland

so-called "de-loading" occurs, i.e. washing out earlier deposited phosphorus from the bed. The observed increase in the efficiency of phosphorus removal can refer to previous bed de-loading, thus re-improvement of the bed efficiency to phosphorus binding. Studies by Arias et al. [22] and Brix et al. [23] confirm the necessity to use filling with large amounts of iron in beds with vertical flow to improve the efficiency of phosphorus removal.

CONCLUSIONS

The analysis of the determinations allows for drawing the following conclusions:

1. Decrease in BOD_5 value in constructed wetland reached up to 68.2%, and that of COD_{Cr} – to 79.3%.
2. In case of the tested parameters, their considerable variability resulted from the way of production realized in a small fruit and vegetable processing plant, was apparent. It was characterized by periods of intensified production of fruit and vegetable juice as well as breaks of technological lines during which conservation and washing of devices operations were performed.
3. Organic matter was a general contaminant in wastewater from small fruit and vegetable processing facility.
4. When comparing the nitrogen compounds concentrations, it can be seen that organic fraction was predominant (91.1%). Remarkable part of organic nitrogen is characteristic for food industry plants.
5. The model was characterized by a high efficiency of total phosphorus removal, which was associated with previous "de-loading" of bed from phosphorus, thus re-improvement of its sorption capacity to bind phosphorus.
6. The final evaluation of the constructed wetland usefulness with vertical flow for treatment of wastewater from small fruit and vegetable processing plants requires further studies upon the efficiency of constructed wetland purification depending on temperature.

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