Polish J. of Environ. Stud. Vol. 17, No. 3 (2008), 377-381

Original Research

Evaluation of Effectiveness of Hydrophytic Wastewater Final Cleaning System at in Sierpc, Poland

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Received: September 12, 2007
Accepted December: 18, 2007

Abstract

This article is a study on final cleaning of wastewater in an experimental hydrophytic treatment plant. Wastewater was previously treated in a municipal wastewater treatment plant loaded with a significant amount of brewery sewage. This paper presents research results of the load of basic pollutants, a comparison between the effectiveness of treatment in vertical and horizontal flow plots and continuously or periodically flooded plots, the influence of brewery sewage inflow dynamics on both treatment effectiveness and treated sewage reaction. The results of the analysis indicate that the constructed wetland system is a relatively effective method. This system increases and stabilizes the efficiency of the wastewater treatment plant in Sierpc.

Keywords: hydrophytic systems; final cleaning of wastewater; effectiveness of pollutant removal; periodical; continuous; vertical; horizontal flow.

Introduction

An analyses of the municipal wastewater treatment plant operation in Sierpc revealed a high load of brewery sewage in municipal wastewater, and seasonal quantitative and qualitative variation of brewery wastewater inflow. These dynamics influence the wastewater treatment plant operation and make it difficult to achieve stable and required effectiveness of the treatment [1, 2, 5].

The experimental hydrophytic system was built in the wastewater treatment plant area to perform final cleaning of 1/1000 parts of wastewater treated in the wastewater treatment plant and to increase and stabilize the effectiveness of the wastewater treatment plant operation [3-6].

Constructed wetland systems are used worldwide as an alternative method of wastewater treatment at various treatment steps, including the third step [5, 7, 8, 9]. However, there is still a need for research on the possibility of using these systems for final cleaning of specific industrial sewage.

Experimental Procedures

The research was carried out in a hybrid constructed wetland system with underside wastewater flow (VSB type) [5]. The effectiveness of wastewater final cleaning (in the whole hydrophytic system at beds flooded continuously or periodically with wastewater, and at vertical and horizontal wastewater flow through beds), accuracy and effectiveness of applying the hydrophytic method of mu-

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nicipal wastewater final cleaning, and the possibility for the proposed method to be used in the wastewater treatment plant in Sierpc.

The results of the measurements of wastewater physiochemical characteristics (COD, BOD_5, suspended solids, nitrogen, phosphorus, pH) were the basis for the analyses [6].

Results and Discussion

The analysis of daily loads of pollutants in the inflow to the hydrophytic system in particular years presented a high variation. It was connected with the Sierpc wastewater treatment plant operation (Fig. 1). An unusually high load of organic substances and suspended solids in the system was reported in the inflow in 2004.

On the other hand, the daily loads of basic pollutants in the outflow from the hydrophytic system decreased every year of operation (Fig. 1). In the third year of operation, loads of organic substances, total suspension and total phosphorus decreased markedly in the outflow in comparison with loads of these substances in the inflow.

Loads of total nitrogen in the outflow also decreased continuously, but to a lower extent than those of other pollutants.

The results of the analyses of nitrogen forms and total nitrogen performed in autumn in the third year of operation are presented in Table 1. The concentration of nitrogen forms in wastewater released from the system was very low, thus wastewater was classified as surface water of quality class I. The average effectiveness of removing ammonia nitrogen was very high and amounted to 96.88%, and the average effectiveness of removing nitrate nitrogen (III) amounted to 97.45%.

It must be stated that the concentration of pollutants in the inflow to the hydrophytic system varied significantly, whereas the concentration of pollutants in wastewater put to final cleaning was stable and decreased every year of operation. The effectiveness of wastewater final cleaning increased systematically [6].

Comparison between Continuous and Periodical Wastewater Feeding

In the first year of operation, major differences between continuous and periodical flow plots were determined in relation to the concentration and effectiveness of final cleaning, and when a run-in period for beds had been finished, these differences became inconsiderable (Figs. 2 and 3).

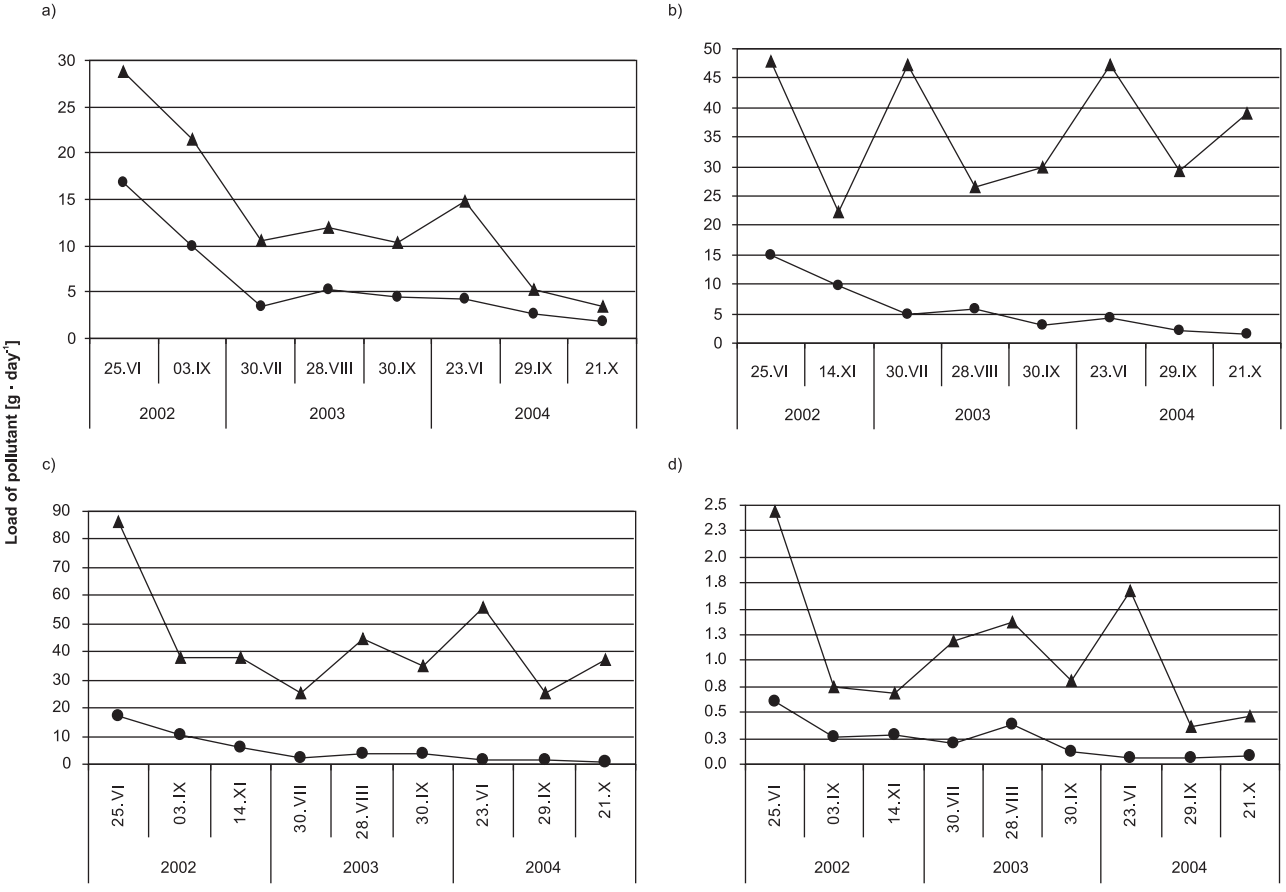

Fig. 1. Daily average loads of pollutants in system inflow and outflow in 2002-04: a) total nitrogen, b) suspended solids, c) BOD_5, d) total phosphorus. (▲ = inflow, ● = outflow).

Table 1. Nitrogen concentration in inflow to the system (samples 0), in outflow from vertical flow plots (samples A1-A4), and in outflow from the system (samples B1-B4) determined on October 21, 2004 [mg·dm^{-3}].

Parameter	0	A1	A2	A3	A4	B1	B2	B3	B4
N- NH_4^+	0.58	0.02	0.03	0.03	0.03	0.01	0.01	0.02	0.03
N- NO_3^-	1.6	2	1.9	1.9	2.4	2.2	1	3.5	4
N- NO_2^-	0.053	0.005	0.012	0.012	0.006	0.001	0.003	0.001	0.001
Total nitrogen	4.2	3.1	3.7	4.1	4.2	3	2.1	4.4	5

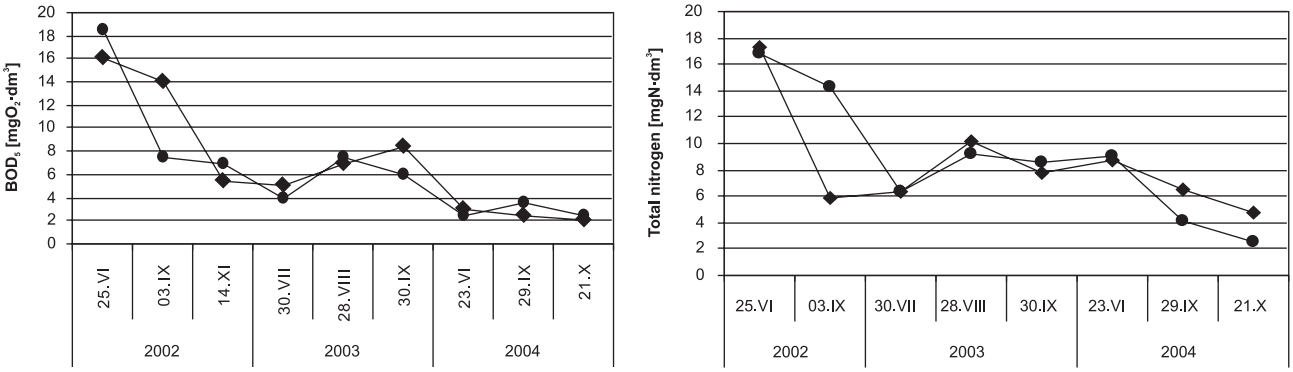

Fig. 2. Comparison between BOD_5 and total nitrogen concentration in wastewater outflow from continuous (◆) and periodical (●) flow plots in 2002-04.

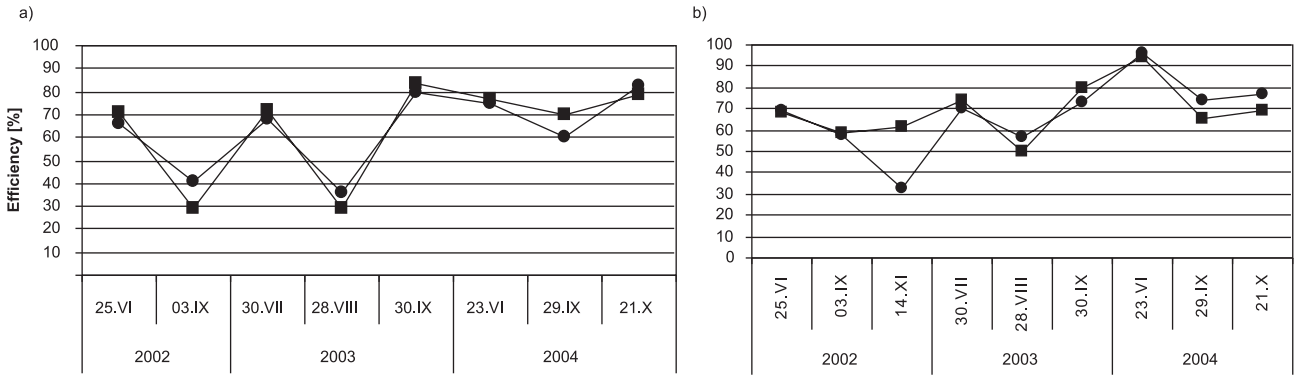

Fig. 3. Comparison between: a) COD and b) total phosphorus removing from wastewater in continuous (■) and periodical (●) flow plots in 2002-2004 [%].

Total suspension and organic substances were slightly more effectively removed in the third year in continuous flow plots than in periodical flow plots. However, total phosphorus was a bit more effectively removed in periodical flow plots (Fig. 3).

The effectiveness of removing total nitrogen in continuous and periodical flow plots differed from each other to a higher extent in the whole research period than other indices. The comparison between total nitrogen concentration in 2004 looked at inflow to the system (tests 0), in flowing through the system, in the outflow from vertical flow plots (samples A), and in the outflow from the system (samples B). The results show that nitrogen concentration decreased regularly when flowing through cascade 2 (continuous flow), and at the same time the effectiveness of final cleaning in this arrangement was satisfactory and higher than that of cascade 3 with the periodical flow (Fig. 4).

Evaluation of Effectiveness of Vertical and Horizontal Flow Plot Operation

On the basis of the results (Fig. 5) it can be stated that the vertical flow plots were the elements determining removal of organic substances from wastewater. On the other hand, as far as total nitrogen is concerned, a comparative share of the vertical flow plots and horizontal flow

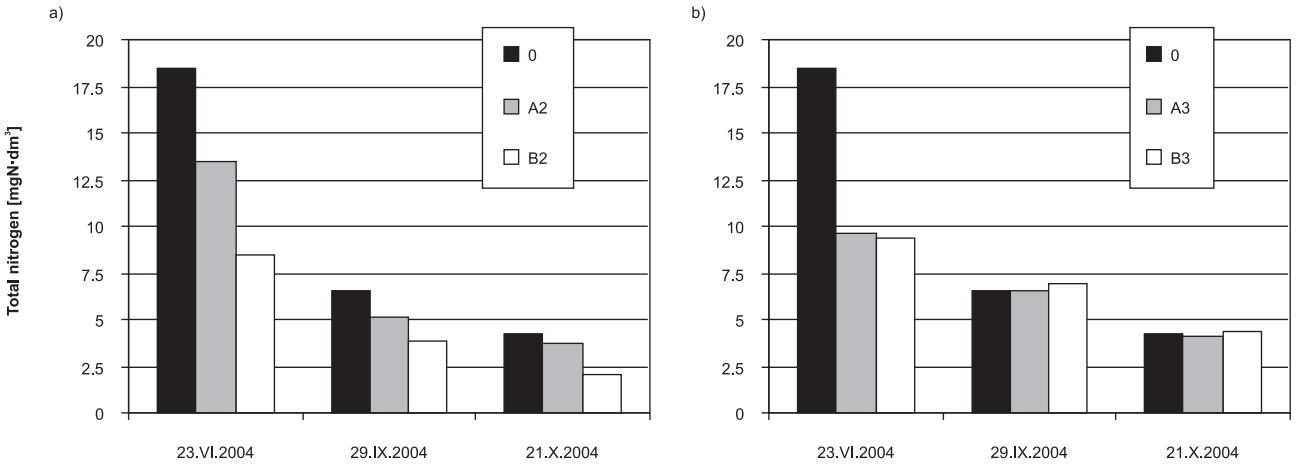

Fig. 4. Comparison between total nitrogen concentration in wastewater flowing through: a) cascade 2 (continuous flow) and above-mentioned concentration in wastewater flowing through: b) cascade 3 (periodical flow) in 2004. Black symbols= inflow to the system (samples 0), grey symbols= vertical flow plots (samples A2, A3), white symbols=horizontal flow plots (samples B2, B3).

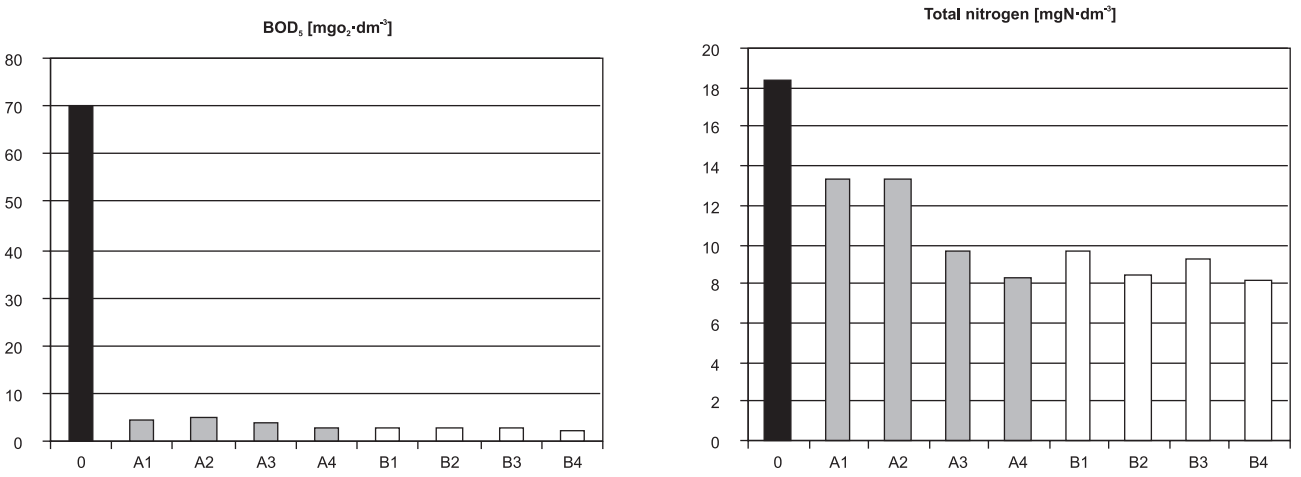

Fig. 5. Concentrations of selected indices of pollutants in inflow to the system (samples 0=black symbols), in vertical flow plots (samples A1 – A4=grey symbols) and horizontal flow plots (samples B1 – B4=white symbols) determined on June 23, 2004.

plots continuously flooded was revealed. The vertical flow plots had a major impact on removing total nitrogen in periodically flooded plots.

The analysis of the results of pollutant concentration and the final cleaning effectiveness in the vertical and horizontal flow plots confirmed that the arrangement of both vertical and horizontal flow plots (VF-CW – HF-CW) should be taken as an entire hybrid system in which wastewater was put to final cleaning flows in series [5].

Quantitative and Qualitative Dynamics of Brewery Wastewater Inflow and Final Cleaning Effectiveness

Research proved that the wastewater treatment plant specifically defined by working parameters played a significant role in the operation of the experimental object. The concentrations and loads of pollutants in inflow to the system were higher each year in months of increased production in the brewery, mainly in June and July. Despite the increased load of pollutants in the system, the effectiveness of final cleaning was high. It was possible thanks to the fact that roots and reeds are growing intensively during summer months, creating higher demand for nutrients.

Reaction of Wastewater Put to Final Cleaning in Hydrophytic System

Fig. 6 presents the results of pH measurements in wastewater in the inflow to the system (0), in the outflow from vertical flow plot (A4), and in the outflow from horizontal flow plot (B4) of cascade 4 with periodical wastewater flow. A nitrification was effective due to favourable

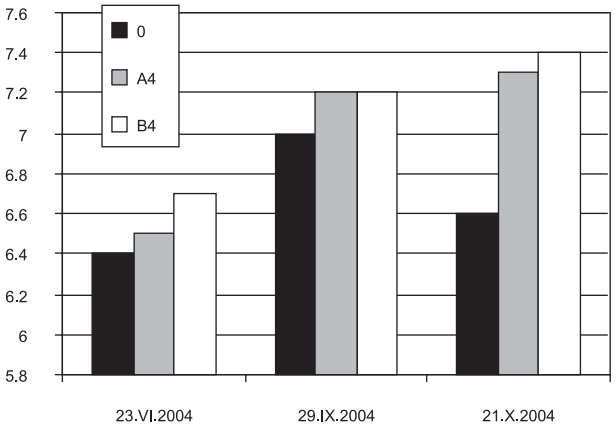

Fig.6. Results of pH measurements in wastewater flowing through cascade 4 in 2004.
Black symbols= inflow to the system (samples 0), grey symbols= vertical flow plots (samples A4), white symbols=horizontal flow plots (samples B4).

pH (range of 6.5 to 8) and removing a significant amount of organic substance susceptible to biochemical decomposition (BOD_5) from wastewater in the vertical flow beds. Wastewater reaction in the system (mainly in horizontal flow beds) favoured denitrification to run effectively. Alkalinity increased (higher pH) in this process, which was confirmed by research results (Fig. 6).

The value of pH in all samples of wastewater that were put to final cleaning did not exceed the range of surface water class I. The average pH of wastewater in the outflow in the whole research period amounted to 7.02. It may be stated that the wastewater reaction in various points of the system favoured processes occurring in hydrophytic system [5].

Conclusions

Operation of many municipal wastewater treatment plants in the world significantly depends on wastewater discharge from the agricultural and nutritional industries. The research results showed that applying a hybrid-constructed wetland system as the third treatment step is effective for final cleaning of wastewater because it stabilizes and increases the effectiveness of operation of the wastewater treatment plant in Sierpc.

In order to obtain the maximum effectiveness of treatment in relation to basic pollutants, it is recommended to continuously and regularly feed beds with wastewater, although satisfactory effectiveness may also be obtained if periodic flooding is applied – four times a day in 2.5-hour cycles.

A vegetation period in which the system showed the highest possibilities for effective final cleaning of wastewater coincided with a period when production in the brewery reached the highest level and with an increase of load of pollutants flowing into the wastewater treatment plant.

The conducted research and results should be checked and verified in other objects with similar conditions of wastewater inflow from agricultural and nutritional industry to municipal wastewater treatment plants. The following issues seem to be of vital importance: durability of hydrophytic system, changes of technical and operating parameters of beds, effectiveness of final cleaning in low temperatures, dynamics of hydraulic capacity of the system and also ensuring that plants are being unfailingly and regularly fed with treated wastewater.

Performing further research appears to be purposeful to explain a mechanism of processes that occur in hydrophytic wastewater treatment plants and to define their competitiveness in relation to other known solutions.

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