

EFFICIENCY OF WASTEWATER TREATMENT IN CONSTRUCTED WETLANDS IN POLAND

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Abstract

This paper presents the results of observation of four sewage treatment plants acting as biofilters which duplicate natural processes to treat wastewater by combining two basic environments: plants and land or soil. Constructed beds of wetland plants are excavated, lined with an impermeable layer, and filled with soil or land. The flow through the wetland medium is the main criterion of constructed wetlands division (the surface flow (SF) or subsurface flow (SSF)). However, another criterion can be also distinguished with respect to filling – filled with natural soil (SCW) or filled with a land mixture (LCW).

The beds in Mroczen and Brzezno are designed for purification of domestic wastes from housing and the local school building (Mroczen). In these two constructed wetlands poplars, willows, reeds and a mixture of grasses have been planted on their beds' surface while in the constructed wetlands in Paszkow and Kletno only reeds have been applied as planting. They purify wastewater all year round. Constructed wetlands in Paszkow and Kletno are examples of LCW whereas constructed wetlands in Brzezno and Mroczen are examples of SCW.

Constructed wetlands have been designed to treat domestic wastewater after mechanical cleaning in septic tanks, which are essential for their efficiency.

Physico-chemical analyses of domestic sewage samples departing from settlers as well as treated sewage samples departing from the biological parts were analyzed. In collected samples the following parameters were determined: BOD₅, COD, ammonium nitrogen, total nitrogen, total phosphorus, suspension.

The constructed wetlands in Brzezno have been observed for the longest time. They have been purifying domestic wastewater from the surrounding villages from 1997 to 2010. That object is characterized by the highest treatment efficiency regarding observed parameters. The lowest pollution reduction was found in LCW.

Observed purification effectiveness for analyzed objects is 74–98% for BOD, 52.4–90% for COD, 45.3–98.6% for phosphorus, 48.9–97.7% for total nitrogen, 71.8–99.7% for ammonium nitrogen.

1. Introduction

This paper presents a brief overview and comparison of the purification effectiveness and research results of four constructed wetlands (CWs). The constructed wetlands have been used for wastewater disposal in Poland dating back to 1990s, especially in north Poland, but also in the south for example Lower Silesia Province.

One of the most common applications of CWs has been treatment of primary or secondary domestic sewage effluent. Constructed wetland systems modeled after those for domestic wastewater are being used to treat the high organic loads associated with agriculture (EPA-manual 2007).

Removal efficiency and water quality parameters (total suspended solids (TSS) and BOD₅) is also a matter of constant researchers attention (Giri R.R. et al. 2006, Kadlec R.H et al. 2000, Koottatep et al. 1997). The efficiency of CWs at the removal of BOD₅ and TSS is usually very high, but nitrogen compounds and phosphorous removal in most of the present generation of operating wetland systems (predominantly horizontal flow beds) are not sufficient mainly due to insufficient supply of oxygen (U.S. EPA, 1993, Reed, S.

C. and Brown, D., 1995). There are also disadvantages of CWs, such as slow treatment rate, large land area requirement or wastewater exposure (Jing et al., 2008), impeding the wide application of the systems. In Poland, based on the Polish legislation, water management authorities require, throughout the whole year, continuous treatment of pollution at wastewater treatment plants (WWTP) under 2000 population equivalents (PE). The maximum value of suspended solids is $50 \text{ mg}\cdot\text{l}^{-1}$, $30 \text{ mgN}\cdot\text{l}^{-1}$ for total nitrogen and $5 \text{ mgP}\cdot\text{l}^{-1}$ for phosphorous if the receiver is a lake or its tributary. The monitored CWs fit quite well within the higher treatment efficiency requirements.

Site description

The Brzezno CW is assigned to annual wastewater tapping, and is located in Brzezno village (Lower Silesia Province). The CW consists of proportioning – storage tank where a batch of wastewater, which is equivalent with daily output (100 m^3) of municipal wastes, is accumulated. The biological part (biofilter) is split into 21 plots (landfill cells) – each of 0.11 ha of area. Poplars and combination of grasses have been planted on their surface. The plots are separated by land dyke with draining system on the depth of about 1.0 m. The draining system is responsible for carrying away purified wastewater – to receiving body of water.

The municipal wastewater has to be mechanically cleaned before accessing the biofilter. Mechanical cleaning is provided in three-chamber settling tanks, located in the village. Each plot should be irrigated every 21 days (average) with wastewater amount equal to 97 mm. The details of construction and principle of Brzezno and Mroczen operations are set up in (Pawęska K., Kuczewski K., 2008).

Another two constructed wetlands are placed in Klodzko valley (mountain region) in Lower Silesia. They are composed of four beds (series and combination) with subsurface wastewater flow. On the surface there are reed plantings. Paszkow CW is designed for municipal wastewater of holiday resort. Municipal wastewater after mechanical treatment are gravity-fed to first bed, and then to smaller beds 2 and 3. The surface of the constructed wetlands is exploited all the year round. Kletno CW is composed of four beds of the same size, designed as cascade. Special construction of outflow for each bed (chained flexible ending) enables individual control of wastewater level in each of bed. The bed surface is also reed-planted, however planting maintenance is difficult because of shade influencing the vegetation. Wastewater treatment plant (Kletno) purifies wastewater from holiday resort. This object also works all year round including winter, in difficult conditions caused by snowfalls (Paweska et al 2009).

Materials and Methods

The samples were collected once a month in period between 2008 and 2009. Samples after septic tank, and samples of purified sewage the following parameters were evaluated quantitatively for:

- total nitrogen – using MerckTest, and spectrophotometer WTW Spectroflex 6600, mineralization
- ammonium nitrogen – using K_2HgJ_4
- BOD_5 – determined respirometrically by OxiTop apparatus
- COD – determined colorimetrically
- suspended solids – using weight method
- phosphours – using MerckTest and spectrophotometer WTW Spectroflex 6600, mineralization

Determination was made max 2 hours after sampling according to valid ordinance (Polish standards).

Results and discussion

Deposits of soil-plant-soil work for the wastewater treatment throughout the year. Their effectiveness is related to adverse weather conditions (especially air temperature) that impact the pollution reduction as well as the time at which they reach full capacity (4 to 5 years).

Wastewater treatment plant–soil in Brzezno, working well under natural conditions throughout the year (plant–soil bed) is one of the objects with a 10–year observation period. Effectiveness of the work after such a long time has not reduced significantly. Removal efficiency of BOD₅ was 98,5% compared to the outlet mean concentration. The mean inlet phosphorous concentration during study period was reduced by 98,6% compared to the outlet mean concentration. The average concentration of total nitrogen was reduced by 99,8%.

In case of Mroczen CW the removal efficiency of BOD₅ was about 98,7%, the total nitrogen was reduced by 97,6% and for the concentration of phosphorous the efficiency was about 98,6%.

The Paszkow CW's removal efficiency of BOD₅ was 98,25% compared to the outlet mean concentration. The concentration of total nitrogen was reduced by 65,13% and for the concentration of phosphorous the efficiency was about 56,68%. The Kletno CW's removal efficiency of BOD₅ was 70,8% compared to the outlet mean concentration. The mean inlet phosphorous concentration during study period was reduced by 65,95% compared to the outlet mean concentration. The average concentration of total nitrogen was reduced by 81,89%. The findings of this research showed that there was a significant difference between purification of waste. The phosphorus and nitrate load removal values are in the lower range of values found in the literature.

Conclusions

The study was aimed to determine the efficiency of constructed wetlands and to compare the removal ability of different substrates. CWs are facilities where wastewater treatment is purified in comprehensive manner.

The results indicate high removal efficiencies particularly for BOD as well as TSS. The efficiency of nitrate compounds removal is quite low and varies when compared with BOD.

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