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The efficiency of hybrid constructed wetland systems

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Domestic sewage treatment plants are becoming more popular in rural areas where there are scattered buildings and the construction of the sewage system is very costly or impossible. As part of the implementation of the provisions of Directive 91/271/EEC of 21 May 1991 concerning urban waste water treatment, the Polish area was deemed sensitive to eutrophication, i.e. requiring the reduction of discharges of nitrogen and phosphorus to the water. Implementation of the Directive requires in the short term, i.e. until 2015 investment action construction, expansion and modernization of sewage treatment plant and sewerage systems, and in areas with dispersed settlements should be installed in household wastewater. Local governments are increasingly willing to invest in the construction of sewage treatment funds from environmental funds or the EU.

Scientific problem, how it was solved in this doctoral thesis can be formulated in the form of questions: 1) what is the efficiency of contaminant removal in hybrid soil-plant wastewater treatment plants, 2) what is the efficiency of production of biomass products used in the analyzed systems? In order to solve such a problem posed in this research work, it was necessary to carry out tests under field conditions in two sewage treatment plants and ground plant located in the Lublin province in towns Dąbrowica (four-stage system VF-HF-HF-VF) and Skorczyce (two-stage hybrid system VF-HF). The objects used in these energy crops, such as common reed (*Phragmites australis* Cav. Trin. Ex Steud.), Basket willow (*Salix viminalis* L.), Jerusalem artichoke (*Helianthus tuberosus* L.) and giant miscanthus (*Miscanthus giganteus*).

Studies on the removal efficiency in two selected constructed wetland systems was carried out in 2011-2013. In order to determine the efficiency of the wastewater treatment plant performed the analysis of the physical-chemical and microbiological wastewater from various stages of purification. Samples of sewage into the physical-chemical analyzes were collected in different seasons: winter (February), spring (May), summer (August) and autumn (November) in each year of the study, according to European Union standards (PN-74/C-04620 / 00, BS EN 25667-2: 1999). Sampling dates were to reflect the change in seasonality in the Polish climate.

The collected samples of water and wastewater determined: temperature, pH, oxygen concentration, suspended solids, BOD<sub>5</sub>, COD, the concentration of total nitrogen, total phosphorus, nitrate, nitrite, ammonium, chloride and sulphate, and the number of total coliforms, fecal coliforms and enterococci stool. The study also determined the efficiency of biomass production and analysis were performed physical-chemical treatment plants that inhabit the analyzed constructed wetland systems. Biomass Research performed in an accredited laboratory of the Department of Energy Measurement and Research "ENERGOPOMIAR" Sp. with o.o. based in Gliwice and included determination of the following parameters: heat of combustion, calorific value, total moisture, ash, total sulfur (S) content of hydrogen (H), carbon (C), nitrogen (N), phosphorus (P), potassium (K), heavy metals: As, Pb, Cd, Cu, Zn, Hg.

In the studied hybrid constructed wetland systems achieved high - over 96% of the effects of the elimination of organic pollutants (BOD<sub>5</sub> and COD) and total suspended solids removal. Average size of the examined indicators of pollution in treated wastewater were several times lower than the limit values laid down in the Regulation of the Minister of the Environment in 2006. Analyzed systems provide 58% of total nitrogen removal efficiency. Minor effects of nitrogen removal indicate that in such systems is necessary to create better conditions for the denitrification process. Examined treatment provide 75-77% effective in eliminating phosphorus. The removal efficiency of phosphorus in these types of facilities can be enhanced by using a bed of filler material, e.g. containing a high content of iron, aluminum or calcium. Hybrid constructed wetland systems provide removal efficiency of 99.99% coliforms, faecal coliforms and fecal enterococci. Number of test bacteria in treated sewage were generally lower than those observed in surface waters in Polish . No negative impact of treated wastewater discharged from the facility No. 2 in Skorczyce on the water quality of the Urzędówka river.

From our analysis it can be concluded that the hybrid constructed wetland systems enables effective protection of the natural environment in the not-rural areas. Our findings may be an important step in the search for high-technology sewage disposal, to ensure effective protection of the aquatic environment, with low operating costs.

The results presented in the trial may have direct practical application to the design and construction of high-efficiency, hybrid constructed wetland systems, which in addition to wastewater treatment at the same time it will be possible the production of plant biomass for energy purposes. The wider use of such systems in the future may help to improve the energy efficiency of the local environment by using renewable energy sources - biomass produced

while operating a sewage treatment plant. The experiences and research results presented in this work will benefit local governments that want to solve the problem of wastewater management in their area through the construction of sewage treatment plants. The widespread use of hybrid soil- plant wastewater treatment plants in Poland can contribute to improving the quality of surface water and groundwater and the reduction of greenhouse gas emissions.