Use of vegetation for the removal of pollutants from wastewater as an alternative environmental technique for wastewater treatment

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Abstract. The paper focuses on the evaluation of the use of vegetation for the removal of contaminants from wastewater through vegetation-based wastewater treatment plants. Subsequently, the specific efficiencies of wastewater treatment using a selected vegetation-based wastewater treatment plant are evaluated. The results show that vegetation-based wastewater treatment plants generally work at relatively high treatment efficiency, but one of the main factors influencing the treatment efficiency is the values of pollution indicators at the inflow to the wastewater treatment plant.

1. Introduction
In the past decades, Europe has made significant efforts to improve surface water quality, treat wastewater and protect marine and freshwater habitats and species [1]. However, according to the EEA’s most recent data [2], only about 40% of surface waters in Europe are in good chemical status. In the field of wastewater treatment, much has been done across Europe to enable the collection and treatment of urban wastewater. The percentage of the population connected to wastewater treatment in the Southern, South-Eastern and Eastern Europe has increased over the last ten years [3], but still, in a number of European countries less than 80% of the population is connected to public urban waste water treatment systems [1]. It should be noted that in the countries of Central and Eastern Europe, almost 30% of the total population live in municipalities with less than 2,000 inhabitants [4]. One of the methods of wastewater treatment in small settlements is the use of biological methods of wastewater treatment. They are based on the principle of imitating and intensifying self-cleaning processes that take place in waters and wetlands in the nature [5, 6]. The first experiments using wetland plants for wastewater treatment were carried out in Germany in the early 1950s [7]. Since then, the constructed wetlands have evolved into a reliable wastewater treatment technology for various types of wastewater [8]. At present, natural wastewater treatment plants (WWTPs) are implemented to a limited extent in the region of Central and Eastern Europe. There are countries that have long-term good experience with this type of process, such as Poland, the Czech Republic and Slovenia and vice versa other countries such as Slovakia, Romania and Bulgaria have minimal or no experience with root-zone WWTPs [4, 9]. The Institute of Environmental Policy of the Slovak Republic states that according to a survey from 2012, there were 10 natural WWTPs in Slovakia, of which 5 were root-zone treatment plants, while there are already approximately 690 functional natural WWTPs in the neighboring Czech Republic, including larger facilities for municipalities with more than 1,000 PE. There are more than 5,500 of them in Austria, of which about 70% are built for 20 equivalent inhabitants [9]. It is necessary to strengthen awareness of vegetation-based WWTPs with the use of root-zone technology at the institutional and local level and to support the application of good practice, as these have the potential
to produce lower amounts of greenhouse gases, create a place for biodiversity and aesthetically pleasing the shape of the landscape.

2. Evaluation of the wastewater treatment efficiency using a vegetation-based wastewater treatment plant

The paper focuses on the evaluation of the treatment efficiencies of vegetation-based wastewater treatment plants and their comparison in the villages of Lužany near Topľa in the Slovak Republic and Hostetín in the Czech Republic. These wastewater treatment plants use the root zone technology as one of the low cost methods to treat wastewater. Wastewater pollution was characterized by parameters: chemical oxygen demand (COD), biological oxygen demand (BOD$_5$) and insoluble particles (IP).

2.1. Characterization of treatment plants

The root-zone wastewater treatment plant in Lužany near Topľa (figure 1) was put into operation in 1996 for a population of 250 PE (population equivalent). WWTP is used to treat wastewater from a mechanical WWTP. The filter area is 440 m$^2$ (20x22m). Treatment zone consists of the aquatic plant Phragmites australis, which is mowed once a year. The average daily inflow of wastewater is 31 m$^3$ per day. The treated wastewater is discharged into the river Topľa. Contamination of the recipient after mixing with wastewater is 1.5 mg / L BOD$_5$, while the limit value according to the requirements for surface water quality [10] is 7.0 mg / L BOD$_5$ and is not exceeded.

![Figure 1. Vegetation-based wastewater treatment plant in Lužany near Topľa, SR.](image)

The root-zone WWTP built in the village of Hostetín in Central Moravia in the Zlín Region (figure 2) was put into operation in July 1996. It is designed for 280 PE. It consists of two filter fields, which occupy an area of 1240 m$^2$. The wastewater flow is horizontal. The average daily inflow is 47.6 m$^3$ per day. Treatment zone consists of the aquatic plant Phragmites australis and Phalaris Baldingera Arundinacea [11].
2.2. Results and discussion

The values of pollutants monitored at the inflow and outflow from both vegetation WWTPs are shown in tables 1 and 2. Subsequently, the treatment efficiencies of the WWTPs were calculated and compared with the limit values of pollution indicators according to the relevant legislation valid for the country according to [10] and [13].

Table 1. Efficiency of WWTP in the village of Lužany near Topľa (SR) according to the regulation of the Government of the Slovak Republic no. 269/2010 [10].

| Indicator    | Inflow (mg/L) | Outflow (mg/L) | Limit concentration of pollution in outflow (mg/L) | Treatment efficiency (%) |
|--------------|---------------|----------------|-----------------------------------------------------|--------------------------|
| COD          | 83            | 45             | 135                                                 | 46                       |
| BOD<sub>5</sub> | 12.2         | 4.8            | 30                                                  | 61                       |
| insoluble particles | 82          | 14             | 30                                                  | 83                       |

Table 2. Efficiency of WWTP in the village of Hostetín (CR) according to the regulation of the Government of the Czech Republic no. 401/2015 [13].

| Indicator    | Inflow (mg/L) | Outflow (mg/L) | Limit concentration of pollution in outflow (mg/L) | Treatment efficiency (%) |
|--------------|---------------|----------------|-----------------------------------------------------|--------------------------|
| COD          | 120.5         | 28.2           | 150                                                 | 77                       |
| BOD<sub>5</sub> | 51.9         | 7.1            | 40                                                  | 86                       |
| insoluble particles | 30.1        | 14.4           | 50                                                  | 52                       |

The above mentioned tables show that the values of pollution of treated wastewater measured at the outflow from these monitored WWTP meet the limit values of indicators according to the requirements for surface water quality in the concerned country. The legislative requirements for the quality of treated wastewater are slightly stricter in Slovakia compared to the Czech Republic. From the comparison of wastewater treatment efficiencies, it can be stated that the achieved treatment efficiency was higher in the Czech Republic by approximately 30% compared to the Slovak Republic in the BOD<sub>5</sub> indicator and even 40% higher in the COD indicator. On the other hand, insoluble particles were removed from WWTP in the Slovak Republic almost 60% more efficiently than in the Czech Republic.
It should be noted that the root-zone wastewater treatment plant in the village of Lužany near Topľa is included as a final treatment stage. This means that the wastewater is already pre-treated and the values of the COD and BOD₃ pollution indicators meet the limit values already at the inflow to the WWTP. This explains the lower treatment efficiency expressed by these indicators compared to WWTP in the Czech Republic. As for insoluble particles, they are treated in WWTP in Slovakia with relatively high efficiency. Vegetation / root-zone wastewater treatment plants generally work on a relatively high efficiency of contaminated water treatment depending on several factors such as climatic conditions, type of used vegetation, length of the filter area, retention time of water in the filter area, as well as input values of inflowing water pollution [14].

3. Conclusions
The paper summarizes the comparison and evaluation of the treatment efficiencies of vegetative wastewater treatment plants in two municipalities in the Slovak Republic and the Czech Republic. Wastewater treatment efficiencies expressed by COD, BOD₃ and insoluble particles were compared. The results showed that although the vegetation root wastewater treatment plant in the Czech Republic shows higher values of efficiency for removal of pollutants expressed by COD and BOD₃ indicators compared to the Slovak Republic, this situation is influenced by the fact that the vegetation root wastewater treatment plant in Slovakia is classified as a treatment stage and the wastewater is already pre-treated. Thus the values of the COD and BOD₃ pollution indicators meet the limit values already at the inflow to the root wastewater treatment plant. As for the removal of insoluble particles, they are treated in WWTP in Slovakia with relatively high efficiency. The values of pollution indicators in selected WWTP in the monitored period complied with the limit values of pollution indicators at the outflow into surface waters according to valid regulations in the Slovak Republic and the Czech Republic.

In conclusion, it can be stated that root-zone treatment plants generally work on relatively high treatment efficiency and one of the main factors influencing the treatment efficiency is the values of pollution indicators at the inflow to the wastewater treatment plant. Under certain conditions, they appear to be a suitable alternative for the treatment of wastewater from smaller sources from an environmental, aesthetic and economic point of view, as they do not represent a strong negative impact on the landscape and their operating costs are minimal.

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