COMBINED BIOREACTOR AS AN EFFECTIVE DEVICE FOR REDUCING PESTICIDE AND NITRATE CONTAMINATION OF SURFACE WATER AND THUS INCREASING THE ECOLOGICAL AND RECREATIONAL POTENTIAL OF THE AREA

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Abstract
This study deals with the development and testing of an innovative combined bioreactor filled with wood chips from Populus nigra in Němčice (Blansko district). The bioreactor was designed as an innovative system for the removal of nitrates, pesticides and other pollutants from surface and drainage water. The bioreactor was put into test operation in September 2023. Its operation is aimed at evaluating the efficiency of denitrification, degradation of pesticide substances, stability of biological processes and long-term functionality of wood chips as a substrate. Results to date have shown the high efficiency of the bioreactor in reducing nitrate concentrations (up to 90%), and pesticide concentrations (up to 35%), with water residence time, water temperature, and microbial activity being key factors. The study confirms the potential of Black Poplar wood chips as a sustainable material for bioreactors and contributes to the development of environmentally friendly solutions for water resource protection. Improving the quality and quality of surface water and water resources contributes to the ecological and recreational potential of the area.

Key words: wood chips, bioreactor, water quality, pecticides, nitrates

Introduction
Contaminants in surface and groundwater are currently a significant water quality problem. In order to eliminate their input into groundwater, the researchers are looking at the use of denitrification bioreactor technology in the Czech Republic. Most often, wood-filled trenches are built at the edge of agricultural areas to support the natural process of denitrification - i.e., the conversion of nitrate (NO) to nitrogen (N) gas, which is subsequently released to the atmosphere (Wegscheidl, Robinson, 2022). This is a relatively simple, passive technology that is included among the official strategies for reducing nutrients in the environment in the USA (Christianson, Schipper, 2016).
However, in addition to nitrates, high concentrations of pesticides and veterinary drugs are also found in water runoff from farmed areas. Previous studies have suggested that these substances could be removed in a denitrification bioreactor by biodegradation and/or sorption to its fill (Aslan, 2005). For this reason, a combined bioreactor was designed, constructed, and put into test operation in the experimental catchment of the Nemcica River as part of a research project.

Methods and Results
The experimental catchment area “Němčice” was established in 2005. It has an area of 347 ha. This basin is terminated by a flood control polder (2012). In its vicinity, the watercourse is fitted with a gauged Thompson profile. The profile is equipped with instruments for continuous flow measurement, rainfall, surface water samplers. Research on the transport of nitrogen, phosphorus and pesticides in soil, sediment and surface water has been carried out in the experimental Nemcice catchment since 2019. The catchment represents typical upland conditions in the Czech Republic (Cambyses, 650 m above sea level) with sloping topography and intensive farming. Transport of substances from agricultural land to surface water bodies takes place here both with water erosion and subsurface runoff. In 2023, a combined woodchip bioreactor was built and started up in the catchment.

Construction design
The bioreactor is a circular polyethylene tank with a volume of 5 m^3. Dimensions 240x120 cm. The water residence time in the bioreactor is adjustable and depends on the set water flow rate, but also on the parameters of the filled wood chips.

The bioreactor includes a Fiedler data station equipped with probes placed at 3 levels of surface height (30, 60, 90 cm) for continuous measurement of temperature, pH, ORP (oxidation-reduction potential), dissolved O_2. The water inlet to the bioreactor and the water outlet from the bioreactor are equipped with ISCO automated samplers.

Fig. 1: Location of the combined bioreactor in the vicinity of the Thomspon gauge profile on the watercourse in k.u. Němčice

Basis of operation and monitoring

The bioreactor has a gravity feed of water from the watercourse through a water pipe from a weir located upstream. The bioreactor feed is wood chips from poplar trees. The plant acts as a biofilter in which pesticides and nitrates are broken down. The aim is to test the function and efficiency of the device under semi-operating conditions. The experimental plant has been in operation since September 2023. Water samples are taken weekly at the inlet (water from the watercourse) and at the outlet (water from the outlet of the bioreactor) of the bioreactor. Continuous sampling by means of ISCO automatic samplers during the day is also addressed.

Fig. 2 Combined bioreactor and surrounding equipment (ISCO sampler, telemetry station)

Fig. 3: View of the internal layout of the combined bioreactor including the woodchip chargé

Efficiency

After 1.5 years of operation, the overall efficiency of removal of the sum of pesticide substances is on average between 30 - 45% with a water residence time of about 10 hours in the bioreactor.

The nitrate removal rate is between 75-90 %. The potential of this plant is particularly in locations where there is a need to efficiently and economically remove pesticides and nitrates from water sources. The bioreactor is constantly under development. Experimentation with residence time, type of wood chips is ongoing. In the first six months of operation, the bioreactor was filled with wood chips from Japanese poplar of fine fraction (1-3 cm). Since 06/2024, the bioreactor has been filled with black poplar wood chips of coarser fraction (3 - 10 cm).

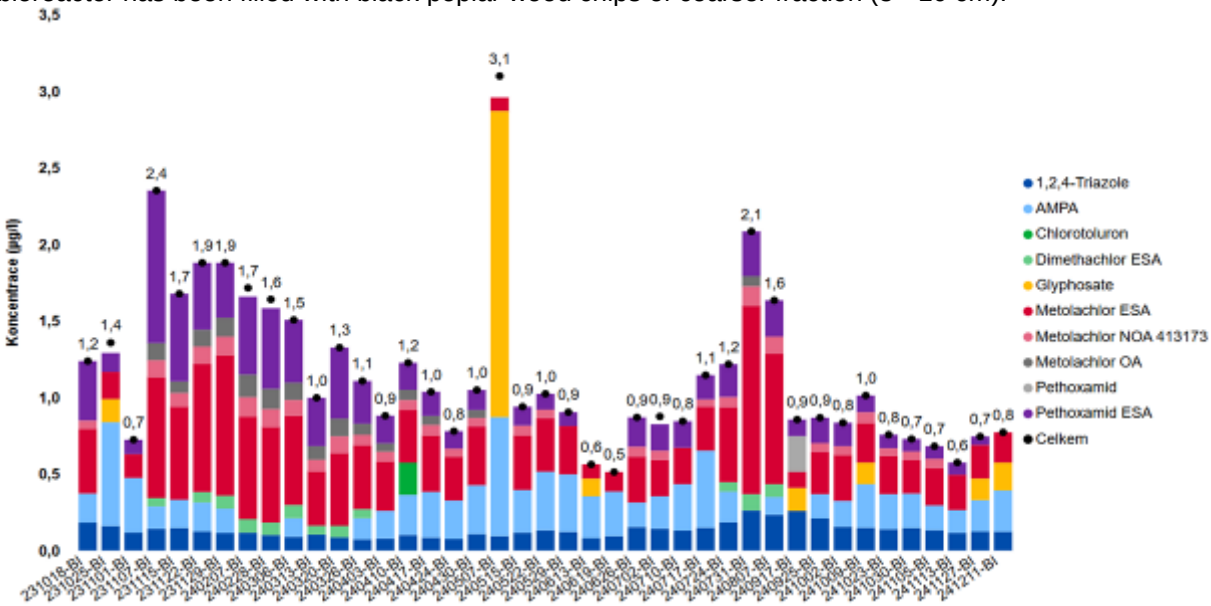

Fig. 4: Pesticide concentrations at the bioreactor inlet during weekly sampling from 10/2023 to 12/2024

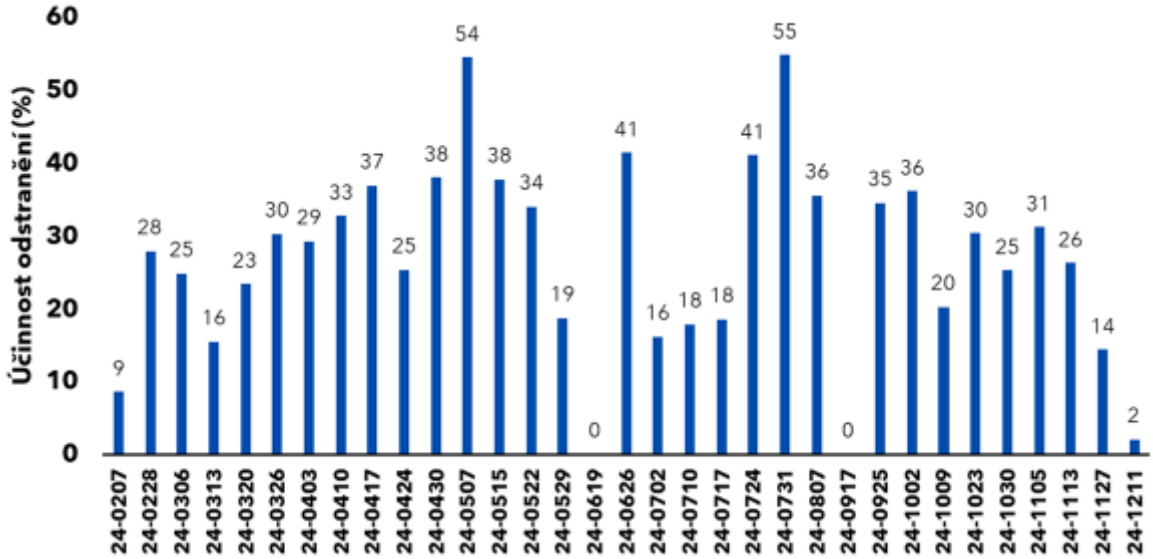

Fig. 5: Removal efficiency of the sum of pesticides at the bioreactor outlet in 2024

Maintenance and operation of the bioreactor

The bioreactor is designed to be maintenance-free. The only maintenance consists of water sampling at the inlet and outlet of the bioreactor, and maintenance of the measuring probes.

Conclusion

Combined bioreactors (biofilters) filled with wood chips are one of the options for reducing nitrate and pesticide concentrations from water. The device should serve as a preventive measure especially around vulnerable areas such as protected areas and water resource protection zones. It is conceptually linked to chipped denitrification bioreactors. The idea of simultaneous removal of pesticides and nitrates from agricultural runoff is based on the fact that pesticide substances sorb to wood chips in the order of tens of percent. Adsorption will lead to a reduction in their concentration in the aqueous phase and at the same time to a prolongation of their residence time in the bioreactor, which is one of the conditions for their biochemical degradation. In addition, biochemical degradation of pesticide substances can be supported by bioaugmentation/biostimulation approaches. Bioreactor testing also looks at chip properties - sorption capacity (versus extent of pesticide contamination), durability (especially porosity and hydraulic conductivity) and the effect of extreme climatic conditions.

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Souhrn

Tato studie se zabývá vývojem a testováním inovativního kombinovaného bioreaktoru plněného dřevní štěpkou z Topolu černého v Němčicích (okres Blansko). Bioreaktor byl navržen jako

inovativní systém pro odstraňování dusičnanů, pesticidů a dalších znečišťujících látek z povrchových a drenážních vod. Bioreaktor byl uveden do zkušebního provozu v září 2023. Jeho provoz je zaměřen na vyhodnocení účinnosti denitrifikace, degradace pesticidních látek, stability biologických procesů a dlouhodobé funkčnosti dřevní štěpky jako substrátu. Dosavadní výsledky ukázaly vysokou účinnost bioreaktoru při snižování koncentrací dusičnanů (až 90 %) a pesticidů (až 35 %), přičemž klíčovými faktory jsou doba zdržení vody, teplota vody a mikrobiální aktivita. Studie potvrzuje potenciál štěpky z topolu černého jako udržitelného materiálu pro bioreaktory a přispívá k vývoji ekologicky šetrných řešení pro ochranu vodních zdrojů. Zlepšení kvality a jakosti povrchových vod a vodních zdrojů přispívá k ekologickému a rekreačnímu potenciálu oblasti.

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