EXTENSIVE TECHNOLOGY USED FOR THE NITRATES REMOVAL FROM AGRICULTURAL RUNOFFS IN CZECH REPUBLIC

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ABSTRACT

The article stated a new and in the Czech Republic as yet unknown technology "denitrifying bioreactors”. This technology is designed to remove nitrates from agricultural areas. Within our research project, we test this technology first in the laboratory conditions. The input and boundary conditions correspond with the environment in Central Europe. We are looking for the optimal configuration including technical and economic parameters. The introduction of new technology in agricultural practice can significantly reduce the load surface water and groundwater by nitrates. Thus, it is possible to protect directly sources of drinking water, or prevent the eutrophication of water reservoirs. The technology is currently used mainly in the USA and Canada. It was developed to reduce nitrate levels in the effluent from "septic + nitrification filter + infiltration object" systems in 90s. Denitrifying bioreactors are to be used to remove nitrates from groundwater in New Zealand.

The bioreactor principle is a filtration of water with increased nitrate content through a suitable organic substrate. An organic material used serves as a medium, as well as carbon and energy source for growing facultative anaerobic microbial organisms. It also provides a suitable anoxic condition for the nitrate denitrification. Thus, the water with a reduced content of nutrients flows into the stream and the potential risk of eutrophication is reduced. Providing the water without the nitrate nitrogen flows into groundwater, there are no health problems if is this water used for drinking purposes. Featured Technology has many advantages: low investment cost, long life, low operating and maintenance costs, while requiring a small using of arable land, which is not also impaired for future agricultural use.

Laboratory research is focused on the initial operational problems, which are published only marginally. In our opinion, the most significant problem seems to be especially in the startup phase [8]. During the startup, high concentrations of organic compounds and ammonia or organic nitrogen are extracted. The worst material showed outflow concentration of chemical oxygen demand (COD) = 6243 mg/L, biological oxygen demand (BOD) = 1362 mg/L and nitrogen (NH_4-N) = 71.2 mg/L. Therefore, it is excluded in a next period for application in a pilot plant. We are still looking for the optimal composition of the substrate and technological parameters of the process. Results for incorporation at a suitable residence times demonstrate the applicability of

certain types of wood materials. By long-term operation, their efficiency at removing the NO_3-N is in the range of (48 - 97) % at relatively low concentrations of COD, BOD and NH_4-N (48, 33 and 0 mg/L).

In this article, we present the results of half-year laboratory measurement, during which we tested in the Czech Republic readily available materials and operating parameters.

Keywords: Agricultural drainage, Denitrification bioreactor, Nitrate, Woodchip.

INTRODUCTION

Denitrification bioreactors for agricultural drainage are one of the newest technologies being investigated for practical edge-of-field nitrate-nitrogen (NO_3-N) reduction. Promising early results from denitrifying bioreactors, also known as woodchip bioreactors, denitrification beds or biofilters or denitrification bioreactors, have led already in 2012 to increased attention over the past five years [3]. The Czech Republic has in the agricultural landscape frequent drainage systems. If the agricultural land intensively fertilizing, artificial drainage modifies the nitrogen cycle as well as the hydrologic cycle in agricultural systems. The relatively rapid transport of drainage water in tile drains decreases the time for natural processes like denitrification to occur [7]. Moreover, denitrification in soils can be carbon limited, especially at deeper depths without plant roots, significantly reducing the likelihood of the soil solution to be fully denitrified before it becomes drainage water [9].

DENITRIFICATION BIOREACTOR PERFORMANCE FACTORS

Many factors can affect bioreactor NO_3-N removal performance, including retention time, temperature, and microbiology [3]. Our results confirm this claim. Bioreactor longevity depends upon several factors, including the type and amount of carbon source (in our case the type of wood media), flow characteristics, consistency and level of saturation, and physical changes in the media over time [10]. Performance life estimates are often on the order of several decades, with empirical data showing at least 10 years saturation [3]. Less consistently water-saturated woodchips towards the surface of these systems will degrade more quickly than deeper-placed chips [2, 5]. Currently, most drainage bioreactors are designed for an expected life of at least 10 years [11].

Retention time

The retention time is based on the state equation. In the bioreactor is dictated by the reactor flow rates combined with media porosity and bioreactor flow volume. As shown our first results, very short retention times experienced in drainage denitrification bioreactors may not be sufficient to reduce the influent drainage dissolved oxygen to a level that allows denitrification to proceed. And conversely, very high retention times provide excellent NO_3-N removal but also the potential for oxidation reduction potentials (ORPs) indicative of undesirable processes, like COD outflow increase, sulfate reduction, thus accompanied with the odor indications. Other authors [6] reported NO_3-N concentration reductions of 10% to 40% at retention times of generally less than 5 h and 100% removal at retention times of 15.6 and 19.2 h.

Temperature

How is shown, the drainage water entering a bioreactor will likely have temperatures that vary seasonally, with early spring temperatures just above 0°C and late summer temperatures at greater than 15°C [4]. Denitrification in a bioreactor is influenced by water temperature. It is possible that sensitivity to temperature can be reduced using a combination of retention time and drainage water temperature. The main issues solved within our work include verification described method for removing nitrate from surface washes and drainage waters. We will verify the impact of the solution described for other nutrients, microbial contamination and quality of outflowing water in general. The main attention will focus on the observation of adaptation phase. Finally it is aim of performance the measures proposed parameters optimization. Based on the evaluation results, we will make a selection of the best and most effective materials for denitrifying bioreactors in the Czech Republic.

MATERIALS AND METHODS

Filter materials of organic origins are tested in a laboratory scale. We are designed columns as permanently saturated condition with a flow in the downward direction. All columns are placed in a special box, connected to the air conditioner with temperature control range (-40 to +90)°C. The height of filter columns is 100cm; a plan view is circular in cross section with a diameter of 30 cm. After flowing through filter material, the water flow upwards via flexible outlet pipe (it allows to control water level).

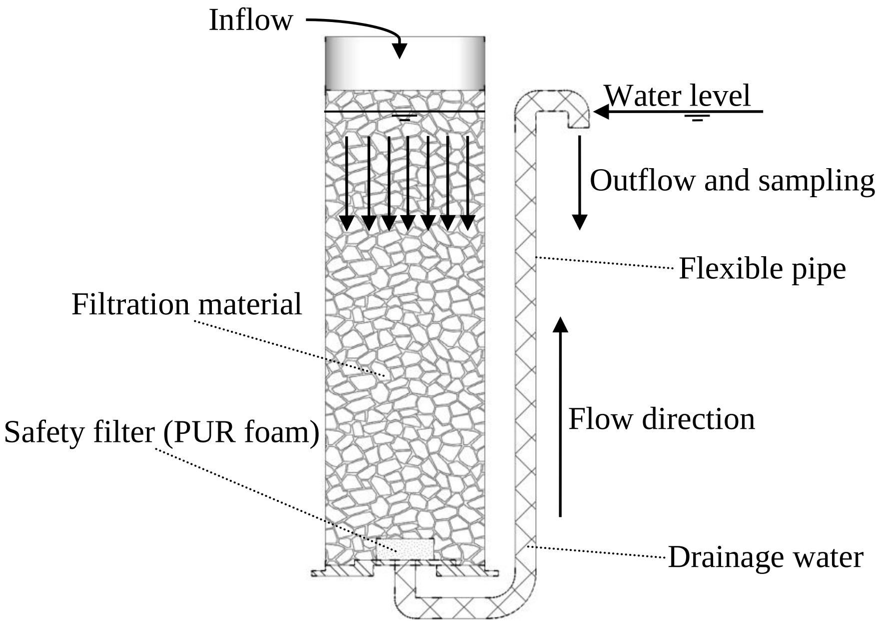

Figure 1. Technological arrangement of laboratory column

Organic materials (tab.1) were selected based on a literature review [1, 2]. In addition to the removal efficiency of nitrogen NO_3-N we also focus on determining the leachate. Summary of used organic materials is shown in table 1. We adjust the NO_3-N inflow by dosing 23 mg/L as KNO_3 into drinking water. Based on literature and results of foreign authors, we start from assumption: temperature 10°C is the corresponding system efficiency 3.0 g/m^3/d, the daily dose we set as Q_d =9.7 L/d.

Table 1. Used filter materials, columns labeling and bulk density

Label	Material	Starting date	ρ (kg/m^3)
F01	Sawdust (loose filling)	17.8.2015	198.04
F02	Sawdust (compacted)	17.8.2015	206.12
F03	Mulch (loose filling)	17.8.2015	144.00
F04	Mulch (compacted)	17.8.2015	229.04
F06	Wood shavings (larch)	15.10.2015	82.86
F10	Oak chips	1.10.2015	120.67
F12	Poplar chips	7.1.2016	217.83

Outflow water sampling occurs weekly, chemical analyses are focused on COD, BOD_5, NH_4-N, N_{Kjel}, NO_x-N, NO_2-N, NO_3-N, turbidity, pH, ORP, O_2, el. conductivity and temperature. We have found high effectiveness in the removal of nitrates, but the reported results concentrating on the negative result of increasing outflow concentration COD. On the basis leachate COD by continuous flow is our objective course the determination of outflow COD pollution. For the purposes of processing the regression equation, we selected the three most important factors:

1. **Time of operation** –at the measurement beginning (Fig. 2) show all of the filtration materials higher outflow COD concentration. The contamination with the gradual incorporation of the system decreases, the process seems to be an exponential function
2. **The retention time** - we assume a linear relationship between the flow rate and the outlet pollution COD (mg/L)
3. **Water temperature** - because it is an environment exposed to biochemical degradation, we can expected COD dependence at a temperature that influences not only the activity of microorganisms, but also destructive chemical processes

For the latter two factors we consider the linear dependence, but it is not possible to confirm this due to the progressively evolving influence of first factor. The resulting regression equation describing outflow concentration of COD has the form (1):

$$COD_{Cr} = c_1 + c_2 \cdot \left(c_3^{c_4 \cdot D}\right) + c_5 \cdot q + c_6 \cdot T \qquad (1)$$

Where COD_{Cr} = estimated outflow COD (mg/L) concentration, c_1 = coefficient specifying the position on the vertical axis, c_2, c_3 and c_4 = coefficients describing the influence of factor D, where D = time of operation, c_5 = coefficient for determining the factor q, q = retention time (day^{-1}), c_6 = coefficient for determining the factors of temperature, T = water temperature (°C)

RESULTS AND DISCUTION

Water temperatures range of 6.06 to 23.78 °C, the median of all the values (measured with an interval of 60 min) is 16.622 °C. So far we have not used air-condition, the temperature is influenced by the outside conditions. Measured retention times (by setting pumps) are in the range 0.52 – 29.62 days, mean of all measurement is 7.33 days. Effect of factor D is shown in fig. 2 – all of used materials show high outflow COD concentration and decreasing course of operation.

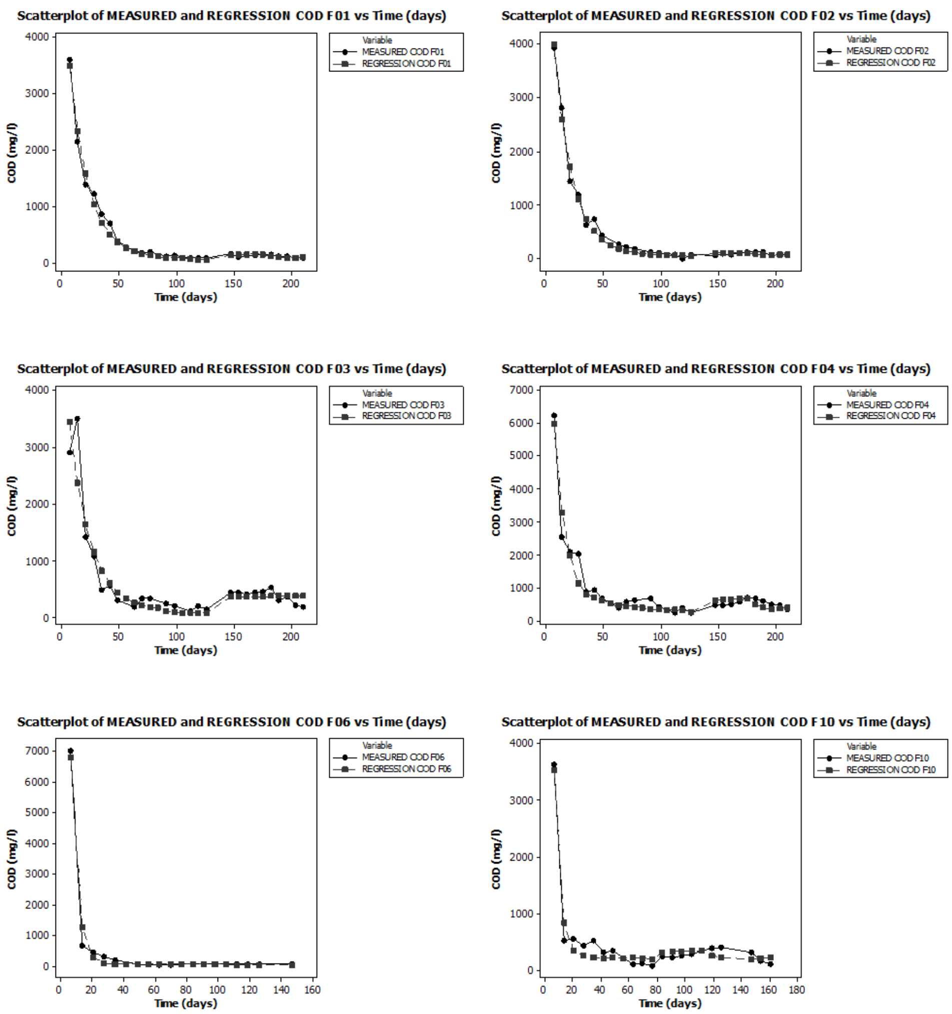

Figure 2. The comparison of outflow concentration COD (mg/L) with the regression

Search for individual values from c_1 to c_6 (tab.2) is carried out using iteration method: first, the estimated coefficient c1 (100x reps), then gradually others, always repeated 100 times. This whole cycle is made 30 times so until R^2 change is only on the third decimal place. As the results show regression equations (fig.3), the reliability is almost always higher than 94%, which can be considered accurate estimate of the course.

Because in real operation will naturally vary the inlet temperature, in Fig. 4 is shown the effect of temperature on the outlet concentration of COD. Temperatures are given in the range of 5-30 ° C and extremely high retention time of 20 days. We deliberately chose such a high time, because in real traffic may occur particularly during droughts.

Table 2. The final coefficients for the regression equation of selected filter materials

Filter/ Parameter	F01	F02	F03	F04	F06	F10	F12
c_1	-124	-49	52	-452	18	-126	-4394
c_2	5181	6067	4900	10896	37113	18000	4575
c_3	1.36	1.38	1.32	1.66	3.46	3.46	1.03
c_4	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20
c_5	2.54	3.06	10.89	12.85	0.22	5.42	60.88
c_6	8.59	5.39	-1.37	42.70	2.07	18.63	35.03
R^2	0.98	0.99	0.88	0.94	0.99	0.96	0.94

In the table 2, high c_2 value predicts a high initial COD outflow. The worst result shows F06 (shavings, larch) – corresponding with measurement (COD = 6996 mg/L). High c_3 value predicts easier material decomposition. Here is the best result on the contrary F06, F12 is the worst material (fresh poplar chips).

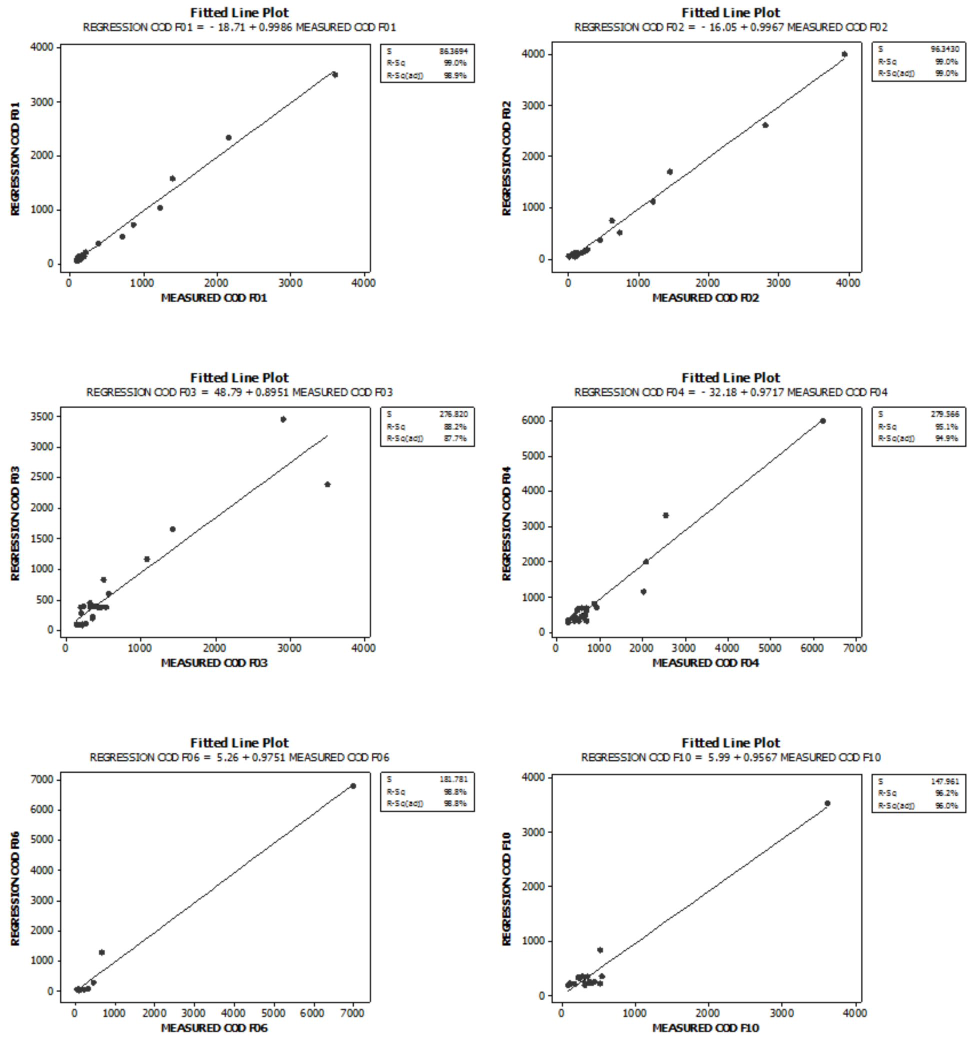

Figure 3. The comparison of regression models with real results, COD (mg/L)

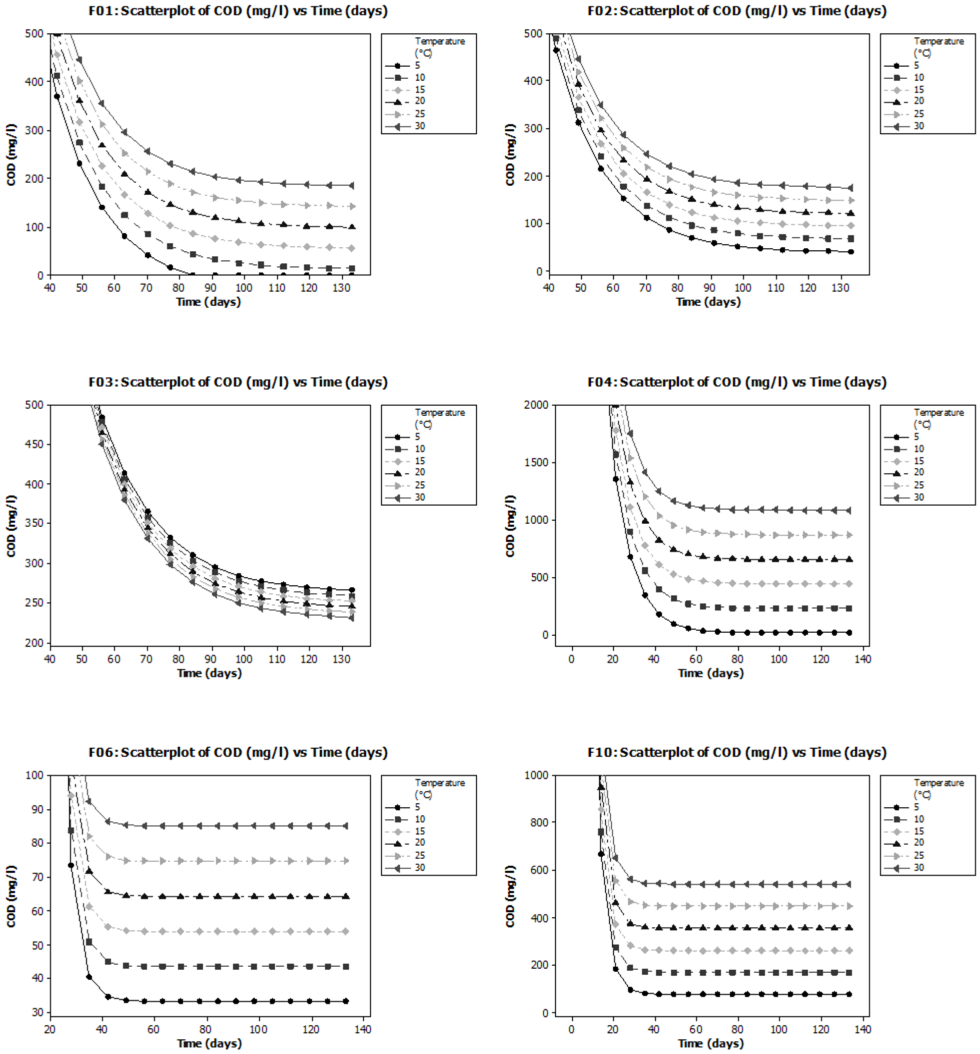

Figure. 4. The estimate of outflow COD (mg/L) by the regression equation

CONCLUSION

The present study reports the results of batch test carried out on fifth different organic carbon source capable to promote biological denitrification. From sustainability view the biological denitrification barrier can surely play the role of the most environmental friendly technology. Selection of a suitable material in most cases considered to by waste, while supporting denitrification, is presented in this paper. Column tests were conceived to determine the influence of density cartridge - which is not appearing to be a major factor. Therefore we focused on the more important factor - operation time, retention time and water temperature. As these results demonstrate, considering to the COD extraction it is important to take account of the material for removing nitrates. When requiring low outflow COD concentration, it is not probably possible to operate the device as permanently saturated. Based on the results of regression equations, in the start-up phase will not help the water temperature decrease. Probably it is necessary to modify the retention time, however, in real operation is often not possible to regulate the water inflow. The only possible solution for these purposes is the provision retention time through regulatory outlet pipe. This allows go on a partially saturated environment while reducing the retention times. Such operation also has the positive effect on reducing the outflow COD concentrations and sulphate reduction.

ACKNOWLEDGEMENTS

Funding for this work was provided by National Agency for Agricultural Research (NAZV) Grant no. QJ 1520280: Sustainable technology to remove nitrates from agricultural water.

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