## NITROGEN REMOVAL FROM TILE DRAINAGE WATER – LABORATORY SCALE TESTS USING DENITRIFYING BIOREACTORS

### 2. Methods and procedures

### 2.1. Installation of bioreactors

Three rectangular shape (length – 130 cm, width – 35 cm, height – 70 cm) denitrification bioreactors (0.32 $m^3$ volume each) were installed in Drainage laboratory of Water Resources Engineering Institute at Aleksandras Stulginskis University. For this purpose, three metal containers coated with insulating material on the inside were used. They were connected to the two (1.0 $m^3$ volume each) communicating plastic water tanks by flexible hoses. Each bioreactor capacity was filled with different woodchips filler. The principal bioreactors installation scheme is shown in Fig.1.

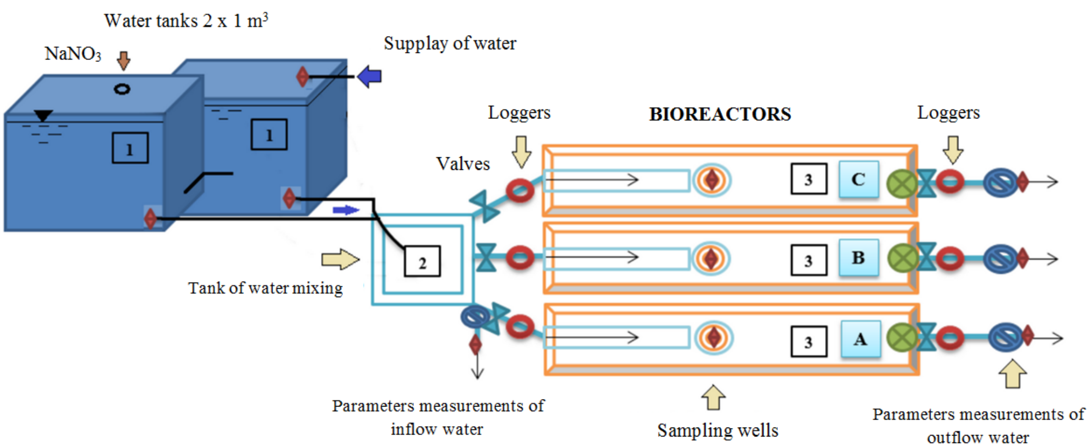



**Figure 1.** Principal scheme of bioreactors installation
(1 – water tank, 2 – distribution tank, 3 – bioreactors: A – deciduous woodchips filler, B – conifer woodchips filler, C – mixed woodchips filler)

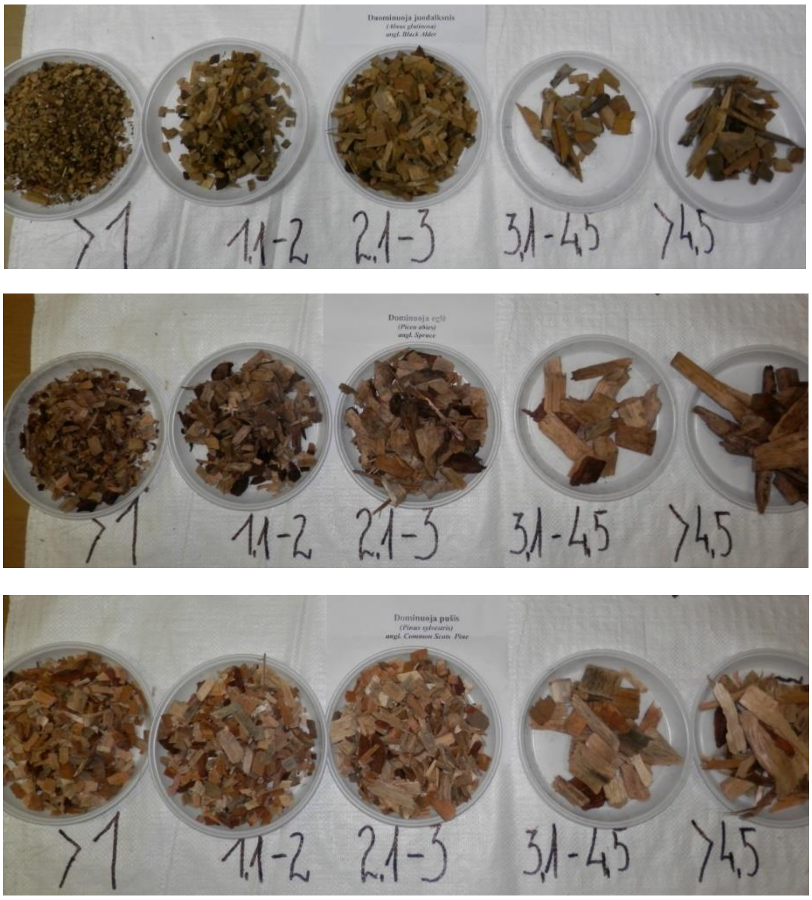
Bioreactor fed nitrate-nitrogen concentrations in the water tanks during the study period ranged from 4 to 15 mg /l. They were typical to the range of $NO_3$-N values found in drainage water under field conditions. The water from the tanks into each of bioreactors was supplied by gravity. Flow velocity was determined by the difference in hydraulic head between the water level in the tanks and bioreactors. The water supply to bioreactors and the outflow rates have been adjusted manually with the help of valves. Control of valves also enabled to achieve different water retention times.

Before entering bioreactors water first got into the water distribution tank, which was equipped with an additional valve for water flow sampling. Water inflow and outflow from the bioreactor readings were recorded with the help of water loggers. Each bioreactor inside was equipped with additional water sampling wells. In all sampling sites, water temperature, pH, dissolved oxygen and $NO_3$-N concentrations were measured. Nitrate- nitrogen concentrations were determined by the means of *Photometer MD600/MaxDirect* system, using a powder-like consistency reagent *Vario Powder Pack*. The dissolved oxygen amount was recorded with a portable *Eijkelkamp 18.28 oxygen meter* and the pH values were measured by the portable *WTW pH/ION340i* device, respectively. Inflow, outflow and inside bioreactor water temperatures were measured by the multifunctional portable system WTW *Multi 350i*.

## 2.2. Determination of physical characteristics of woodchips

Bioreactor tanks were filled with woodchips made from local raw materials – deciduous and coniferous trees offal. The use of woodchips in bioreactors allows heterotrophic denitrifying bacteria to develop. Bacteria need organic material as a carbon source, therefore, a biofilm on the surface of woodchips is formed. Woodchips size and mass porosity are important physical parameters to determine water volume and water retention time in bioreactors. Thus, the percentage distribution of the size of woodchips in the single mass was determined by sieving them with different sized sieves.

Distribution of deciduous trees woodchips was as follows (see Fig.2 (A)): <1.0 cm – 41%, from 1.1 to 2.0 cm – 51%, from 2.1 to 3.0 cm – 4%, from 3.1 to 4.5 – 3%, >4.5 cm – 1%. Distribution of conifer trees woodchips according to their particle size was as follows (see. Fig.2 (B)): <1.0 cm – 10%, from 1.1 to 2.0 cm – 24%, from 2.1 to 3.0 cm – 34%, from 3.1 to 4.5 – 20%, >4.5 cm – 12%. Distribution of mixed woodchips according to their size was as follows (see Fig. 2 (C)): <1 cm – 27%, from 1.1 to 2.0 cm – 41%, from 2.1 to 3.0 cm – 15% , from 3.1 to 4.5 – 9%, > 4.5 cm – 8%.




(A) (B) (C)

**Figure 2.** Distribution of woodchips according to chip size (A – deciduous; B – coniferous; C – mixed)

From characteristic textures and colors of woodchips it was found that alder dominates in deciduous woodchips, spruce dominates in coniferous woodchips and pine trees dominate among mixed woodchips.

Woodchips porosity was determined using standard porosity determination procedure described by Christianson et al. (2010). The chips were placed into a container of known volume and filled with water up to the top of the container. Covering with polyethylene blanket (to prevent water evaporation) container was kept for 24 hours. After 24 hours part of the water was absorbed by woodchips. In order to provide uniform impregnation of chips water content in the container was constantly supplemented. When the water level in the container remained constant and coincided with the water saturation boundary in woodchips (this happens after approximately 48 hours.), the water was poured off and its volume was measured. Subsequently, woodchip mass porosity was determined according to the formula:

$$p = \frac{V_p}{V_b} * 100 \qquad (1.2)$$

where: $p$ – woodchips porosity (%), $V_p$ – water volume with woodchips (l); $V_b$ – container volume (l).

The analysis revealed that conifer woodchips porosity was – 54%, porosity of deciduous trees woodchips accounted for 53%, and mixed trees woodchips – 53%.

## 2.3. Determination of other characteristics

Hydraulic conditions may have direct effect on the $NO_3$ removal efficiency in bioreactors. The most important of them – the calculated quantity expressing the mean time that water spends in bioreactor, i.e. water retention time. This parameter was calculated according to the equation 1.3 and the water discharge – according to the 1.4, respectively:

$$\tau = \frac{\rho V}{Q} \qquad (1.3)$$

here: $\tau$ – water retention time (hour), $\rho$ – porosity of woodchips, $V$ – bioreactor volume ($m^3$), $Q$ – water discharge ($m^3$/hour).

$$Q = \frac{Sk_2 - Sk_1}{\Delta T} \qquad (1.4)$$

where: $Q$ – water discharge ($m^3$/hour); $Sk_1$ – water volume (meter readings) at inflow ($m^3$); $Sk_2$ – water volume (loggers readings) at outflow (m3); $\Delta T$- time step (hour).

Experimental tests have been started first with bioreactor loaded with the deciduous woodchips (A). Water supply velocity into this bioreactor ranged from 1.95 to 173.55 l/h, while into bioreactor (B) – from 2.17 to 161.13 l/h, and into bioreactor (C) – from 2.11 to 152.31 l/h. Water supply rates were relatively consistent with those measured under the field conditions. For example, the average daily flow rate at the outlet of 13.6 ha tile drainage system in Kaunas MIS experimental station ranged from 3.6 to 136.8 l/h for the period between the years 1967 and 1985 (Sakalauskas, 1990).

During the experiment the water samples were taken at irregular time steps according to water supply and water retention time characteristics. Nitrate-nitrogen concentrations were determined in the inflow water, in the water of sampling wells and in the outflow. Variation of measured parameter values allowed to presume the ongoing nitrogen transformations in bioreactors. Nitrate nitrogen removal efficiency in bioreactors was calculated according to the equation:

$$E = \frac{C_{in(NO_3-N)} - C_{out(NO_3-N)}}{C_{in(NO_3-N)}} * 100 \quad (1.5)$$

where: $E$– nitrate nitrogen removal efficiency (%), $C_{in(NO_3-N)}$ – nitrate nitrogen inflow concentration (mg/l), $C_{out(NO_3-N)}$ – nitrate nitrogen outflow concentration (mg/l).