Moving Bed Biofilm Reactor (MBBR) - Drain water from horticulture

Location 1

Country: Belgium
City: Destelbergen
Coordinates: N 51.07039 - E 3.81565 (PCS)

Location 2

Country: Belgium
City: Nevele
Coordinates: N 51.03476 - E 3.52911 (Floristry Meuninck)

Location 3

Country: Belgium
City: Heusden
Coordinates: N 51.01719 - E 3.81290 (Floristry Azaro)

Location 4

Country: Belgium
City: Zaffelare
Coordinates: N 51.12407- E 3.85402 (VDS Plant)

Location 5

Country: Belgium
City: Lochristi
Coordinates: N 51.08085- E 3.82130 (Microflor)

Location 6

Country: Belgium
City: Oosteeklo
Coordinates: N 51.19255 - E 3.72398 (Filip Willems)

Problem description

The agricultural use of nitrates has been a major source of water pollution in Europe. To limit their emission, the EU issued the Nitrates Directive (1992), which has subsequently been integrated in national legislations by the member states. In response to this Directive, vulnerable zones were established, in which the standard of 11,3 mg NO_3-N/l is exceeded.
A way to limit the emission of nitrates in the environment is the use of good farming practices to avoid the production of nutrient-rich wastewater but this is not always possible. In Belgium the generated wastewater can be applied on grassland but growers do not always have sufficient grassland available. In this case, an end-of-pipe treatment is the only alternative.
Nitrate removal from wastewater can be achieved by biological denitrification of nitrate into nitrogen gas. The working mechanism of the Moving Bed Bio Reactor (or MBBR in short) is based on this

principle. The recovery of nitrogen is not possible with this system (in contrast with a zero valent iron-system). A 2-steps constructed wetland (also present at PCS since 2002), has the same working principle as the MBBR.

Filter description

A Moving Bed Biofilm Reactor is a reactor that, by means of biological processes, removes nitrogen from water by the denitrification of nitrate (NO_3) into nitrogen gas (N_2):

$$2\ NO_3^- + 10\ e^- + 12\ H^+ \rightarrow N_2 + 6\ H_2O.$$

Because of the lack of readily biodegradable COD in the influent, the addition of an external carbon source is necessary for the denitrifying bacteria.

PCS has intensively investigated the MBBR application for horticulture. Since the drain water volume in this sector is rather limited, a small-scale filter system was found to be suitable.

The MBBR consists of a tank (1 m³) filled with water and special plastic carriers that provide a surface where a sludge (biofilm) can grow on. This biofilm carries out the denitrification. The irregular and large specific surface area of the carriers forms an ideal habitat. In the installation at PCS, AnoxKaldnes K5 carriers are used with a specific surface of 800 m^2/m^3. The tank is filled for 40% with these carriers (Photo 1). It takes a few weeks for the biofilm to develop on the carriers, but this can be accelerated by transferring a certain number of carriers from a MBBR installation already in operation. An air pump creates some movement in the carriers and to prevent clogging of the biofilm in the carriers.
CarboST is used as carbon source, injected by a dosage pump working together with the influent pump. The COD concentration of CarboST is 1,12 kg O_2/L.
A filter tank of 1 m³ can treat between 2 m³ and 3 m³/day.

Photo 1: Plastic carriers in a MBBR, on which a biofilm develops.

Results per location

PCS

The MBBR filter has been installed since the summer of 2018 at PCS. Water from a storage pond is pumped through the MBBR. In the storage pond, water from the covered fields of azalea is collected which mostly contains high nitrate concentrations. The water surface of the storage pond is covered with Hexacover to prevent the growth of algae and duckweed (Photo 2 and Photo 3).

The water level in the MBBR is controlled with 2 sensors (minimum and maximum level). An air pump with a membrane disc diffuser is working each 3 hours for a minute to create some movement in the carriers and to prevent clogging of the biofilm in the carriers.

CarboST is used as C-source, injected by a dosage pump working together with the influent pump.

Photo 2: Hexacover on the water surface in the storage pond

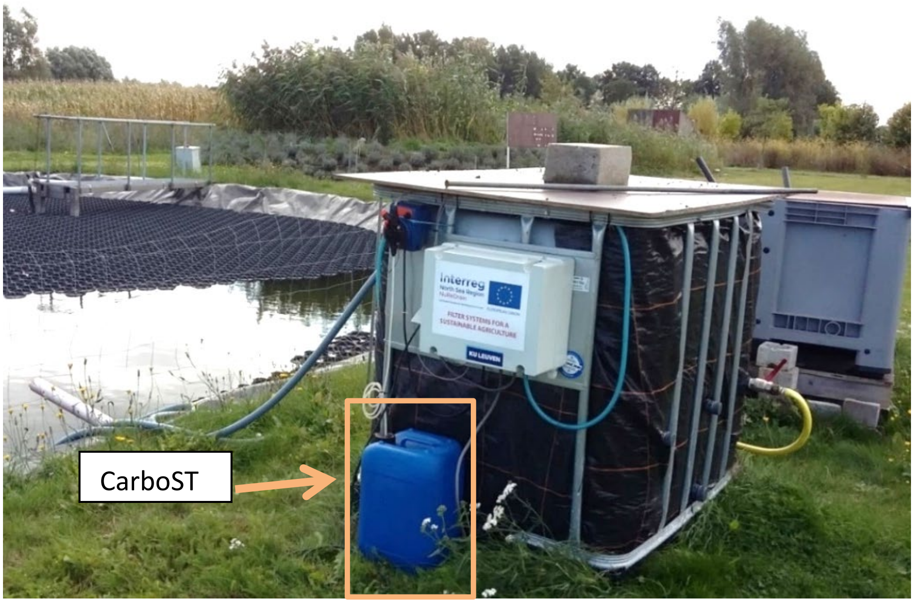

Photo 3: Moving Bed Biofilm Reactor at PCS with CarboST as C-source

Photo 4: Moving Bed Biofilm Reactor at PCS, filled with AnoxKaldnes K5 carriers

Photo 4 shows a detail of the MBBR at PCS. The MBBR consists of a cubitainer filled with water and plastic carriers on which a biofilm develops. In this installation, AnoxKaldnes K5 carriers are used with a specific surface area of 800 m2/m3. The tank is 40% filled with these carriers. At regular intervals the carriers are aerated, in 2021 aeration was done every 3 hours, for 15 min each time. In 2022, this was adjusted to 1 min every hour. Based on the water level between 2 sensors (minimum and maximum level), the water volume in the MBBR is controlled. When the water level has reached the minimum level, water from the storage pond is pumped into the MBBR until the maximum level (about 80% of the total volume) is reached. For the MBBR at the PCS, this means that 100 l of water is then pumped from the disposal pond into the MBBR, this takes 3 min each time. The residence time of the water in the filter is 8 hours. The effluent is regulated to 2 l/min (2.88 m^3/day).

It is necessary to provide a carbon source for the denitrifying bacteria. Since 2022, Carbo ST-HC-C was used as the C source.
At the MBBR filter, Carbo ST was injected by a pump (maximum capacity 5 l/hour). This dosing pump worked in conjunction with the influent pump.

Floristry Meuninck
At Floristry Meuninck, already for several years, all drain water is collected in a storage tank during winter, and in spring/summer, water is pumped through P filters. In 2019, also a MBBR filter was installed adjacent (Photo 5 and Photo 6).
Initially, the water from the water silo flowed first through the MBBR and then went through 2 phosphor filters but, due to clogging problems in the phosphor filters, it was decided to reverse the order. This clogging was probably due to biofilm that developed in the MBBR and was carried along to the P filters. During the winter of 2021-2022, the system was modified so that the water goes through the 2 phosphorus filters first and then through the MBBR. It was also observed that the ICS granules in the phosphorus filters were saturated; these were also replaced in early 2022. Carbo-ST is added to the MBBR and the system is aerated every hour to prevent clogging.

Photo 5: MBBR at Floristry Meuninck

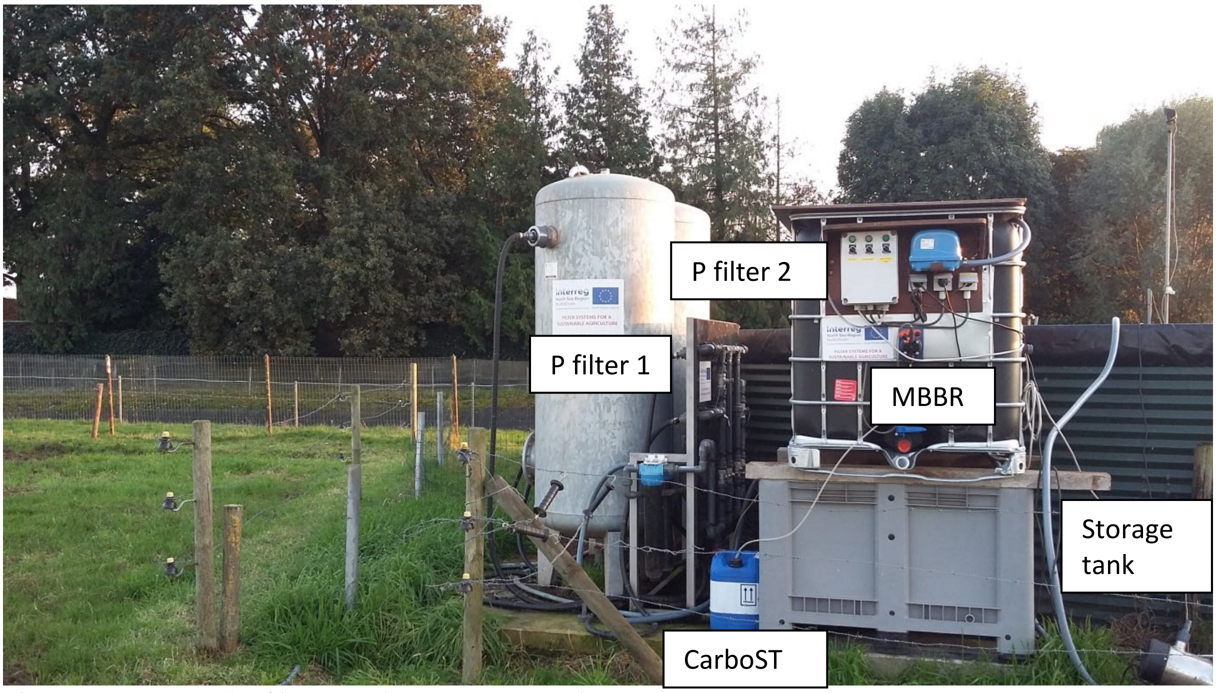

Photo 6: MBBR and P filters at Floristry Meuninck

<u>Azaro</u>

At Floristry Azaro, the MBBR was initiated at the end of September 2019 (Photo 7). About 10 L carriers were taken from the MBBR installation at the PCS to inoculate the new installation. After some weeks, a biofilm was developed very well on all carriers. Nitrates in the drain water were removed very well by the MBBR.

Photo 7: MBBR at Floristry Azaro

VDS-Plant

In early July 2022, a 2-in-1 do-it-yourself filtration system was installed at VDS Plant. The first IBC is filled with ICS granules for P removal, the second IBC is a Moving Bed Bioreactor (MBBR) responsible for N removal (Photo 8). Carbo-ST is added to the MBBR and the system is aerated every hour to prevent clogging of the system. These filtration systems process the effluent from an azalea greenhouse. The water is collected in an underground citern and then flows from bottom to top through the P-filter and then flows by gravitation to the MBBR. Daily, the filters process 1.5 m³, but can handle up to 3 m³ if necessary.

Photo 8: 2-in-1 N and P do-it-yourself filter system at VDS Plant

<u>Microflor</u>

In mid-November 2022, a 2-in-1 N and P do-it-yourself filter was installed at the company Microflor (Photo 9), a young plant company of mainly orchid and Helleborus. All effluent produced at this farm is collected in a silo. This contains the backwash water from backwashing the multimedia filter and residual water from drain wells. Per day 760 l is processed (pump running every hour for 1 min) from this silo at the request of the company. The actual capacity is higher, namely 3000l (3 m^3). CarboST is added as carbon-source. Care is taken to ensure that the system cannot freeze in winter, because this company also has effluent in winter.

During the first winter, nevertheless, the filter was down for a while. Microflor also has a constructed wetland that must be adequately fed with a continuous flow, and so, the treated water of our filter system, was sent back into the large citern. But due to an increase in the COD value, it seemed better to drain the effluent from our filters into the first aerated constructed wetland instead of into the collector silo.

Photo 9: 2-in-1 N and P do-it-yourself filter system at Microflor

Filip Willems

In spring 2023, a subsequent 2-in-1 N and P do-it-yourself filter was installed on Filip Willems' azalea farm (Photo 10). This farm consists of 7.6 ha (greenhouses + covered fields). The drain water at this farm is captured; but it is not disinfected via a slow sand filter like at VDS-Plant, but via a high-pressure UV filter, just like at Microflor. In front of the buffer tank in which all drain water from inside and outside is collected, a sieve bend is installed as primary purification (= to remove organic material). To ensure good transmission, a multimedia (= fast sand filter) is installed in front of the UV filter. At regular intervals, this rapid sand filter is backwashed. This backwash water is rich in nutrients and purified by the new 2-in-1 filter systems. The system has been up and running since the summer of 2023.

Photo 10: 2-in-1 N and P do-it-yourself filter system at Filip Willems

Financial aspect

Because a MBBR is simple to construct yourself, a MBBR filter construction manual has been made. This manual clearly lists all components needed and the different steps to take to construct the MBBR. Total investment cost has been estimated to amount to € 2 700. One day and a half of handy manpower should be counted to build the filter.

Conclusion

At PCS (Ornamental Plant Research), 2 filters were tested for nitrate removal, namely a 2-stage constructed wetland and a Moving Bed BioReactor (MBBR). Both the 2-stage constructed wetlands and MBBR have given great results for nitrogen removal for several years. With a Moving Bed Biofilm Reactor 60-80% of the nitrates can be removed from the wastewater. It has also many advantages compared to a classic biological water treatment with constructed wetlands. The system is more resistant against peak loads and temperature fluctuations. The filter is very compact and requires relatively little maintenance and check. For both systems, CarboST appears to be a very good C-source. However, this C-source is very important, when not supplied one can expect a drop in efficiency very quickly. Both systems (2-stage straw field is 30 m² + 55 m² and a MBBR 1 m³) can process 3 m³ of spray flow per day. The operation of both systems does drop almost completely at cold temperatures. If the nitrate concentration is too high in the effluent, there are some things to check: (1) the level of the carbon source, (2) whether the dosing pump is working correctly and (3) the outlet flow varying between 1.4 l/min to 2.8 l/min.

At 5 floriculture companies, Floristry Meuninck, Azaro, VDS Plant, Microflor and at Filip Willems, 2-in-1 DIY systems were tested for the removal of N and P from greenhouse wastewater (for Azaro only

MBBR, no P-filter). In general, the systems on these farms work very well (at Filip Willems only just started up) and the same results are obtained as for the PCS-filters being a 60-80% nitrate removal from the greenhouse effluent.