Interreg
North Sea Region
NuReDrain
European Regional Development Fund

EUROPEAN UNION

FILTER SYSTEMS FOR A SUSTAINABLE AGRICULTURE

# FIELD CASE DESCRIPTION

## Moving Bed Biofilm Reactor (MBBR) for drain water from horticulture

PCS
proefcentrum voor sierteelt

# Locations

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)

# 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. Unfortunately, the recovery of nitrogen is not possible. A 2-steps constructed wetland has the same working principle, also available and experience with at PCS since 2002.

## Filter description

A Moving Bed Biofilm Reactor (or MBBR in short) 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 $m^3$) 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 $m^3$ can only treat between 2 $m^3$ and 3 $m^3$/day.

*Photo 1 Plastic carriers in a MBBR, on which a biofilm will develop*

# Results (following up of several seasons)

## Location 1

### Summer 2018

The MBBR filter was installed in the summer of 2018 at PCS and was constructed by KULeuven (Photo 1). Water from the storage pond was pumped through the MBBR. In the storage pond, water from the covered fields of azalea was collected which mostly contains high nitrate concentrations.

The results are shown in Figure 1. The filter was only during a short period in operation. There were problems with the dosage of the C-source and there were also several problems with a blockage of the filters due to duckweed, algae and sludge in the storage pond. The influent pump sucked this up into the MBBR with an effect on the level measurement. Therefore, the efficacy could not be evaluated very well.

*Photo 1 Moving Bed Biofilm Reactor at PCS in 2018*

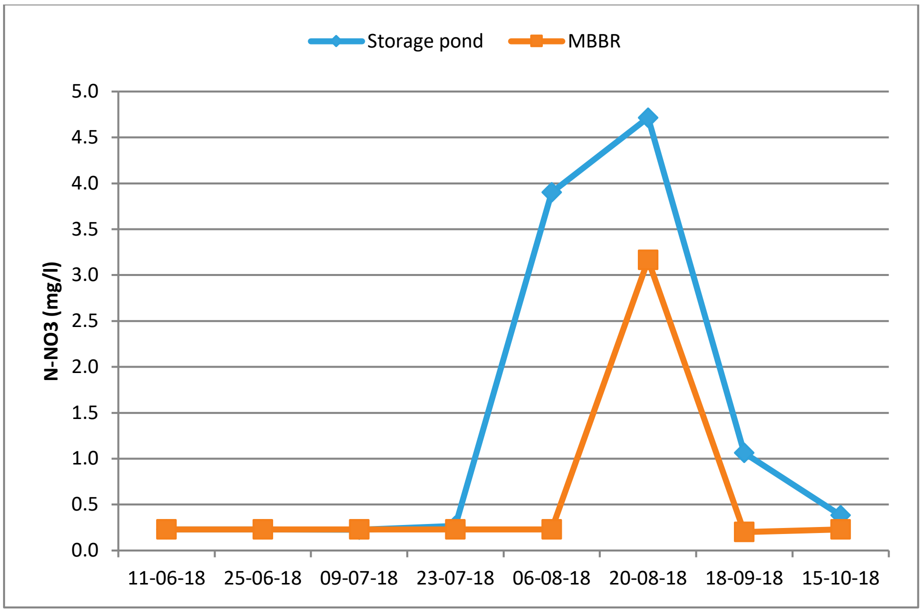


*Figure 1 Results for N filter (MBBR) at PCS during Summer 2018*

## Summer 2019

During winter, the storage pond was drained and cleaned and the leaks in the storage pond were repaired. Afterwards, the water surface of the storage pond was covered with Hexacover to prevent the growth of algae and duckweed (Photo 2). So, problems with blocked filters were solved.

At the start of the season, the installation was replaced by an adapted installation (Photo 3). KULeuven designed this 'new' MBBR as a low cost self-assembly package in an IBC tank. Water level was 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. The effluent flow is reduced to 2 l/minute (120 l/h) by a tap. The residence time of the water in the filter was 8 hours.

CarboST was used as C-source, injected by a dosage pump (5 l/h) working together with the influent pump. The dosing rate was set at 8% (= 0,4 l/h). When the MBBR is filled, 100 l is pumped from the buffer basin during 3 minutes. This means that the MBBR treats 2880 l/d (or 2 l/min) or is operational during 86,4 min/d. The dosing pump likewise is operational for 86,4 minutes and consequently injects ca. 0,58 l/d.

The MBBR was in operation from mid-May onward (Figure 2). Till the beginning of August, the N concentration in the storage pond was not so high and a good adjustment of the installation (flow rate and dosage of C-source) took some time. From the beginning of August, also wastewater from the fertilizer unit of PCS was pumped into the storage pond and N concentrations increased consequently in the storage pond. 60 till 90% of the nitrates in the storage pond were removed by the MBBR. On 08/08/19 and 03/09/19, N was not removed from the drain water because the C-source was not added (bottle was empty or a defect on the influent pump). From mid-September, the nitrate content in the storage pond decreased because it was diluted by the rain which flowed also in the storage pond.

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

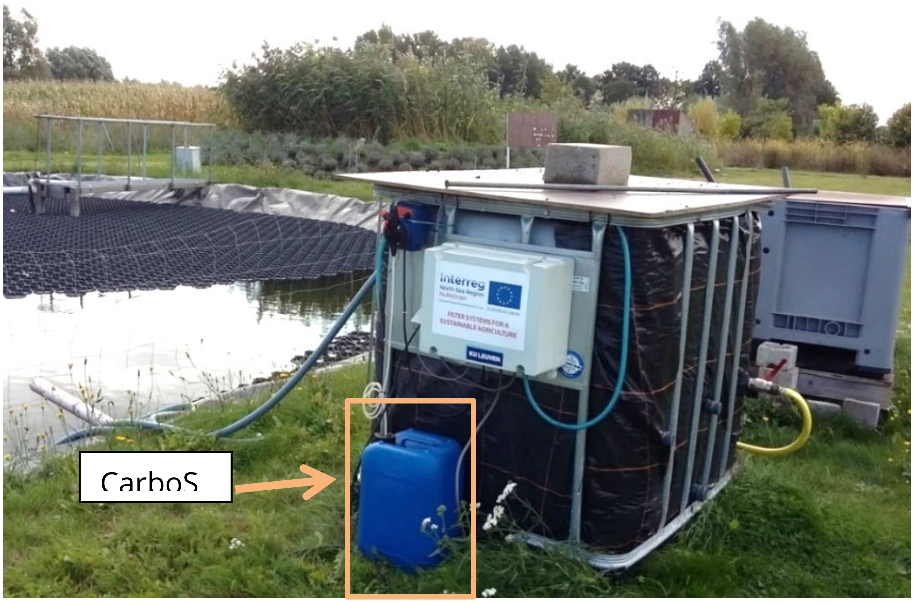


*Photo 3 Moving Bed Biofilm Reactor at PCS in 2019 with CarboST as C-source*

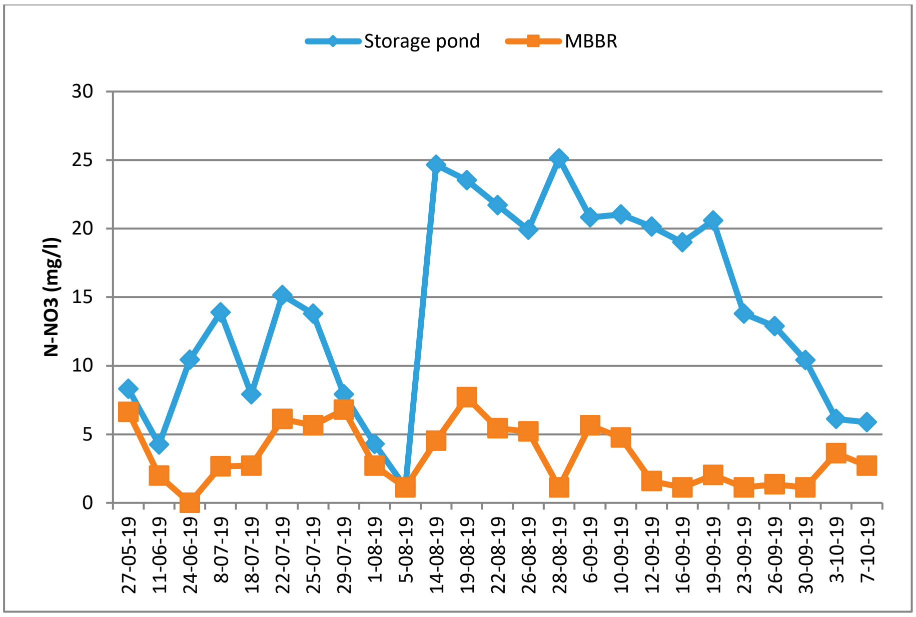


*Figure 2 Results for N filter (MBBR) at PCS during summer 2019*

### Winter 2019 – Summer 2020

Because there is no wastewater from the covered fields during winter, the MBBR was moved to the storage pond containing wastewater from the fertilizer unit at the end of November. Due to problems with blockage of the MBBR, there were some limited analyses and the nitrates were not removed from the drain water. The presence of water in the supply hose caused the MBBR being less effective, this because water in the hose will cause large quantities of biomass that can cause clogging. The drip hose attached to the hose will ensure that all water in the hose will flow back to the pond. As long as the pump is not working, the hose will remain empty. This was adapted at the end of the winter.

The MBBR filter worked well during Summer 2020, as can be seen in Figure 3. N-$NO_3$ never exceeded the level of 11,3 mg/l N-$NO_3$ (50 mg/l $NO_3$) after the MBBR.
The effluent flow remained 2 l/minute (120 l/h) with a residence time of the water in the filter of 8 hours.

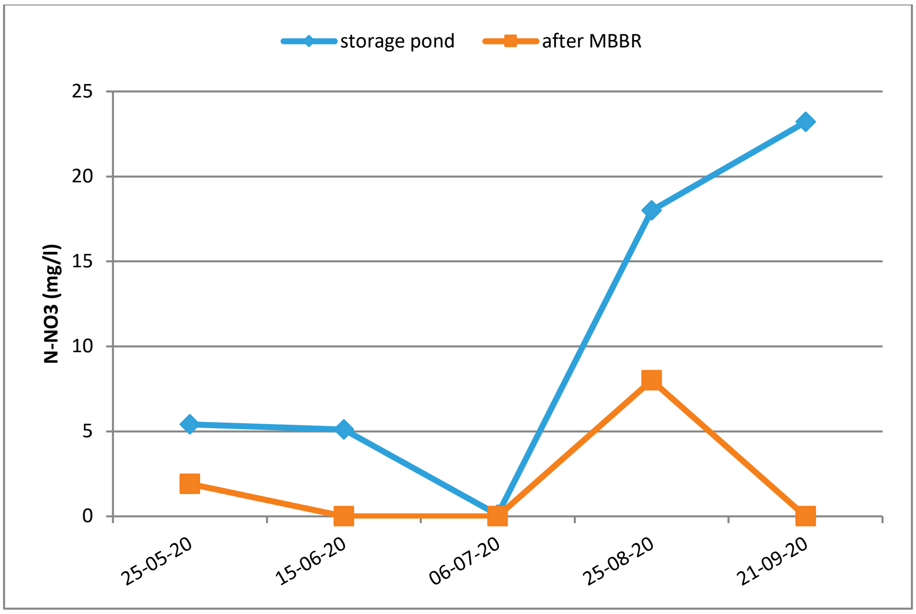


*Figure 3 Results for N filter (MBBR) at PCS during Summer 2020*

## Location 2

At Floristry Meuninck, already for several years, all drain water is collected in a storage tank during winter, and in spring/summer, water was pumped through P filters. In 2019, also a MBBR filter was placed at Floristry Meuninck (Photo 4).
To result in a good development of the biofilm on the carriers in the MBBR filter, and consequently a good N removal, there must be some P in the drain water. Therefore, the MBBR filter was placed between the storage tank and the P filter to remove also N from the drain water. An additional bin was placed after the MBBR to collect the water after denitrification and before it was pumped through the P filters. Photo 5 shows the water flows of the drain water through the different filter systems.

The MBBR was initiated at the beginning of August 2019, about 10 L carriers were taken from the MBBR installation of the PCS to inoculate the new installation. On these carriers, there was already a good development of the biofilm. On 22/10/19, there was a good working biofilm on the K5 carriers in the MBBR (Photo 6). The installation removed nitrates from the drain water very efficiently. The N-NO3 concentration in the buffer tank was 28,7 mg/l N-NO3 and after the MBBR, the concentration decreased till 5,4 mg/l N-NO3 (Figure 4). In the tank beyond the MBBR, even all nitrates were removed. Photo 7 shows clearly that there is biofilm leaching from the MBBR. So, any additional denitrification can occur in the gray bin after the MBBR which can explain the complete removal of nitrates after the P filters. Also in 2020, the results for the MBBR were very good as can be seen in Figure 5. On 21/09/20, nitrates were not denitrified as expected, because the bin of the carbon source was empty.

*Photo 4 MBBR at Floristry Meuninck*

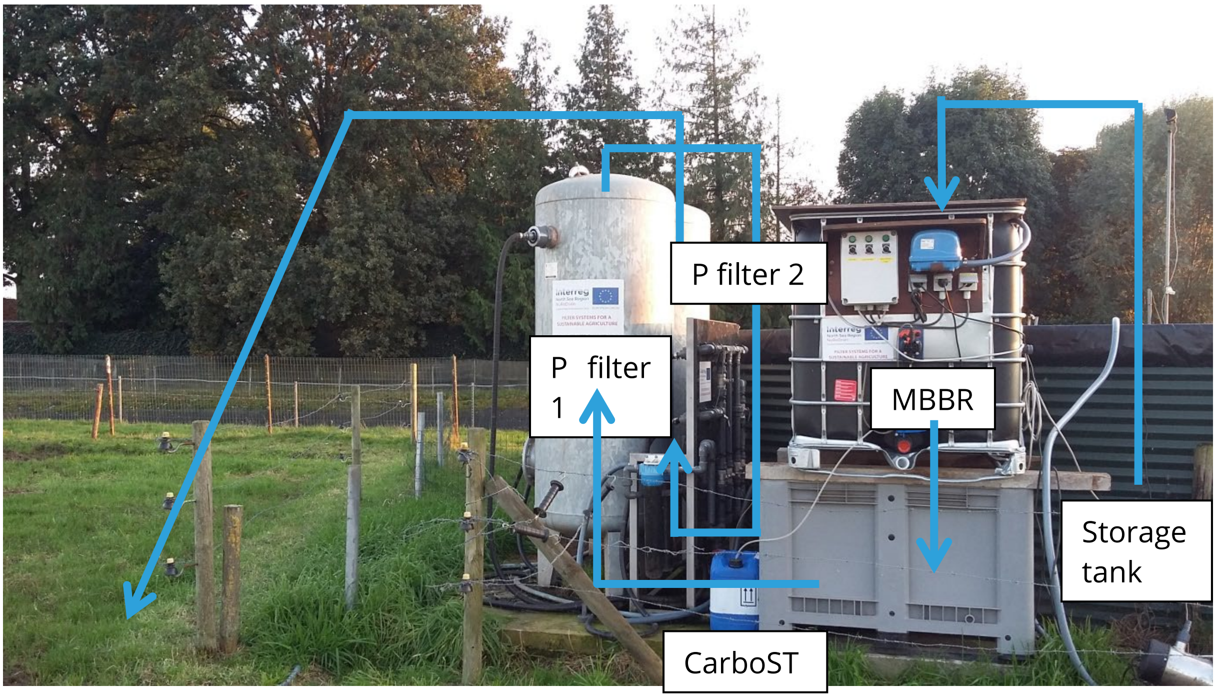


*Photo 5 MBBR and P filters at Floristry Meuninck with an indication of the water flow*

*Photo 6 K5 carriers from the MBBR at Floristry Meuninck on 22/10/19*

*Photo 7 Bin which contains water that is passed through the MBBR at Floristry Meuninck on 22/10/19*

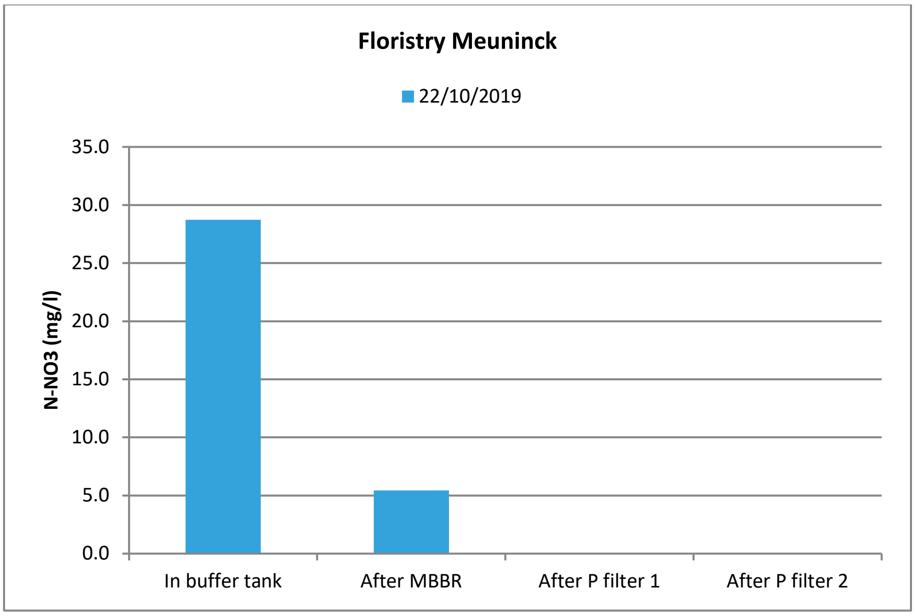


*Figure 4 Results of nitrate removal for MBBR at Floristry Meuninck on 22/10/19*

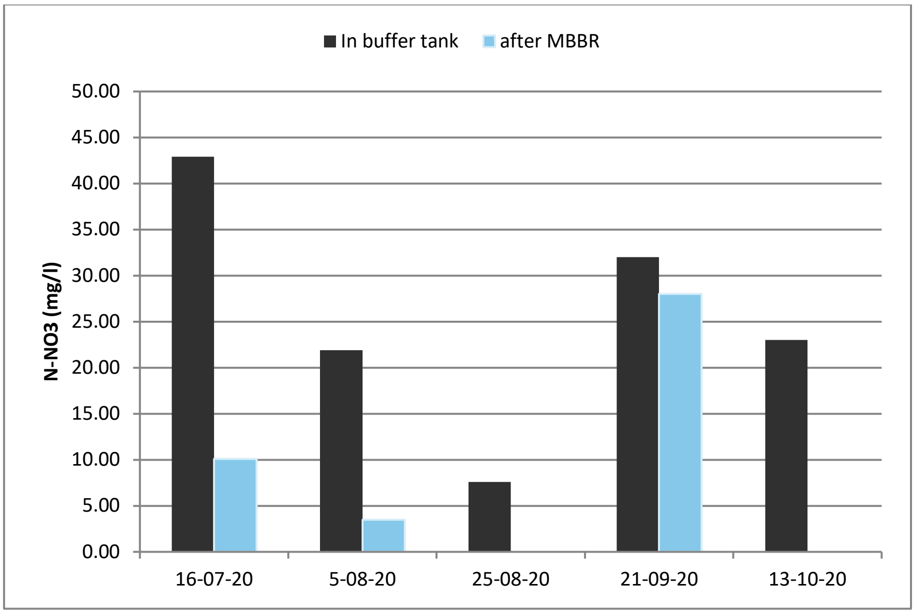


*Figure 5 Results of $N\text{-}NO_3$-removal for MBBR at Floristry Meuninck in 2020*

## Location 3

At Floristry Azaro, the MBBR was initiated at the end of September 2019 (Photo 8). 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 (Photo 9). Nitrates in the drain water were removed very well by the MBBR. Figure 6 shows some results. N content in the storage tank was 23,2 mg/l N-NO3 and after MBBR, N content was lower than 0,1 mg/l N-NO3. On 12/11/19, the N content in the storage tank was 12,0

mg/l N-NO3 and after MBBR, there was 7,7 mg/l N-NO3. Afterwards, the MBBR was placed indoor to protect the installation for frost damage.
In 2020, when carbon was added, the MBBR worked very well. Unfortunately, sometimes the carbon source was not added, therefore, the efficiency of the MBBR could only be measured twice (Figure 7).


*Photo 8 MBBR at Floristry Azaro*

*Photo 9 K5 carriers from the MBBR at Floristry Azaro on 24/10/19*

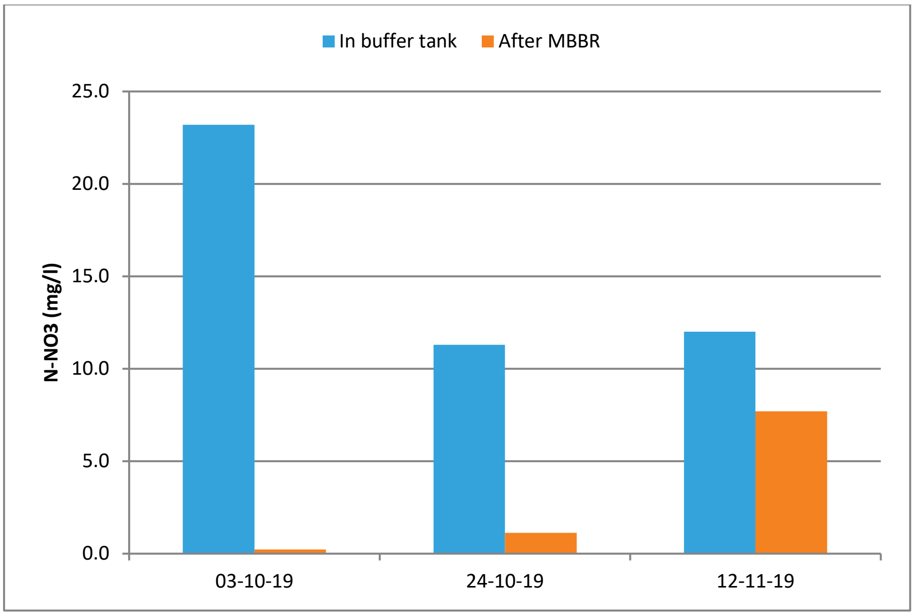


*Figure 6 Results of nitrate removal for MBBR at Floristry Azaro in 2019*

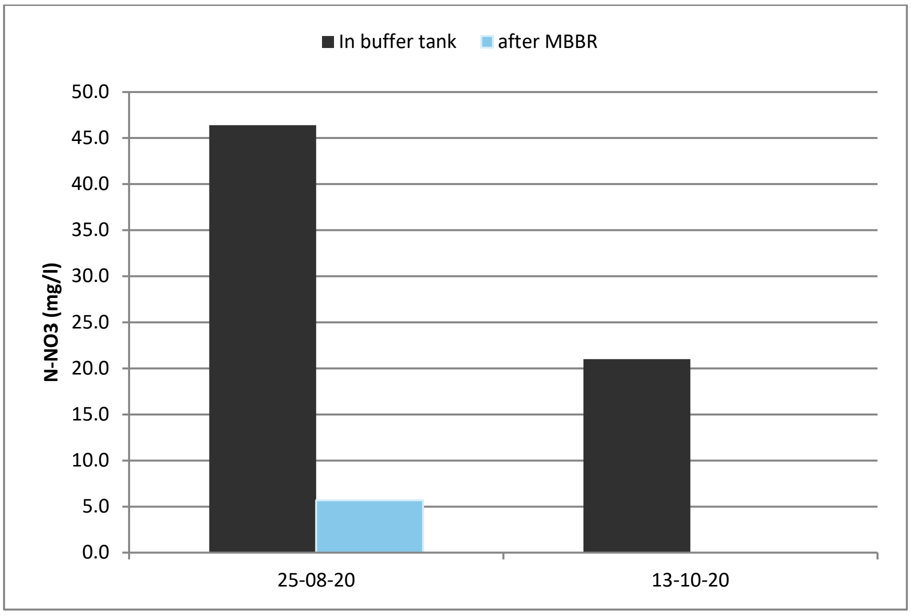


*Figure 7 Results of N-nitrate removal for MBBR at Floristry Azaro in 2020*

# Financial aspect

Because a MBBR is simple to construct yourself, a MBBR filter construction manual has been drafted. 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 up to € 2 700. Besides, one day and a half of handy manpower should be counted to build the filter.

# Conclusion

With a Moving Bed Biofilm Reactor more than 80% of the nitrates can be removed from the waste water. 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. Maybe, a bottleneck of this system can be that residues of plant protection products can have a negative impact on the denitrification, but further research is needed on this aspect.

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.