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Nitrification and Denitrification with Rotating Immersion Biodiscs

Closing a gap in rural wastewater treatment

The requirements for sewage treatment plants and their effluent values are constantly increasing in order to continue to meet the legitimate demands of future generations for clean water and an intact environment. In this context, wastewater treatment in rural areas, i.e. from a detached single farmhouse to a community of 5,000 inhabitants, is faced with special challenges.
Challenges include:

- significant fluctuations in volume throughout the daily cycle,
- strong fluctuations in volume throughout the weekly cycle,
- seasonal fluctuations, especially in areas with a lot of tourism,
- phases of very highly concentrated wastewater,
- complex drainage systems which have undergone sporadic, discontinuous development (e.g. in response to strong fluctuations in population density) and which often require partial modernisation,
- often different areas must be connected to the system gradually, in multiple stages, but sometimes the opposite is true and the network must be gradually dismantled,
- planning documents are frequently outdated.

In addition, rural areas are struggling with low staffing levels and rising costs.
Therefore, a simple, reliable and low-maintenance process is required.
Value for money is also a decisive factor, especially considering that the majority of the investment and the operating costs are usually incurred in the areas of sewer construction and sewer maintenance.

Simple, effective removal of contaminants and nutrients

Natural processes such as plant filters and sedimentation ponds have been used for a long time, but these systems are increasingly reaching the limits of their performance with regard to effluent values. In addition, these large ponds and plant filters require a lot of space and are relatively high maintenance, simply due to the volume of plant waste created. Existing sewage treatment plants of this type must therefore increasingly be upgraded or replaced completely.
The challenge here is to find a technically simple and low-maintenance solution which will remove contaminants and nutrients from the water in an effective and controlled manner. Fixed-bed methods, in which the biomass needed to metabolise contaminants in the water is retained on special growth areas, are often the answer. Aerobic biological purification has proven especially suitable for rural areas, since the lower surface area required is often financially advantageous. Experience has repeatedly shown these fixed-bed processes to be a pleasure to operate, provided that the entirety of the growth areas can be kept available long-term, as is the case with rotating immersion biodiscs with smooth discs.
With increasingly demanding requirements for nutrient reduction, the question of suitable technology is especially relevant in rural areas, which may have fluctuating inflow volumes and highly concentrated wastewater. For $N_{tot.}$ upper limits of < 40 mg/l nitrogen, elimination rates of 75% and more are sometimes required.

Therefore, in rural areas there is an increasing demand for reliable denitrification solutions which also allow for largely autonomous operation due to low staffing levels.
During denitrification, nitrate ions (NO_3-N) which were formed during nitrification are broken down into elemental atmospheric nitrogen (N_2) during the anoxic process. By adjusting the recirculation rate, denitrification performance can be increased according to the following formula: *"Degradation performance = n / n+1"* [n = recirculation rate]
This produces a curve which asymptotically approximates a limit value (Figure 1). Accordingly, an increase in recirculation is usually only expedient up to a recirculation ratio of 4, also with regard to the available carbon source and the energy consumption required.
In the activated sludge process popular in larger plants, nitrification and denitrification take place in tanks in which either the wastewater is pumped around or an aeration system is intermittently switched on and off. However, the regulation of this process is normally costly and complex. Both the initial investment costs and the maintenance costs required for the measurement and control technology are high and significant demands are placed on the personnel. The energy costs are also comparatively high, since, in comparison with fixed-bed methods, the sludge content is proportionately lower and accordingly much more water has to be kept in motion. In addition, an activation system relies on the biology from the secondary sedimentation basin being returned to the process as re-circulated sludge. The strongly fluctuating volumes and changing concentrations often prevalent in rural areas therefore pose the risk that the biology could be washed out. In addition, the activation process requires the flake to be kept in a constant state of suspension through pumping or aeration, which further explains the high energy requirement of this process.
Due to their naturally low-maintenance and energy-saving design, fixed-bed systems such as rotating immersion biodiscs are therefore the more attractive solution for denitrification in rural areas.

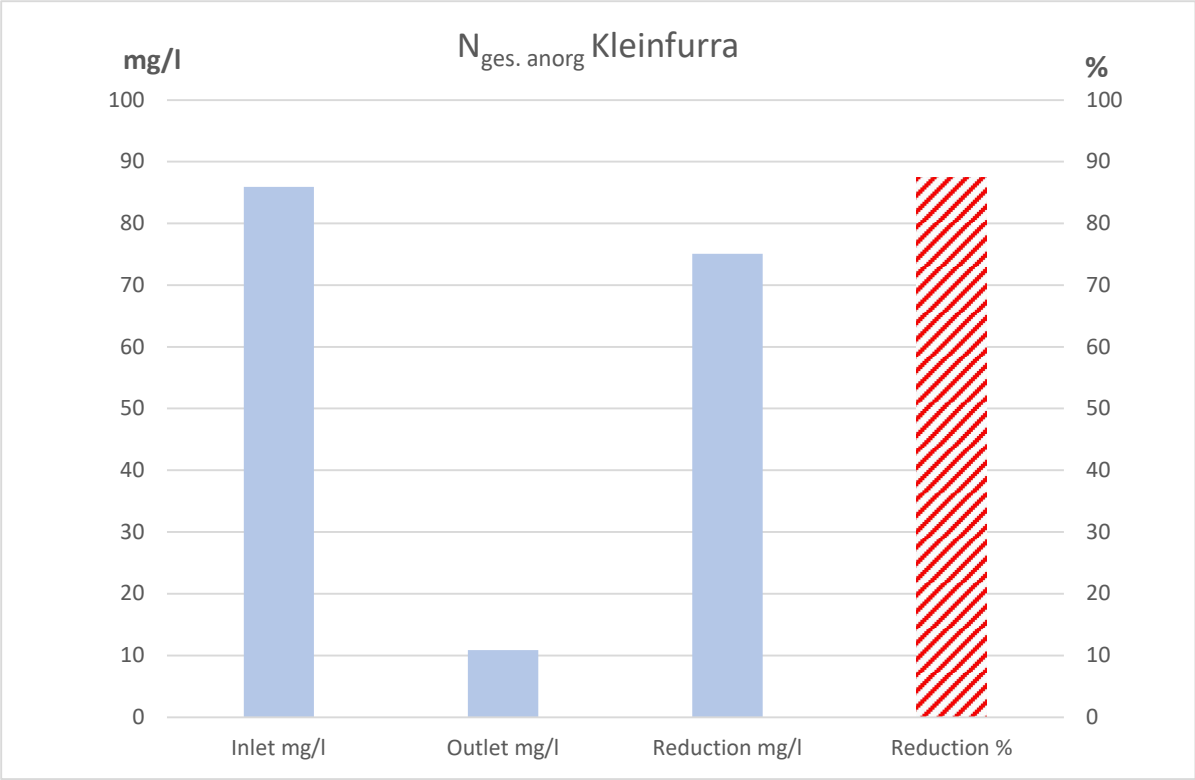

Figure 1:

Average loads of N_{tot} from of inlet and outlet; Plant „Kleinfurra“ (Thüringen).

Denitrification on rotating immersion biodiscs

One of the advantages of rotating immersion biodiscs, as well as other fixed bed systems, is that the biology does not float in the solution, but is fixed in place on special growth surfaces, and therefore is not washed out with the wastewater (Fig. 2). This fixation also means that, when the biomass encounters contaminants, then a very high amount of sludge encounters only low levels of pollution. The biomass formed is accordingly robust. In addition, it is not necessary to keep the entire volume of water in motion in an energy-intensive manner, but only the biomass that is directly involved in purification. The decisive factor in these systems is their controlled sludge discharge. Experience shows that the findings from the aerobic process can also be applied to the anoxic process. In order to utilise the entire surface area determined in the planning phase over decades, the growth areas must be prevented from becoming overgrown by an induced sludge discharge.

Here, processes which do not attempt to artificially create a higher surface area have proven successful, since experience has shown that this surface inevitably becomes overgrown despite efforts to the contrary, and ultimately only a smooth surface remains. Rotating immersion biodiscs with smooth discs and the associated controlled sludge discharge are a technically mature solution which maintain the planned surface area long-term.

Continuous development has made rotating immersion biodisc systems a market-ready and functional solution for denitrification, which simultaneously meets the previously-mentioned requirements for a modern and future-proof wastewater treatment system in rural areas, whilst offering low maintenance costs.

These systems are characterized by:

- simple management,
- low maintenance requirements,
- largely autonomous operation.

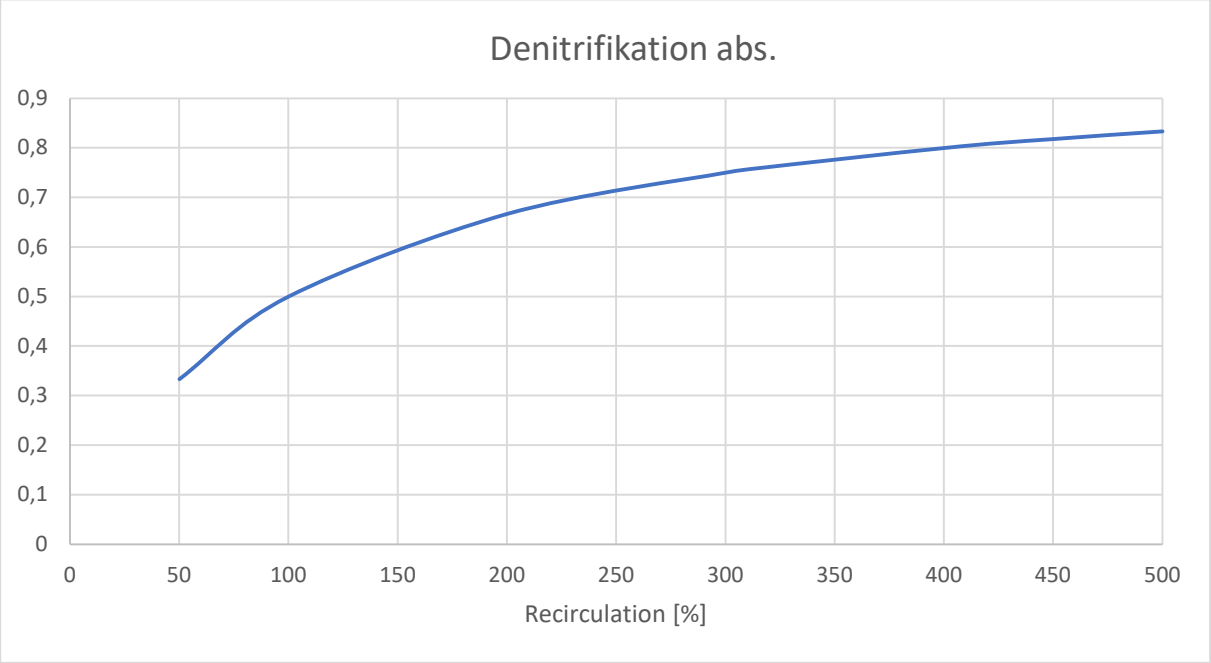

Figure 2:

Shows absolute Denitrification depending on recirculation.
A significant increase in Denitrification can only be realized up to a recirculation ratio of roughly 4 (=400%)

Applying the technology in practice
Figure 3 shows an example of a plant that works with this technology:
Upper limit $N_{tot.}$ < 25 mg/l
Technology with submersed discs (Leutershausen Brunst, Bavaria - Germany)

The submerged discs are clearly recognizable, which allows the continuity of the process with easy access at the same time.

The plant at Kleinfurra was built in 2019 and has been in operation since 2020. The facility is designed for 1,500 inhabitants, who are gradually being connected. The average values were determined from the summer months in 2021 and 2020 between May and November. The inflow is 85.92 mg/l, the outflow is 10.87 mg/l $N_{tot.}$,anorg.
The reduction in $N_{tot.}$,anorg. by a total of 87% between inflow and outflow clearly demonstrates the plant's efficiency. The average reduction over 6 months in 2 summers is 75 mg/l. The data only relate to inorganic nitrogen. If organic nitrogen is included, a higher purification performance is to be expected. The plant can operate continuously and reliably, since the system automatically discharges sludge, and is also easily accessible for visual inspections and possible maintenance.
The systems can be used as "stand-alone" systems or to upgrade and expand existing plants, e.g. pond or plant filter systems. Likewise, combination with activation systems and

subsequent nitrification with rotating immersion biodiscs is possible. Integrated phosphorus precipitation is now standard.
A precise planning process based on the applicable A222 and A281 norms is the most important factor to ensure the reliable operation of the system.

Conclusion
In summary, it can be said that the plants meet the need for a low-maintenance, simple-to-operate and energy-saving wastewater treatment system whilst simultaneously achieving the required effluent values.
Plants with rotating immersion biodiscs for denitrification represent a significant step forward in wastewater treatment methods and offer rural communities a practical alternative with good effluent values.

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