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# Saturated buffer zones: a monitoring challenge but possibly a rather cost-effective measure to reduce nutrient load of aquatic systems

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## INTRODUCTION

Saturated buffer zones (SBZ) are a novel mitigation option in Denmark to reduce the nutrient pollution of aquatic systems. The technology has been tested at multiple sites in Iowa (USA) over several years starting in 2010 (Jaynes and Isenhart, 2019). The simple principle is that drain water from the field becomes reconnected to the riparian zone as the drainage water is diverted to a buried, lateral distribution pipe running parallel to the stream (Figure 1). The drainage water infiltrates from the lateral pipe into the riparian soil towards the stream, which will cause the riparian soil to become saturated and consequently create anoxic conditions to support denitrification. The SBZ is also expected to reduce overland flows depending on the slope, width, and remaining water infiltration capacity of the buffer zone.

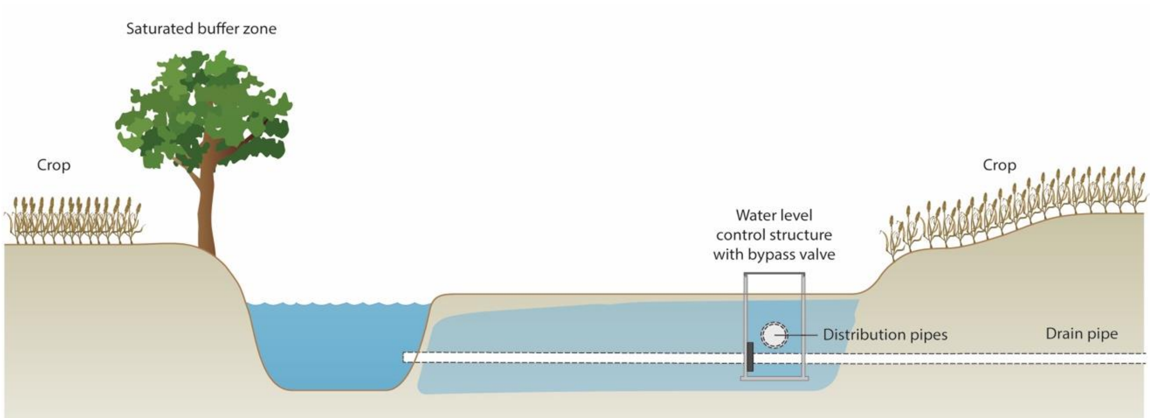


**Fig. 1. Saturated buffer zones as edge of the field technology to reduce nutrient losses to aquatic systems. The drainwater is diverted into a distribution pipe charging the buffer zone until water saturation.**

Until now, the nutrient removal efficiencies of SBZs reported from USA have been highly variable (Jaynes and Isenhart, 2019). Poor performance of the SBZ have been linked to selection of unideal sites containing non-permeable soil layers or sites with lower fraction of water diverted to the SBZ. The fraction of tile drain water that can be diverted into the SBZ is controlled by the infiltration capacity of the SBZ. The vegetation might also influence efficiency as sites with established perennial vegetation showed higher removal rates , which might be due to that either more labile carbon was added to the soil to support denitrification or that microbial N immobilization was enhanced by the more developed rhizospheres (Jaynes and Isenhart, 2019). As shown in this pilot study in US, it remains difficult to assess the removal efficiency of SBZs in particular if sites are charged by unknown amount and quality of incoming groundwater.

## METHODS

Two sites have been selected to test their suitability as SBZ for nutrient removal located in the Odder Kommune ca. 30km south of Aarhus, Denmark (Figure 2). The names Ulvskov and Gylling are related to the neighboring villages and both are situated along small agricultural impacted streams. The reconnection of drainage pipe and installation of the distribution systems was first established at the Ulvskov site (November 2018) and a few months later at the Gylling site (February 2019). In December 2019 the distribution system in Gylling was reconstructed by lifting up the distribution pipe and mowing it downward in order to improve the infiltration of the diverted water in the SBZ soil (Figure 2). The area of SBZ is roughly determined by the length of the distribution pipe (ca. 80 m) and the distance between the pipe and the adjacent stream (ca. 50 m). The most distinct difference between the two sites is the soil type where Ulvskov is characterized by sandy soils (depth 1-2 m) with underlain clay while Gylling has a ca. 3 m deep peat deposit with muddy sediments at the bottom.

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**Fig. 2. Two saturated buffer zones are currently being tested in Denmark (south of Aarhus). The distribution pipe receives the water from the field drain and is buried ca. 0.5 m below the surface. The inlet water is monitored continuously by KROHNE flow meter and piezometer transects in the buffer zone enable the monitoring of water tables and water chemistry.**

RESULTS and DISCUSSION

Water infiltration into both SBZs was on average 1 L/s or 90 $m^3$/day, respectively. However, the diverted flow at both SBZ sites was highly variable and differed by one order of magnitude within only a few days. Full water saturation was only established in parts of the mineral SBZ Ulvskov, which indicates a rather heterogeneous water infiltration or distinct preferential water flow paths, respectively through the SBZ. The average water table at this site was approximately 1 m higher in the SBZ than in the control transect located  adjacent to the SBZ. The water table of the SBZ in Gylling was only raised by few decimetres close to the distribution pipe while the water table was not elevated in any other areas of the transects, thus further changes of the water distribution system is needed. Both sites are substantially impacted by groundwater inflow which importance is not quantified so far.

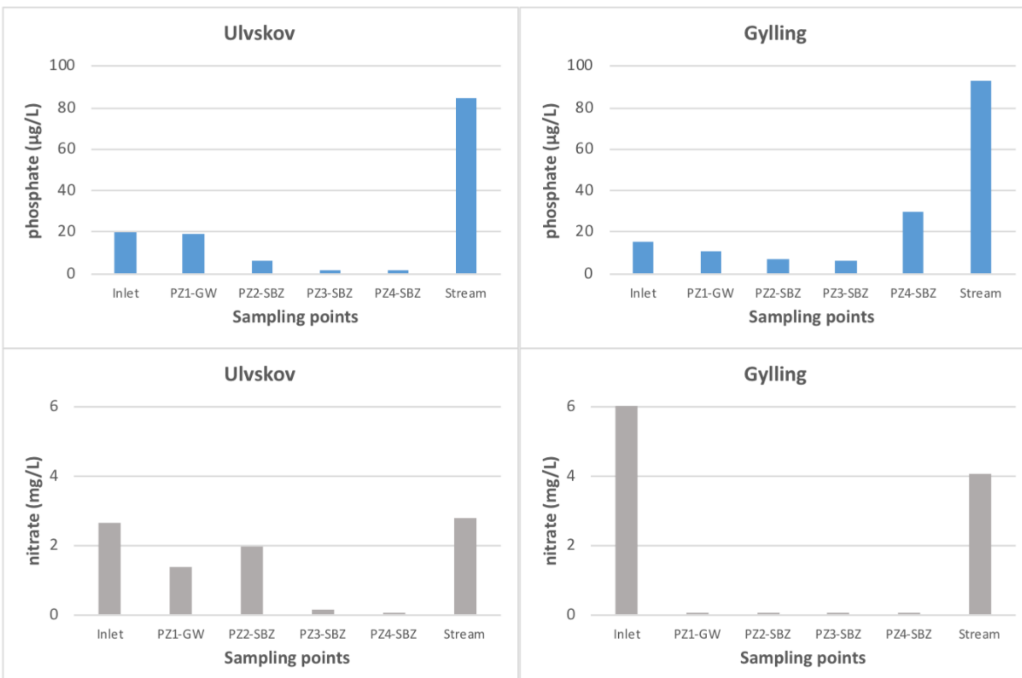


**Fig. 3. Comparison of water quality at different sampling points of the saturated buffer zones (SBZ) Ulvskov and Gylling in October 2019. The inlet refers to the drain water from the agricultural field, which discharge the SBZ via a distribution pipe in the ground. The sampled transect consists of four sampling points where PZ1 is the first piezometer located before of the distribution pipe in order to monitor the incoming groundwater (GW) from the fields. PZ4 is the last sampled piezometer in the transect close to the stream which was also monitored.**

Highest concentrations of nitrate and phosphate were recorded either in the inlet or in the adjacent stream at both sites (Figure 3). The nutrient concentration of the infiltration water coming from the drainage system was similar to the inflowing groundwater at the Ulvskov site, but there was a large difference for nitrate at the Gylling site. Here the nitrate in the inlet reached a value slightly higher than 6 mg N/L but concentrations in incoming groundwater was closed to the detection limit of 0.01 mg N/L (PZ1-GW, Figure 3). The nitrate concentrations were not changing in the soil water towards the stream others than the phosphate concentrations. While there was a slight decrease within the transect the last sampling point (PZ4, Figure 3) had the highest concentrations with round 30 µg/L. For Ulvskov both nitrate and phosphate were lowest at the last sampling point in the transect being 40 or 100 times lower, respectively than the concentrations in the adjacent stream (Figure 3). This steep gradient of nutrient concentrations was less apparent in subsequent sampling occasion during the cold winter season implying a reduced nutrient retention capability at lower temperatures and/or higher water discharge as found previously in integrated buffer zones (Zak et al. 2018).

## CONCLUSIONS

Our preliminary results underpin the challenges of variable water inflow, preferential water infiltration and the impact of groundwater when establishing SBZs as also shown in previous SBZ studies. Full water saturation of the SBZ cannot be expected, however depending on the area slope and hydraulic gradients, water tables can be raised substantially in the whole treatment area, which favour the conditions for nitrate removal by denitrification. While the mineral SBZ site (Ulvskov) tended to be a significant phosphate sink, an increase of phosphate release seemed to be occurred at the SBZ site with organic soil (Gylling). Currently, the overall lower nutrient concentrations in the SBZ compared to both the infiltrating drain water and the stream imply that at least the mineral SBZ site act as effective nutrient filter. However, the interpretation of these first monitoring data and the processes behind is still highly uncertain in particular for the Gylling site, since here a significant dilution effect from incoming groundwater seems to be obvious.

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