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# REDUCTION OF EMISSIONS USING BIOMANIPULATIONS OF ACTIVATED SLUDGE: SELECTED FULL-SCALE EXAMPLES

Innovative wastewater treatment processes and bioenergy production techniques were developed by means of artificial selection/biomanipulation processes. In this paper, we present some examples of advanced biomanipulation of full-scale wastewater treatment plants and biogas plant. To achieve different goals, e.g. reduction of sludge volume index, augmentation of sludge concentration in the reactor or/and improvement of nutrient elimination, five different innovative process engineering concepts have been developed, tested and applied.

## 1. INTRODUCTION

The activated sludge process, which was first used in England at the beginning of the 20th century, has become a huge success story based mainly on an effective separation of sludge and water in the downstream sedimentation/secondary clarification basin.

Separation is based on specific sedimentation properties of the activated sludge flocs. These occur automatically after a certain run-in phase, even without inoculation with activated sludge from an existing plant, because all particles which do not sediment are washed out of the system. If this selective pressure towards sedimentation did not exist, for example such as in membrane-biology plants, no or very few flocs would form.

The classical activated sludge process is therefore already based on a pronounced bio-manipulation.

Many further bio-manipulations have been developed up to the current time in many variations in order to “breed” new required characteristics such as nitrification, biological P elimination, reduction of the sludge volume index (SVI) etc., into the activated sludge.

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## 2. SELECTED PLANT EXAMPLES

Most of the examples presented were designed and built by LimnoTec Abwasser-anlagen GmbH and are operated on the SBR principle (sequence batch reactor) (HOLM et al. 2000, RÖNNER-HOLM et al. 2006), because these have extremely high flexibility in operations management and have been investigated in detail in the context of research projects (RÖNNER-HOLM et al. 2008 1 and 2, SCHWITALLA et al. 2008, HOLM et al. 2008, SCHARFSCHEER et al. 2008, ALEX et al. 2008).

Since the bio-manipulation principles are, however, of a general nature, we will also deal with a few conventional continuous waste water treatment plants. In addition, examples for bio-manipulation of anaerobic sledges from biogas plants will be presented.

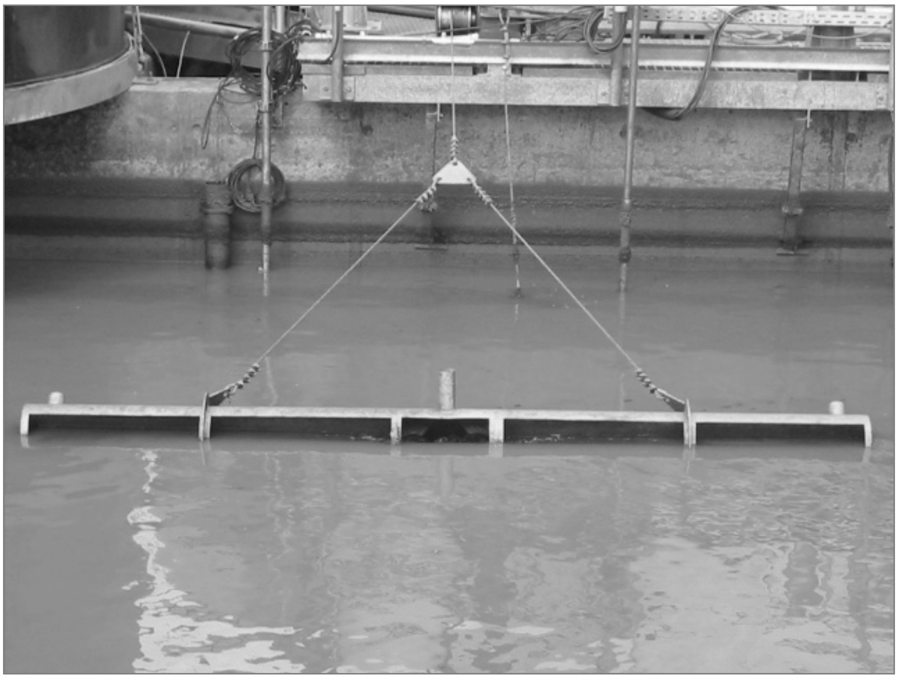

Fig. 1. Photo of decanter during decanting at the Gemüse Meyer works

The main centre of focus in the bio-manipulations presented here is formed by the various processes for reducing the sludge volume index:

1. The SBR–SAS select process used in the process waste water treatment works at Gemüse Meyer.
2. The SAS select process used at the Bad Salzuflen waste water treatment plant.
3. The “classical” bio-augmentation used at Weißtal waste water treatment plant.

4. The RS process for reducing the sludge index.

5. The SER–SBR process used in the process water treatment works at Gemüse Meyer

In addition, a few special manipulations for improving the nitrification/denitrification and biological P elimination will be presented:

1. The turbid SBR process used at Weißtal waste water treatment plant

2. The RS process for the improvement of nutrient elimination

In this case, we must consider that all processes for reducing the sludge volume index can also be used immediately for improving the cleansing performance and therefore reduction of emissions, since additional "space" is created which can also be used if required for the improvement/intensification of nitrification, denitrification and/or biological P-elimination.

## 3. THE SBR–SAS SELECT PROCESS USED IN THE PROCESS WATER TREATMENT WORKS AT GEMÜSE MEYER

This process wastewater treatment plant (PWWTP) has an activated sludge stage (SBR reactor) for the treatment of turbid water from the anaerobic pre-treatment stage.

Here, the SBR process has been taken to its peak so that the clarified supernatant water decanter is not only used for clarified waste water removal, but also simultaneously removes the surplus activated sludge (SAS) formed in each cycle.

This special decanting strategy is used on the one hand for sludge volume index reduction, whereby the activated sludge concentration in the SB-reactor is considerably increased. In addition, decanting of the surplus activated sludge is required for the downstream precipitation stage in this specific application.

This bio-manipulation principle is based on the fact that, during the sedimentation process in an SB reactor, the more slowly sedimenting flocs with a higher, i.e. worse sludge volume index are in a disproportionately high fraction in the upper sludge layers at the limits of the clarified waste water layer.

## 4. THE SAS SELECT PROCESS USED AT THE BAD SALZUFLEN WWTP

The Bad Salzuflen waste water treatment plant is a continuous pass plant with intermittent nitrification/denitrification. Approximately 60.000 residential units are connected to the Bad Salzuflen works. The works is under loaded in terms of freight, but highly loaded hydraulically due to a very high storm weather inflow.

This is viewed as problematical by the operator in connection with a comparatively high sludge volume index of up to 170 ml/g.

At the current time, a new process for sludge volume index reduction is being tested on a large scale at the plant. The process being used is the SAS select process developed by LimnoTec. The process is being financially supported in the context of accompanying R&D investigations by MUNLV in North Rhine Westphalia (MUNLV 2008–2010).

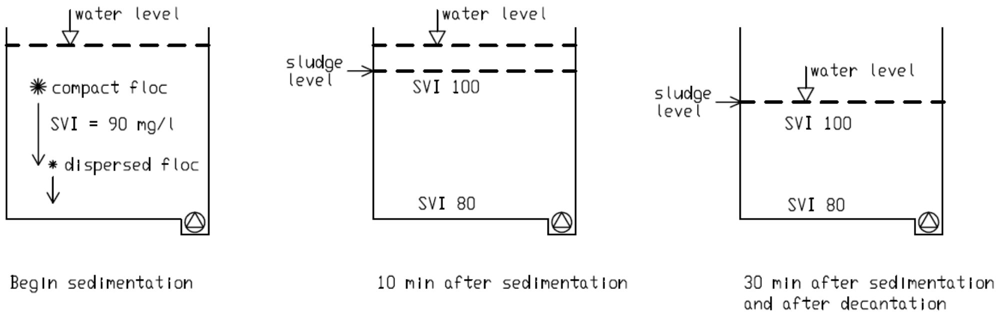


Fig. 2. SBR-SAS-Select

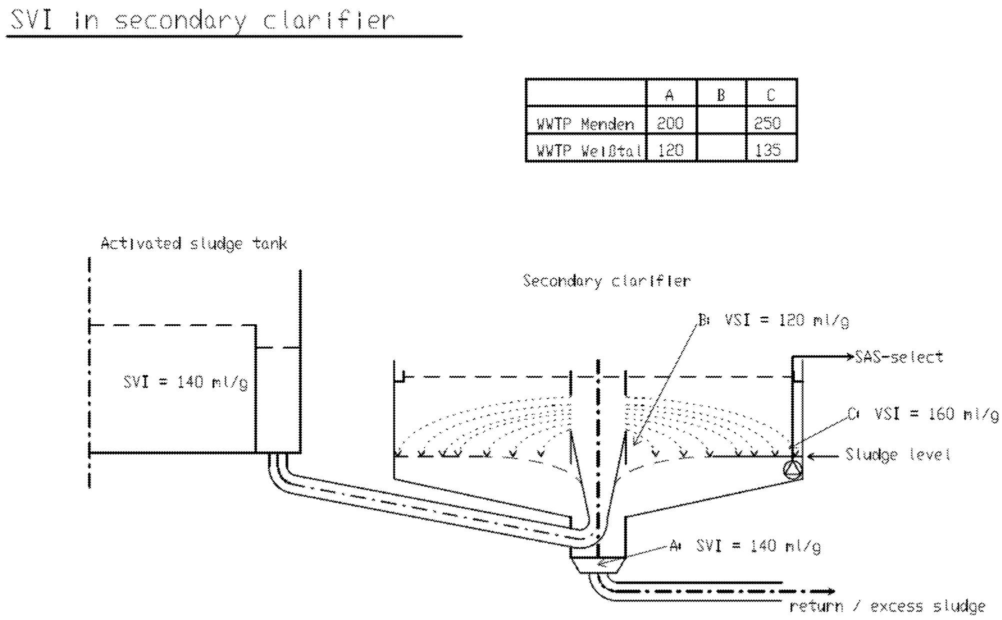


Fig. 3. SAS select process in a continuous pass plant

In accordance with this process, excess sludge is no longer removed from the return sludge in continuous pass activated sludge plants, but is taken separately from the periphery of the secondary clarification basin (see figure 2). The underlying idea is that rapidly sedimenting activated sludge flocs settle mostly in the centre of the secondary clarification area, whereas more slowly sedimenting flocs with a higher, i.e. worse sludge volume index tend to sediment around the outside edges. Trials carried out at several plants have shown that this sludge volume index spread actually does exist and that the requirements for selection therefore exist on a large scale.

The first results are expected at the end of 2008.

## 5. THE “CLASSICAL” BIO-AUGMENTATION USED AT WEIßTAL WWTP

With regard to its size (around 20.000 residential units) the Weißtal WWTP is a relatively complex plant. Both continuous pass biology (upstream denitrification with 2-stage nitrification) and SBR biology are being operated in parallel. The primary and excess sludge’s are anaerobically stabilised in a digestion process.

In the context of a R&D process subsidised by MUNLV (MUNLV 2005–2008), various procedural optimisations have been investigated by LimnoTec both on a large scale and in simulation. The SBR surplus activated sludge process stage into the influent of the continuous pass plant is presented below:

The aim of this new process stage is optimisation of the nitrification and reduction of the sludge volume index in the continuous pass plant, since the sludge index with average 170 ml/g is very high, whereas the sludge volume index in the SBR biology remains constant at around 75 ml/g throughout the year.

With regard to optimisation of the nitrification, the SBR biology has been loaded with almost the entire turbid/filtrate water flow from the digestion since autumn 2007 (with around 1000 mg/dm$^3$ $NH_4$-N) in order to increase the proportion of the nitrification population, see also Chapter 9.

From July 2008 onwards, the SBR surplus activated sludge has been transported into the continuous flow biology influent instead of into the anaerobic sludge treatment section. The sludge volume index in the continuous pass biology has reduced down to approx. 110 ml/g after around five weeks.

This means that there is no danger that sludge will be driven out of the continuous pass biology secondary clarification stage during heavy rainfall flow in the future.

## 6. THE RS PROCESS FOR REDUCING THE SLUDGE VOLUME INDEX

The RS process has now been introduced in around 10 of the SBR plants designed and constructed by LimnoTec Abwasseranlagen, and has been investigated in detail in the context of an R&D contract subsidised by the MUNLV at Spenge (MUNLV 2004–2006).

In accordance with this process, a small proportion of the activated sludge from the SB reactor(s) is returned intermittently to the buffer reservoir using a bypass. The original intent was to improve the denitrification and biological P elimination, please also see Chapter 9.

The RS process is shown diagrammatically in figure 4.

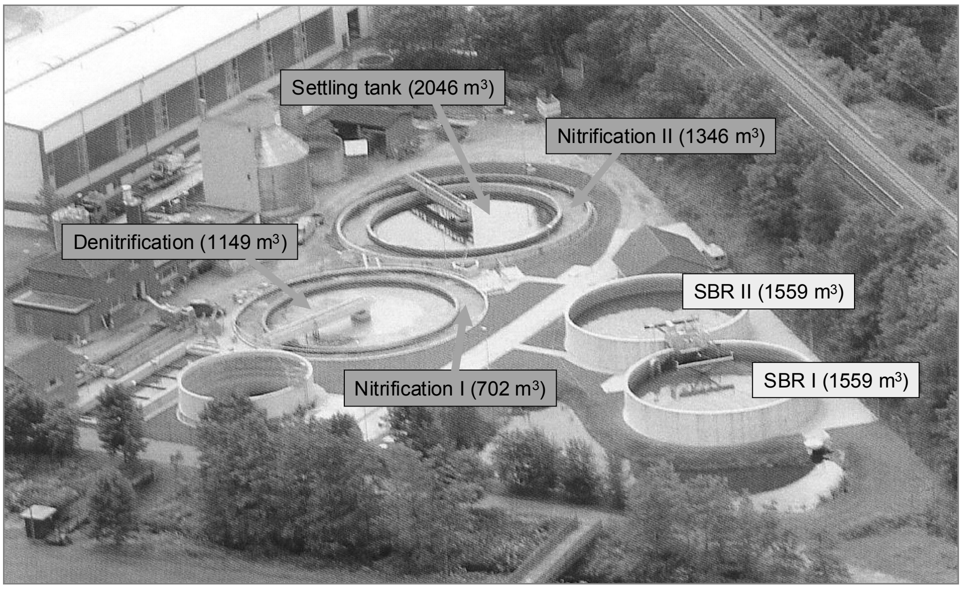


Fig. 4. Weißtal WWTP

This process can, however, also be used for the bio-manipulation of the sludge volume index.

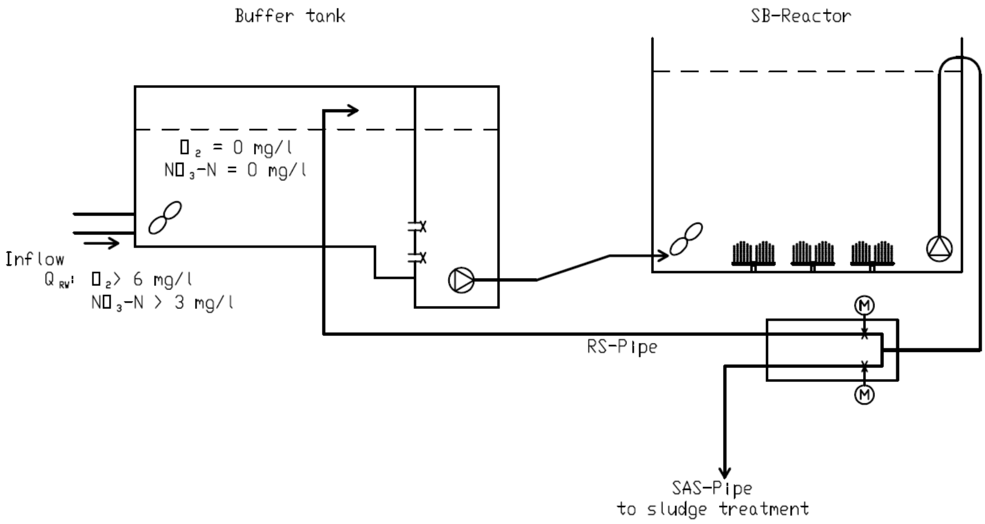


Fig. 5. RS-SBR process

1. It is possible that the sludge volume index is (considerably) different in individual SB reactors. In this case, it is preferable that the RS process is operated using the SB reactor which has the lowest sludge volume index. As a result of this, SAS sludge removal for sludge treatment will mostly take place from the other reactors and their sludge volume index will be reduced by the addition of the lower sludge volume index from the buffer reservoir.

2. The RS sludge is removed around 20 minutes after commencement of the sedimentation phase, and the SAS sludge is removed after this. This will contain a disproportionately high floc fraction with a higher sludge volume index, since RS sludge with disproportionately high numbers of flocs with a lower sludge volume index has previously been removed. After this, the activated sludge will be selected in the reactors in the direction of a lower sludge volume index.

## 7. THE SER–SBR PROCESS USED IN PWWTP AT GEMÜSE MEYER

Attempts were made to operate digestion plants using the SBR principal in the USA around 20 years ago. This was not continued for various reasons.

Fig. 6. View of digester and SER reactor at Gemüse Meyer treatment works

LimnoTec Abwasseranlagen GmbH has developed a digested sludge enrichment reactor (SER). This process is based on an external SB reactor which is connected to the actual digester with several sludge and gas pipelines. Cyclically, this SER is fed with digestive sludge added from the digester, de-gassed, sedimented, then the sludge fraction is returned to the digester and the excess turbid water fraction is removed. This means that the anaerobic sludge amount in the digester can be increased by several scales depending on the input/output dry matter content.

Currently, the optimisation potential of this process is being investigated in an R&D process subsidised by the DBU (DBU 2008–2010).

## 8. THE TURBID SBR PROCESS USED AT WEIßTAL WWTP

The influent to the Weißtal WWTP is fed through a primary clarification basin after raking and sand removal. After this, around 45% is fed to the SBR line and 55% to the continuous flow biology. This means that the effluent is only restrictedly suitable for realisation of the DIC-SBR process (Differential Internal Cycle strategy), (see figure 7).

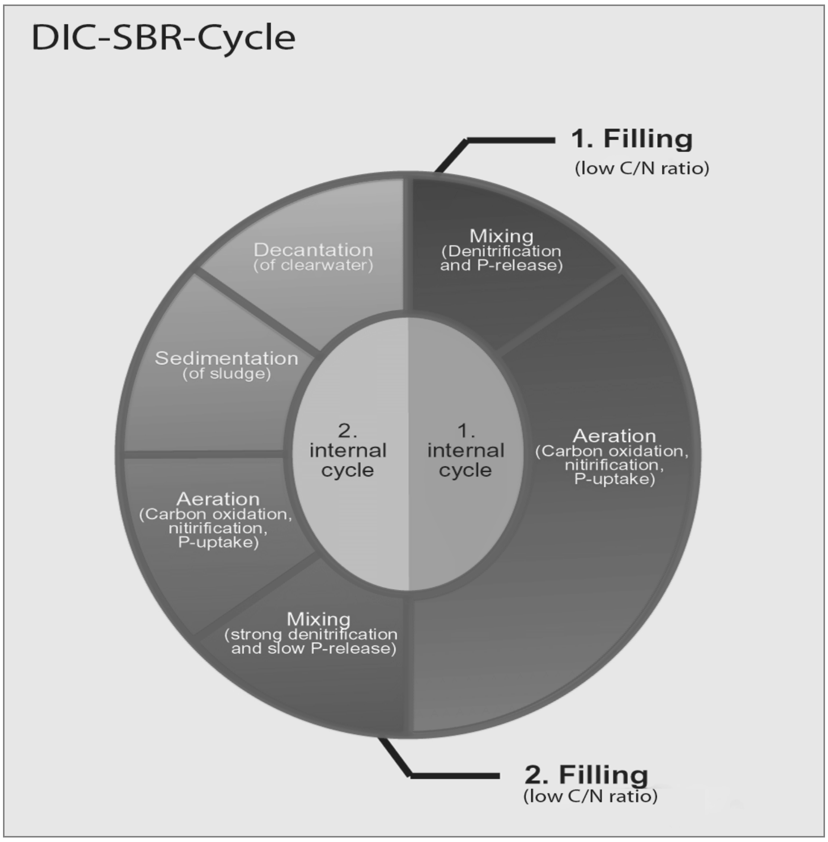


Fig. 7. Schematic representation of the DIC-SBR process with high N freight in the first feed and low N freight in the second feed

The influent flowing into both activated systems shows an very low C/N relationship, since high C-freights are removed in the primary clarification (the primary sludge is transported directly to the digestion), and also comparatively high turbid water quantities with high N-freights from the digestion need to be treated in the activated sludge systems.

In Weißtal, the DIC principle has been implemented as a variation by only supplementing the fillings with turbid water from the digestion during the initial fillings, and by increasing the proportion of the secondary fillings (only with waste water influent and without turbid water from the digestion) to 40% (see figure 8).

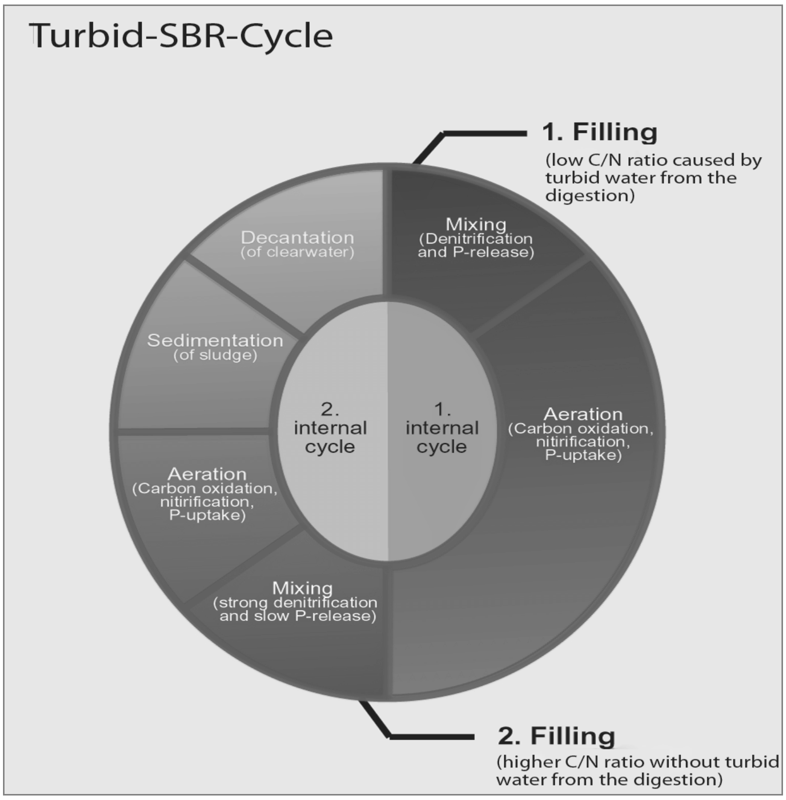


Fig. 8. Schematic representation of the turbid SBR process at the Weißtal WWTP with high N freight in the first feed and low N freight in the second feed

Due to the second increased filling without turbid water from the digestion, the denitrification rate can be correspondingly increased. However, the C/N relationship is overall still so high that in times of very high turbid water influent a proportion of the flow to the SBR line is fed to the influent for the entire plant or into the continuous pass biology system.

A second bio-manipulation stage consists of diverting the SBR surplus activated sludge (which contains an increased proportion of nitrificants due to treatment of the digester turbid water) into the influent in the continuous pass biology system, see Chapter 5. This has the intention of increasing the nitrification speed there in order to create more "space" for the denitrification and, if necessary, also the biological P elimination.

## 9. THE RS PROCESS FOR THE IMPROVEMENT OF NUTRIENT ELIMINATION

The RS process was first implemented on a large scale at Deuz WWTP. The background in this case was the observation that oxygen concentrations (and also nitrate concentrations) only reduced marginally during heavy rain influent stages, and that partially high oxygen levels occurred during SBR feeds which limited the denitrification and biological P resolution.

The intention of the RS process is to permanently and completely eliminate the oxygen and nitrate quantities in the buffer reservoir. This is competently ensured by the recycling of activated sludge from the SB reactors back into the buffer reservoir even during times of rainwater influent, and bio-manipulation of the activated sludge towards the establishment of stable bio-P populations and improved denitrification also takes place. This has been clearly confirmed by measurement campaigns and dynamic simulation investigations in both Deuz and Spenge.

## 10. SUMMARY AND OUTLOOK

Whereas the results of the SAS select process in the Bad Salzuflen and Oerlinghausen WWTP's with regard to continuous pass plants are still awaited, there is already a whole series of large-scale successfully tried-and-tested and implemented procedures available right now with which the sludge volume index in SBR treatment works can be specifically lowered.

Most of these processes can be integrated in existing plants at very low cost, however the requirement in most cases is that there is an upstream buffer reservoir.

The ultimate aim of sludge volume index reduction in existing plants is, of course, ensuring a sufficiently high sludge content in the reactors in addition to a floc-free clarified waste water outflow.

Once a low sludge volume index has been established, there are many possibilities for improving the cleaning performance and/or lowering of operating costs.

The investigation of operational management strategies, with which considerable operating cost reductions are possible but unfortunately are unfavourable to the sludge volume index, will be of especial interest in the future. This applies, for example to the operational management strategy which strive for a $O_2$ target value of around 0.2 mg/dm$^3$ and a $NH_4$-N outflow value of around 2 mg/l by special aeration strategies. Can this strategy be operated without unfavourable consequences for the sludge volume index if measures for sludge volume index reduction (e.g. SBR-SAS select and/or RS-SBR) are implemented?

This should be intensively investigated in the future since energy savings measures are becoming increasingly important.

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