How to boost the biology in a municipal waste water treatment plant

How to boost the biology in a municipal waste water treatment plant, a case study

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ABSTRACT

A bioremediation pilot program was successfully executed at WwTW Halsteren, the Netherlands, operated by the Dutch water authority Water board Brabantse Delta. The program was based upon dosing proprietary Aqua Assist biocatalysts into the activated sludge reactor to boost the biology with the primary aim to reduce the production of waste activated sludge.

The Aqua Assist solution relies upon the regular dosing of an engineered microporous silica oxide-based dry-to-the-touch granular matrix with particle sizes in the range of 200 – 600 microns, inoculated with a specific proprietary microbial population, directly into the activated sludge reactor. Within the reactor the media will typically have a retention time equal to the sludge retention time. The particles are protecting the microbes from predators, bacteriophages and/or toxins and act as a nursery for the biomass to grow, with doubling times of 2 – 3 hours under more or less optimal circumstances, once the material is dosed into the activated sludge basin. With a sludge retention time of 19 days in the Halsteren activated sludge basin, the introduced Aqua Assist biomass roughly contributes to at least 10% of the total biomass present. Studies have revealed that the Aqua Assist dosing initiates a shift in bacteria species which favour the process conditions for wastewater treatment.

The trial was performed between June and November 2019, dosing a small amount of Aqua Assist twice a week into the activated sludge tank. It resulted in the increase of the MLSS concentration from 2.7 g/l up to 3.7 g/l without any impact on SVI, effluent quality and plant operation stability. The objective to reduce WAS production was achieved with a dry solids reduction of around 25%. As a result, a positive business case was demonstrated and a follow-up of the project is initiated.

Introduction

Maintaining the optimal MLSS in a municipal wastewater treatment plant is important for both treatment performance and energy efficiency. The more organic matter is consumed by the biomass, the lower the biochemical oxygen demand (BOD) will be in the discharge. The goal of this Aqua Assist pilot program was to minimize waste activated sludge (WAS) production by raising the MLSS to a higher level without this interfering with the process of purification.

At higher MLSS values, solids retention times (SRT) are longer, enhancing the tendency for endogenous respiration of the microbes. Endogenous respiration involves the consumption by microbes of internally stored carbon, leading to lower sludge yields (Loosdrecht & Henze, 1999). A full scale trial was executed in the Netherlands to verify the impact of dosing Aqua Assist. Tests were performed at WwTW Halsteren, operated by the Dutch water authority Brabantse Delta, during 2019.

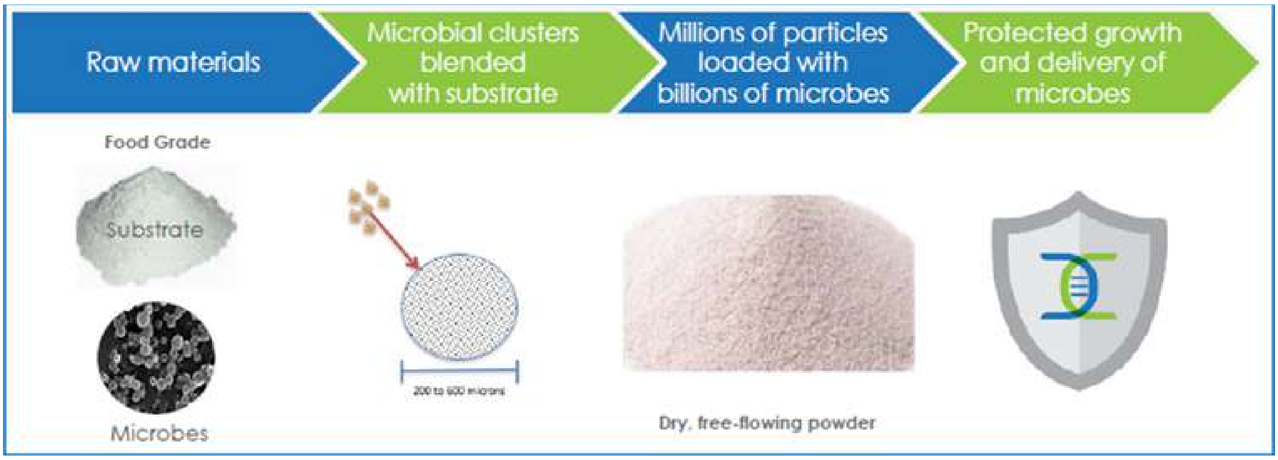
WwTW Halsteren , The Netherlands

How does it work?

For microbes to survive in a competitive environment within an activated sludge plant for wastewater treatment and to contribute to the effective treatment, three main conditions must be created. First, access to food needs to be facilitated – microbes obtain food from organic matter by first adsorbing the COD molecules onto the outer surface of the cell, prior to the diffusion of the molecules into the cell; a high surface area for adsorption promotes access to food. Secondly, microbes must be protected from predation by other organisms and/or toxins. Finally, the environment needs to enable microbes to be retained for extended periods of time in the treatment system (refer to figure 2).

By dosing Aqua Assist particles, all three criteria are met by creating a favorable environment of carefully selected bacteria. The solution relies upon the regular dosing of an engineered microporous silica oxide based dry-to-the-touch granular matrix with particle sizes in the range of 200 – 600 micron, specific density of 590 kg/m3, inoculated with a specific proprietary microbial population, as indicated in figure 1.

Figure 1 – Production process Aqua Assist

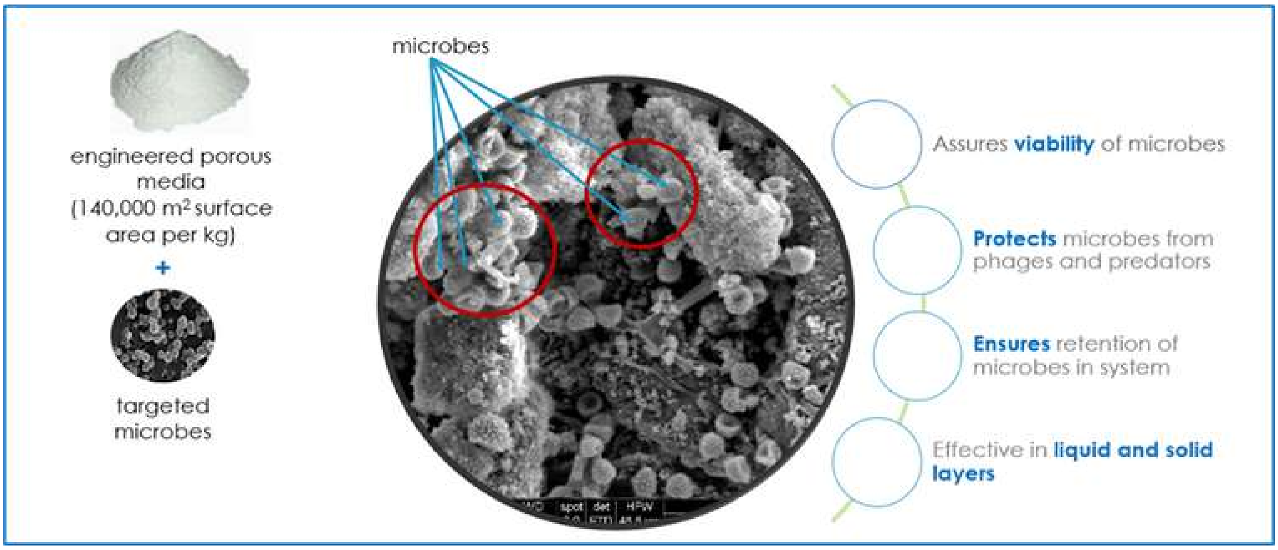


The biocatalysts are dosed directly into the activated sludge tank, with a typical retention time equal to the sludge retention time. The particles protect the microbes from predators and/or toxins and act as a nursery for the biomass to double every 2 – 3 hours under more or less optimal circumstances. As the microbes proliferate within the pores of the particles, they are exuded into the bulk liquor.

The microbes which are loaded onto the inorganic silica microporous medium are characterized by their high capability for efficient metabolizing, not being filamentous in nature but floc forming, and enhancing hydrolysis with both lipophilic and halophilic functionality. With regards to their oxic preferences, the microbes are facultative and aerobic.
The ideal growth rate of the microbes in the granular environment will have a relevant impact on the total biomass present in the activated sludge basin. This impact has been calculated for the Halsteren plant with a total activated sludge volume of 2,580 m3, an average MLSS content of 9,000 kg and a SRT of 19 days. 1 kg of product contains 50 g of microbes (5% by mass), with a maximal growth potential in the secured environment. During the test period with Aqua Assist dosing (April – November 2019) a daily dosage of 600 g of product was applied, equalizing the addition of 30 g of microbes per day.

Although the dosage is low, the high sorption capacity of the porous media and the protective properties that it provides enable the microbes to enter rapidly into an exponential growth phase. With typical doubling times of about 2-3 hours, a yield is established of 50-100 kg of biomass within a 24-hour timeframe.
The applied technology should not be confused with biomass growth on top of carriers in Moving Bed Biological Reactor (MBBR) systems, as the mechanism for growth is different. In an MBBR system, biofilm growth starts from outside in. The microbes are not carefully selected but are already present in the system and are only using the carrier to grow and retain inside the tank. In contrast, the microporous Aqua Assist media carries carefully pre-selected, embedded microbes.

Figure 2 – Main drivers for Aqua Assist impact



Changes in microbial population due to Aqua Assist dosing

The microbial culture was studied in some activated sludge plants located in Massachusetts, USA before and after dosing Aqua Assist to find out whether and, if so, how the shift of microbial population occurs. In the table below, the most relevant microbial species found in the activated sludge tank are tracked

Before and after regular dosing over the course of a year.
The results indicate that a clear shift is taking place, with particular species growing strongly while other species tend to decrease after dosing. This shift contributes to growing a population of microbes which are favourable for the biological processes in the wastewater treatment plant.

For both aeration tanks AT1 and AT3, table 1 lists the microbes with a relative abundance greater than or equal to 2% in either the initial or final sample and have decreased or increased by 15% or more after the use of Aqua Assist. As more factors are impacting microbial shifts in activated sludge processes, these findings should be verified carefully.

Table 1 Predominant changes in microbial population before and after Aqua Assist dosing in a serial activated sludge scheme at activated sludge plant located in Massachusetts, USA

	Aeration tank **AT1**			Aeration tank **AT3**		
	% Abundance			% Abundance		
	Initial	Final	% change	Initial	Final	% change
Arcobacter sp	9.3	7.9	-15%	6.1	28.9	+370%
Comamonas sp	2.5	0.0	-100%	2.3	0.0	-100%
Curvibacter sp	2.2	3.6	+67%	3.2	2.2	-30%
Denitromonas sp	2.9	0.0	-100%	4.2	0.0	-100%
Flavobacterium sp	2.1	6.8	+221%	2.3	4.5	+98%
Haliea sp	6.3	0.0	-100%	5.6	0.0	-100%
Hoeflea sp	0.3	10.4	+3694%	0.2	10.7	+6682%
Hydrogenophaga taeniospiralis	3.4	0.9	-74%	3.3	0.5	-84%
Hyphomonas jannaschiana	3.9	0.2	-94%	4.1	0.1	-97%
Marimicrobium arenosum	3.8	0.0	-100%	3.9	0.0	-100%
Psychroserpens mesophilus	13.1	0.0	-100%	14.8	0.0	-100%
Rhodobacter sp	3.0	11.0	+271%	1.6	8.9	+471%
Vitellibacter nionensis	7.9	0.1	-99%	9.1	0.1	-99%
Sulfurimonas sp	_	_	_	0.4	2.4	+431%
Lewinella nigricans	0.7	8.6	+1086%	_	_	_
Thauera phenylacetica	2.1	0.0	-100%	_	_	_

PROOF OF PRINCIPLE AT WWTW HALSTEREN

WwTW Halsteren (figure 3), the Netherlands is operated by the water authority Brabantse Delta and is characterized as a low-load biological treatment plant, with a capacity of 12,700 pe, a maximum hydraulic capacity of 525 m3/h. Phosphorus is chemically removed by dosing aluminum into the aeration tank (AT). WAS is thickened and stored prior to transport to a central sludge digesting facility.

Figure 3 – WwTW Halsteren

To analyze the effectiveness of dosing Aqua Assist, an initial comparison was made with the process data from 2017, a year with more or less similar process operations.
The dosing started early June 2019 and was continued until the end of November 2019. Twice a week (typically Monday and Thursday) during this period, a fixed amount of 2.1 kg of Aqua Assist was manually dosed into the return sludge flow mixing with the feed water. This caused an ideal mixing of the material. Initially the MLSS was not changed and remained at 2.7 g/l. From the end of July onwards the MLSS was increased over 120 days to a concentration of 3.7 g/l. A summary of the results is available in Table 1.

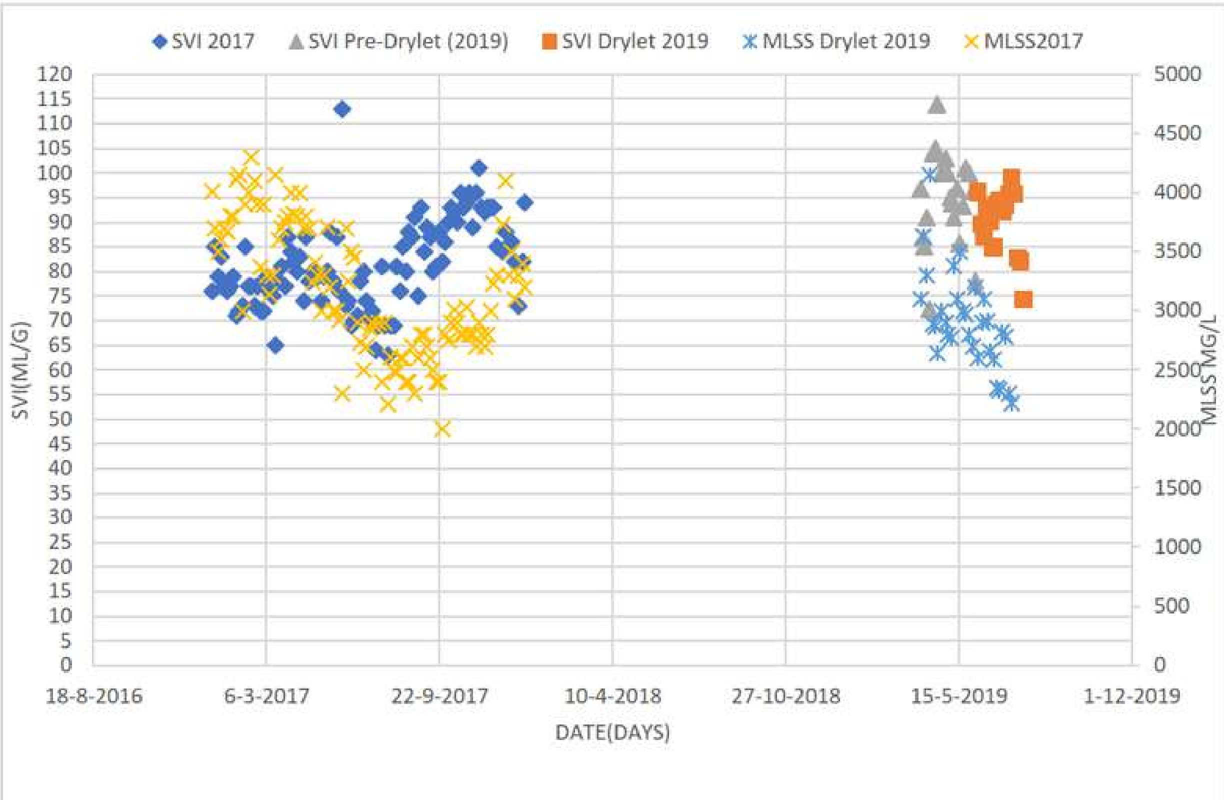
Table 1 – Summary of pilot Aqua Assist dosing at WwTW Halsteren

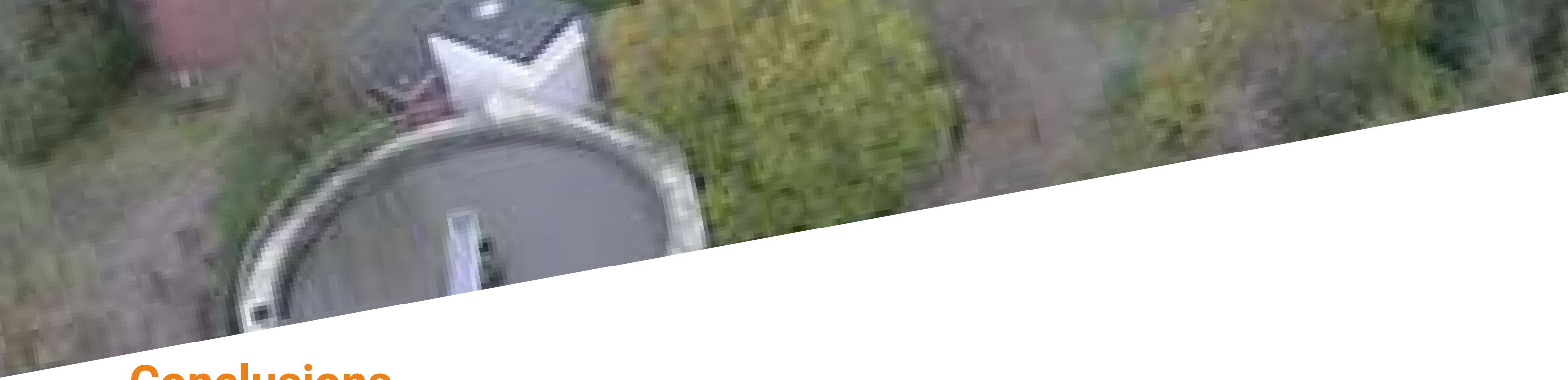
Year	No. of days	Average SVI (ml/g)	Average MLSS (mg/L)	Total sludge discharge (m3)	Total WAS flow (m^3)	Average sludge discharge TSS (kg/d)	Average sludge discharge DS (g/L)	Total sludge discharge TSS (kg)	Yield based on BOD_{feed} (kg/kg)	Yield based on COD_{feed} (kg/kg)
2017	120	87	2,673	2.997	19,688	540	21.8	64,795	0.76	0.27
2019	120	91	3,650	2.676	12,492	426	19.1	51,101	0.55	0.21

In Figure 4, both the 2017 and 2019 data were plotted for MLSS and SVI, indicating no impact on SVI after increasing MLSS concentrations. The combination of Aqua Assist dosing and the possibility to run the plant at an increased MLSS concentration resulted in a decrease in sludge production of 25%. This equals a decrease in the specific WAS production from 15.5 kg solids per pe per annum to 12.2 kg solids per pe per annum.

Furthermore, the effluent quality remained stable and good. No impact of rainy weather flow conditions causing higher solids concentrations in the final effluent, which were recorded in the reference year 2017, was detected in 2019.

Figure 4 - SVI and MLSS plotted in time





Conclusions

The pilot program at WwTW Halsteren resulted in a 25% reduction in WAS production, from 200 ton dry solids per annum to 155 ton dry solids per annum. At the same time the operating conditions remain stable and final effluent quality consistently meets the criteria. MLSS could be increased from 2.7 g/l up to 3.7 g/l without any process consequences. The effluent quality remained stable and good throughout the piloting period.

An economically positive business case for deploying Aqua Assist has been demonstrated in this case study. The cost for dosing the material is significantly lower than the annual savings on sludge handling. By reducing the WAS production, the water authority is contributing to its objectives of reducing waste production and achieving operational savings. Ongoing research is scheduled, in which the mass balances will be considered in more detail and the microbial analysis of the prevailing species will be taken into consideration.

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