Wastewater Treatment in the Dairy Industry – Development of customized solutions for direct and indirect discharge

- illustrated by the example of the dairy factory Milchwerk Jäger -

1. The challenge

Milchwerk Jäger GmbH is the oldest private dairy company in Germany, operating a milk-processing factory at Haag in Upper Bavaria in the (southeast of Munich). With the company's milk catchment area extending into Austria, they produce mainly Italian-style cheeses and butter for export.

The waste flows generated during the production process are mainly wastewater from the classical milk processing process (with a very high content of fat) and vapour condensates and permeates from the milk powder drying process. These wastewaters were previously discharged to the public sewer system and treated together with the market town's wastewater on the local municipal sewage treatment plant. Due to the company's continuously growing production the sewage treatment plant eventually reached its capacity limits and was not able anymore to continuously and reliably meet the effluent limits set by the authorities. The available alternatives were either expanding the municipal sewage treatment plant, with a high financial contribution from Milchwerk Jäger GmbH, or building an own plant for full or partial wastewater treatment. The planning office they therefore commissioned to examine possible variants and do some preliminary planning had been working for the municipality before. Due to the special characteristics of the vapour condensates and whey permeates with their high nitrogen contents, it was agreed to carry out pilot tests at first. As space was limited, the option favoured was a membrane bioreactor system.

Fig. 1: HUBER Membrane Filtration BioMem® demo unit for the determination of design parameters (photo not taken at Milchwerk Jäger GmbH).

2. Preliminary pilot testing with the MBR system

The wastewater, the reduction properties and the general suitability of the MBR system for these wastewaters were tested on a HUBER Membrane Filtration BioMem® pilot plant. The key component of this plant is the membrane bioreactor, a combined tank in which the processes of biological contaminant removal and membrane filtration with ultrafiltration modules take place quasi-simultaneously. Blowers, pumps and controls are provided as associated equipment for this tank chamber to allow for fully automatic plant operation. Different variants of denitrification can be tested with intelligent operation modes of plant feeding. All operating parameters are logged by the control system. Chemical parameters are analysed in the company's own laboratory.

The test plant was installed at the end of 2015 and, after a short adaptation phase, operated until April 2016. Intermediate data and the resulting adjustments during the adaptation phase were regularly discussed with the plant operators and planners.

The wastewater was at first put into a small buffer tank so that the later actual wastewater composition could be simulated better. Furthermore, all plant components were insulated and heated to prevent freezing in winter. Automatic sampling devices were installed to obtain representative composite samples from the buffer tank and effluent. Due to the low COD values related to the nitrogen, residual whey was mixed into the influent to enable the complete degradation of nitrogen in the denitrification phase. Furthermore, sodium hydroxide solution was added regularly to keep the pH values neutral – a basic requirement for the biological degradation of contaminants and a stable sludge structure in a MBR.

COD degradation
The COD inlet concentrations varied greatly from 20 to 200 mg/l and were generally rather low to ensure both the basic metabolic rate of the microorganisms and denitrification. Available residual whey with a COD of approximately 30,000 to 40,000 mg/l, or whey semi-concentrate with approximately 60,000 to 80,000 mg/l respectively, was therefore added as external carbon source. The COD concentration in the effluent from the plant was, with few exceptions, constantly below 10 mg/l. This value was significantly below the limit concentrations for direct discharge or infiltration.

Phosphate reduction
The concentrations of total phosphate were between 5 and 20 mg/l in the inlet. The outlet concentrations were partly even higher than the inlet concentrations, presumably due to the phosphate entering the plant with the whey. Besides, the respective biocoenosis developed and adapted to the wastewater only in the course of the test operation. At the end of the test phase, the total phosphate in the outlet was permanently below 1 mg/l. Nevertheless, a permanent installation should include simultaneous precipitation to ensure the applicable effluent requirements can reliably be met.

Conversion and reduction of nitrogen
After a short operation phase already, the ammonium nitrogen started to be reliable converted into nitrate nitrogen, i.e. the toxic ammonium nitrogen is decomposed completely and converted into nitrate ("nitrification"). Sufficient anoxic conditions and the presence of carbon are required for the degradation of the nitrate nitrogen ("denitrification"). Degradation started only after adaption of the overall system and after a certain period of operation. The total nitrogen was then reliably below 10 mg/l, and thus below the typical effluent requirements.
After a test phase of approximately two months, it was noticed that nitrogen degradation had deteriorated and no nitrate nitrogen was present anymore, presumably due to insufficient aeration times and the generally unstable biological process.

Pilot test results and résumé
The work task was to verify the operation of a MBR system with the HUBER BioMem plant and review the nitrogen reduction rates in the whey treatment process at Milchwerk Jäger GmbH. Very good effluent values could be achieved for all main parameters, partly far below the typical requirements for dischargers of this size. Fluctuations in the efficiency of degradation were on the one hand related to variations in the wastewater composition. On the other hand, operational failures caused short-term operating troubles (e.g. insufficient oxygen supply). In a full-scale plant, both variations in inlet concentration and operational fluctuations should be significantly lower. A sufficiently sized mixing and balancing tank, as usual, should therefore be built. This will ensure that both uniform loading of the biological treatment system as well as constant effluent values and a high operating stability are achieved.
Automated pH control for optimal pH value adjustment will also improve the operating stability in general. The addition of whey as external carbon source is necessary to ensure a sufficient supply for the microorganism and especially a sufficient denitrification.
All in all, very good effluent values could be achieved, except for only few operational outliers. Evidence was thus presented that the vapour condensates and permeates can without problems be treated by a MBR plant, with reduced space requirements compared to conventional wastewater treatment systems.

3. Proposal for solution

The pilot test results and the experience the engineering office had gathered with wastewaters from milk processing industries served as the basis for the following development and implementation of the new wastewater concept. Special consideration was given to the extremely limited space at Milchwerk Jäger and the effluent requirements agreed with the municipality.

The focus of the concept was not to completely withdraw from discharging to the sewer system and treat all the wastewater independently on site. Instead, a complete solution concept was developed in consultation with the municipality and with consideration of the requirements of the municipal sewage treatment plant. It was decided that only the aforementioned wastewaters from vapour condensation and the whey permeates should completely be treated on site and discharged directly, whereas the production wastewaters should still be introduced into the public sewer system after physical-chemical pre-treatment.

This concept has the advantage that the nitrogen-rich wastewaters that are especially critical for the municipal sewage treatment plant

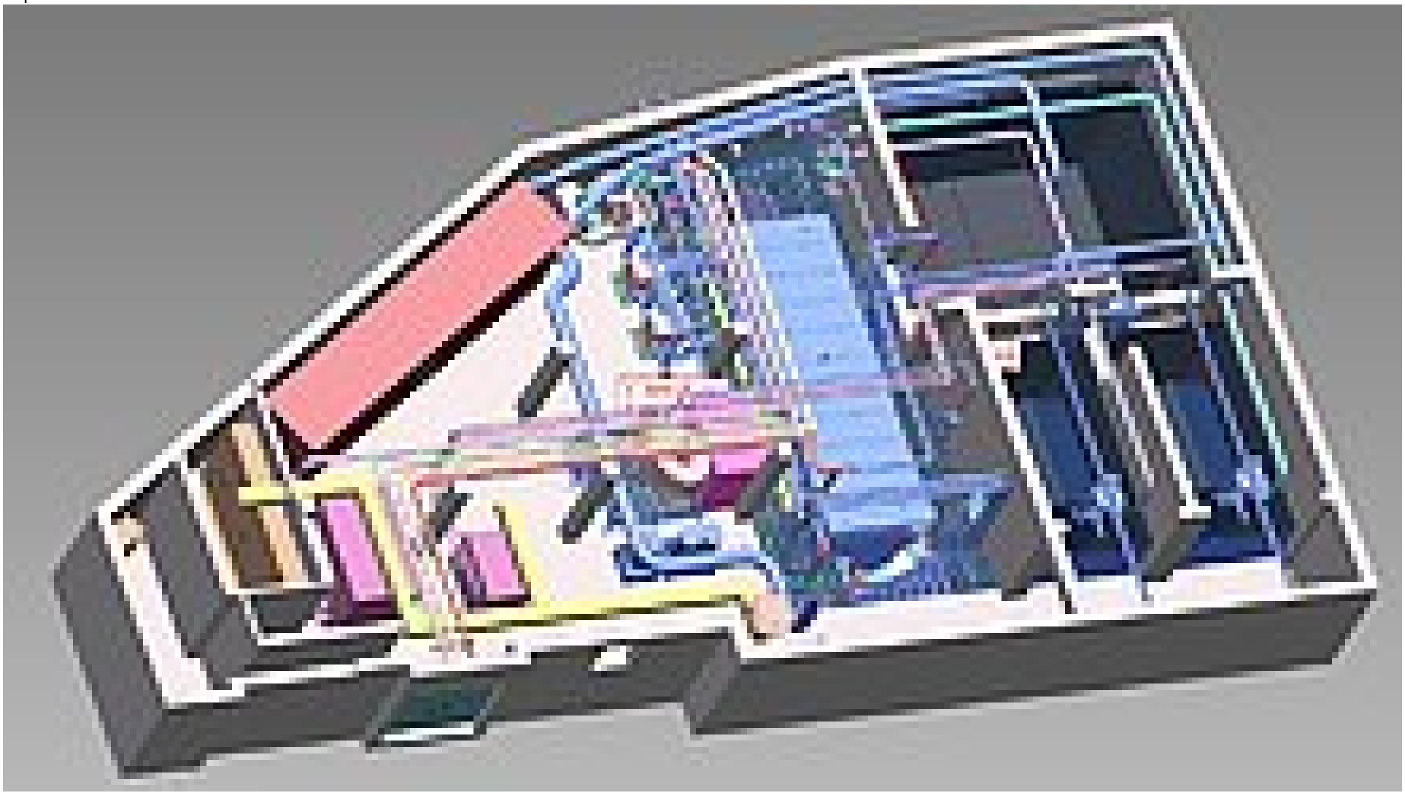

Fig. 2: General layout of the wastewater treatment plant at Milchwerk Jäger

Fig. 3: HUBER Dissolved Air Flotation Plant HDF S 20

Fig. 4: MBR plant with a HUBER Membrane Filtration VRM® 30/18 RF in one filtration chamber

Fig. 5: Thickening of flotate and excess sludge with a HUBER Disc Thickener S-DISC

can completely be treated on the company site while the production wastewaters are still passed on to the municipal sewage plant that needs these volumes to work efficiently. In case of necessity, the total wastewater can be introduced into the sewer network.

4. The overall concept and its implementation

Milchwerk Jäger GmbH produces two different types of wastewater for which different treatment concepts were provided. The first wastewater flow is typical and classical production wastewater from the cheese production line that is rich in fat, solids and COD and collected in a 165 m³ supply tank. A stirrer is installed to ensure the tank contents are well mixed and homogenized and the downstream wastewater treatment plant can work with uniform loads. The wastewater treatment plant is equipped with a so-called Dissolved Air Flotation Plant, type HUBER HDF S20. A pipe flocculator is installed upstream of the flotation plant for wastewater conditioning, with a dosing and mixing unit for precipitants, flocculants as well as acid, lye and defoamers, according to the wastewater composition. In the flotation plant, the pre-treated wastewater-sludge mix is mixed with the air-saturated and dissolved clear water return flow. Fine air bubbles are generated during mixing that float up and form a carpet of pre-thickened sludge on the tank surface. The virtually solids-free wastewater flows towards the outlet guided by baffle plates. The sludge carpet is removed by a surface cleaning system and passed into the sludge effluent from the flotation plant. The flotate sludge is fed to the wet sludge storage tank.

The second wastewater flow comes from the condensation of vapours generated with milk powder drying and from thickening and concentration of whey (so-called whey permeates). This wastewater flow has a relatively low solids and COD content but a comparatively high nitrogen content. This nitrogen, and also the COD contained, is treated in a two-line MBR system. Residual whey was added for effective denitrification and due to the low COD content. A maximum of 80 m³/h clarified wastewater is removed via two HUBER Membrane Filtration VRM® 30/18 RF machines and discharged to a small receiving water course. To reduce covering layer formation on the ultrafiltration membranes, the membranes are at regular intervals backwashed with permeate from the second line. Furthermore, chemicals are added from time to time.

The excess sludge from the MBR system is removed and passed on to the mechanical sludge thickening system. Polymer is added to the sludge before the sludge is fed to the HUBER Disc Thickener S-DISC gravity thickener. The thickened sludge is stored in the wet sludge tank from where it is collected at regular intervals.

For lack of space, the entire plant is installed completely underground and has been covered with a ceiling. The covered area can be used as parking space by the employees. The complete exhaust air is passed through a biofilter to minimize the odour annoyance for directly neighbouring residents.

Milchwerk Jäger built and automated the complete control technology and the process control system themselves according to their own standard. For optimal regulation of chemicals addition in the HUBER Dissolved Air Flotation Plant HDF, a turbidity-dependent control system for chemicals dosing was installed for the first time in this project. This need-based system, in contrast to mere volume control systems, should ensure that chemicals consumption is adjusted to the actual inlet situation.

A combined ammonium-nitrogen probe is used in the MBR system for optimal control of the nitrification and denitrification times. The phases are thus regulated as required for the strongly varying composition of the inflow.

The complete plant was put into operation in autumn 2017. After a run-in phase and period of further adjusting and optimisation, the plant has been operating regularly since mid 2018.

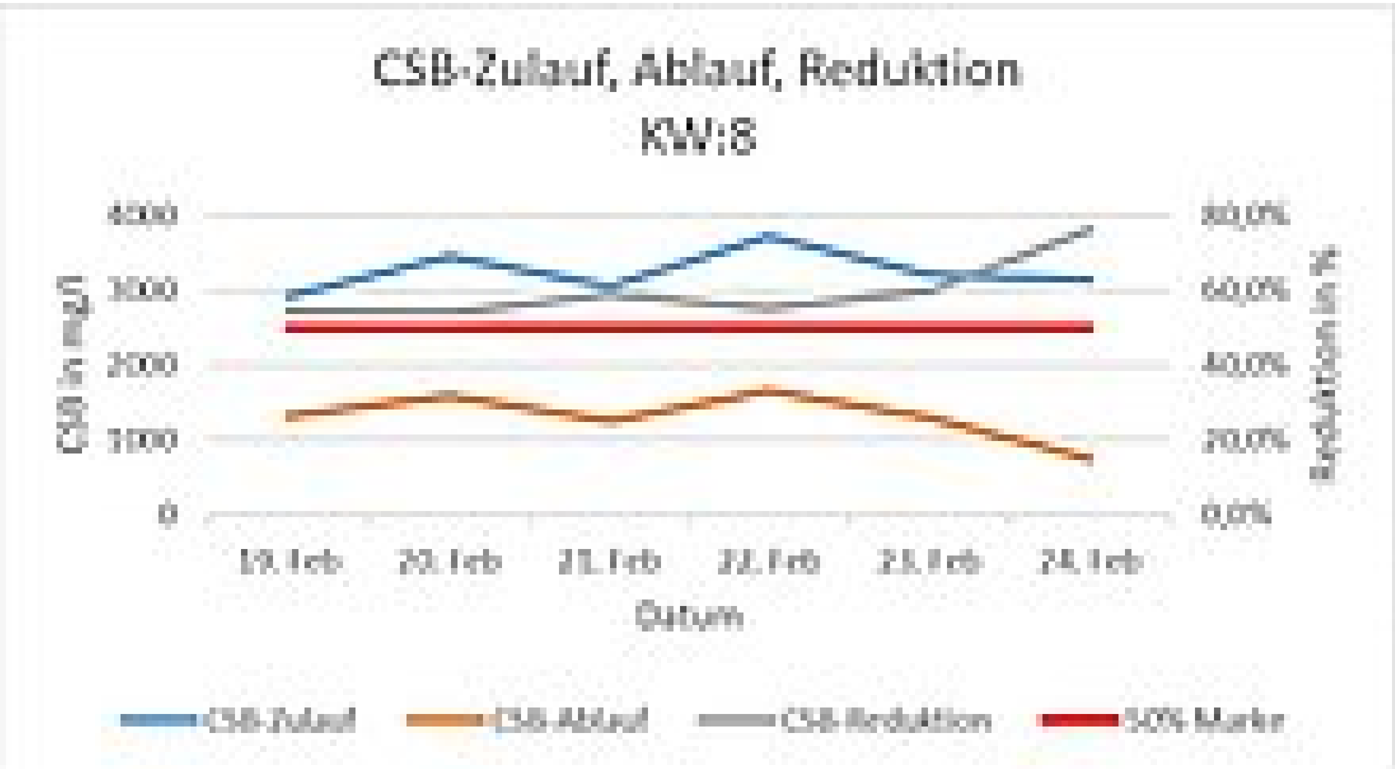

Fig. 6: COD inlet and outlet values of the production wastewater by the example of the data of calendar week 8/18

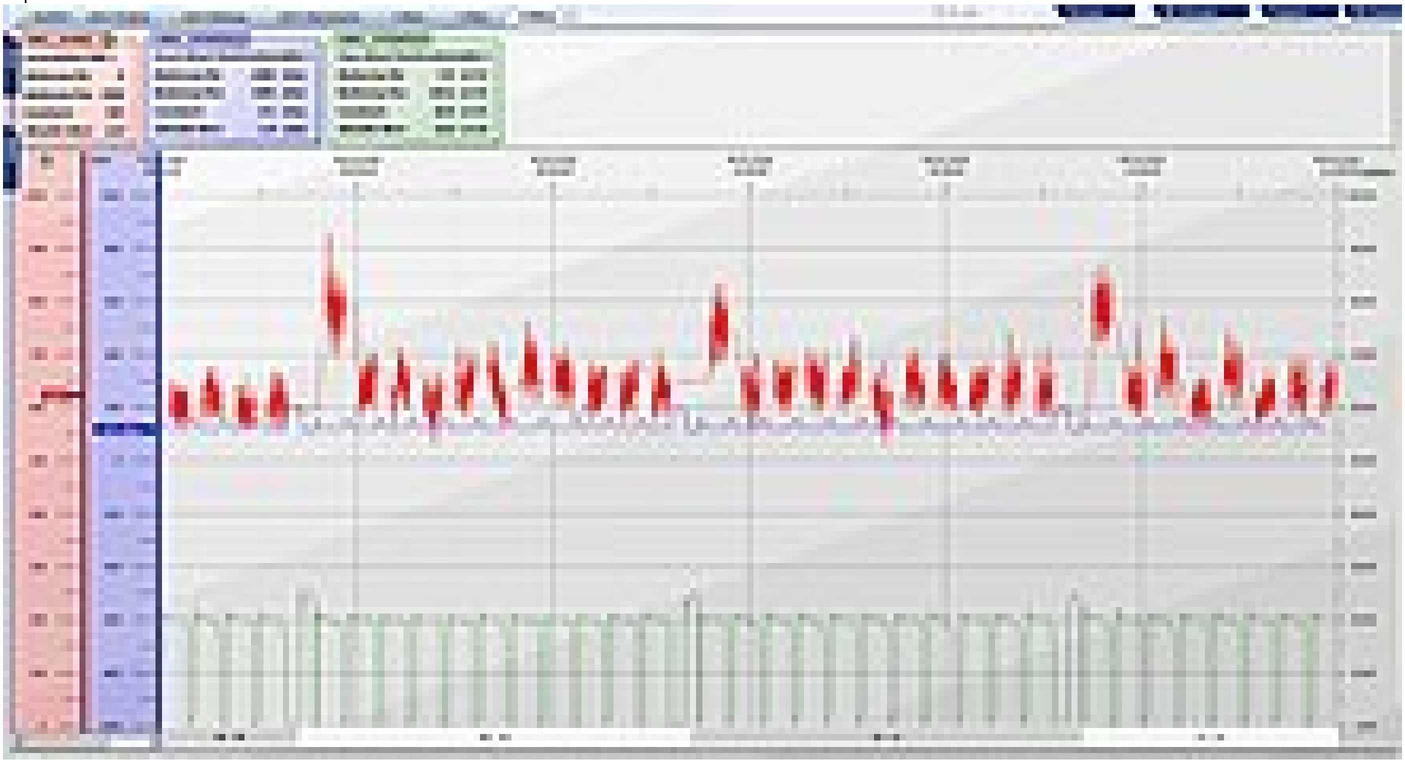

Fig. 7: Part of the process control system, visualisation of the membrane filtration plant ; red: permeability curve

5. Operating results achieved to date

The HUBER Dissolved Air Flotation Plant HDF S was put into operation in October 2018 already and since has treated the production wastewaters prior to their indirect discharge to the local sewer system. The daily mixed samples analysed by the dairy company's laboratory staff confirmed that the required 50% COD reduction is achieved.

To avoid overdosing of precipitant, the new HUBER DigitDose System, a freight-dependent chemicals dosing system, was installed for the first time in this project and calibrated to the specific wastewater characteristics in a three-week adaptation phase. This was necessary as wastewaters from different industries always show a different turbidity, colour and conductivity. Installation and application dependent calibration is therefore required.

At Milchwerk Jäger, the COD inlet concentration varies from 1,500 mg/l to 8,000 mg/l. Especially the high values became apparent for the first time due to these measurement methods and have led to adjustments in the production process. Due to the precipitant control system, the typical consumption values were reduced by approximately 10% already in the first operating phase. In addition to the optimisation of precipitant consumption, further adjustments are made on the flotation plant, e.g. the flotate sludge removal interval has been increased as the flotate sludge is thickened to nearly 15% DR already in the machine, which is problematic for further transport to the flotate sludge storage tank.

Commissioning of the MBR plant for treatment of the vapour condensates and whey permeates took place at the end of 2017. As to nitrification control, great importance was attached again to a high degree of automation, including the use of an ammonium-nitrate probe for nitrification and denitrification control. The operation of this system was also optimized and adjusted to the actual wastewater characteristics over a period of several months. Figure 7 shows a small section of the process control system.