INDUSTRIAL wastewater

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Easy Upgrade

A membrane bioreactor enables a meat processor to upgrade its wastewater treatment system with little fuss

Ralph Teckenberg, Sandra Schuler, Andreas Böhm, Torsten Hackner, and Markus Roediger

Hans Kupfer & Sohn GmbH & Co. KG (Heilsbronn, Germany), a large meat processor in the German state of Bavaria, had an onsite wastewater treatment system that included mechanical screening, flotation, and biological treatment. The company had expanded its production facilities over the years but not the treatment system. Eventually, the system began repeatedly exceeding its discharge limits. Furthermore, the effluent is discharged into a small creek that can barely handle peak loads.

The company hired a project team to plan a new, state-of-the-art wastewater treatment system. The team selected a membrane bioreactor (MBR) because it has a small footprint, removes 100% of suspended solids, and provides reusable effluent.

Treatment System Design

The project team designed the pilot-test system to handle a maximum feed rate of 2.5 m^3/h (660 gal/h). Because of the wastewater's high grease content, the team decided to install a dissolved-air flotation (DAF) unit upstream of the MBR. So, the treatment train includes a settling tank with scumboard, a 2-m^3 (528-gal) pump and holding tank, a DAF unit with chemical treatment, a second 2-m^3 (528-gal) pump and holding tank, and an MBR.

The settling tank and scumboard remove coarse material, such as sausages and meat pieces, from wastewater. The DAF unit removes free and emulsified grease from wastewater. Treatment chemicals, such as iron chloride and polymer, enhance grease separation.

The vacuum rotation MBR provides both carbon degradation and nitrification. (Denitrification was omitted during this test.) During testing, the aeration tank contained 8000 to 12,000 mg/L of mixed liquor suspended solids (MLSS), while the filtration chamber contained 12,000 to 16,000 mg/L of MLSS (an aeration-to-filtration MLSS ratio of 2:3). The 12-m^3 (3170-gal) membrane chamber provided a membrane surface area of 108 m^2 (1163 ft^2). Flow rates varied from 0.5 to 2.5 m^3/h (132 to 66 gal/h), corresponding to membrane flux rates of 0.12 to 0.48 $m^3/m^2 \cdot d$ (2.9 to 11.8 $gal/ft^2 \cdot d$).

Vacuum Rotation Membrane

Membrane filters use a pressure differential to remove suspended solids from water. The pressure forces or draws water through the membrane while leaving solids, bacteria, and even most viruses behind. The amount of pressure needed depends on membrane quality and pore size.

In a vacuum rotation membrane (VRM®) bioreactor system, the membranes are installed in separate chambers after the aeration tanks. Trapezoidal ultrafiltration-membrane plates are installed in parallel on a rotating drum supported on a frame (see Figure 1, p. 2, and Figure 2, p. 3). Each plate also is connected to a permeate-discharge hose that leads to a permeate-collection pipe. The pipes are guided onto a special support from where permeate is discharged.

The overflows required to keep the ultrafiltration membranes operating are achieved via airflow in the bioreactor.

Wastewater Parameters

Before starting pilot tests, the project team collected 24-hour composite samples of the wastewater and analyzed them for pH, chemical oxygen demand (COD), ammonia–nitrogen, nitrate–nitrogen, and phosphate–phosphorus (see Table 1, p. 3). The team also collected grab samples to determine biochemical oxygen demand (BOD) and, therefore, evaluate

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Algal Biofuel Industry May Need Wastewater To Prosper

As entrepreneurs rush to meet the growing demand for renewable fuel sources, many have focused on algae. The lowly plant material grows quickly, can be raised on marginal land, and produces oil that can be converted into biofuel. Observers acknowledge that wastewater from industrial, municipal, and agricultural sources could play a key role in the development of this potential fuel source. Such a partnership would provide the nascent biofuel industry with a

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the wastewater's biodegradability (via the ratio of COD to BOD). A COD:BOD of 2.0 or more generally indicates that the wastewater will not biodegrade easily. The ratio for this facility's wastewater ranged from 1.8 to 2.2. The team attributed the higher ratios to the wastewater's relatively high grease content.

Pilot-Test Results

In general, pilot tests showed that an MBR requires an adequate pretreatment or solids-treatment system. Iron-chloride additions in the DAF cut total phosphorus from 20 to 9.8 mg/L, on average (a 54% reduction).

DAF cut the average COD from between 1800 and 2000 mg/L down to 1000 to 1200 mg/L. This shifted the COD:BOD closer to 2, thereby reducing clarification costs and increasing treatment stability. The good solids properties also ensured better filterability, thereby increasing membrane flux.

However, DAF had virtually no effect on ammonium concentrations, which ranged from 5 to 7 mg/L.

Transmembrane pressure and flux indicate that DAF pretreatment improved MLSS and filterability. The pilot test also showed that

Figure 1. Principle Drawing of a Vacuum Rotation Membrane Unit

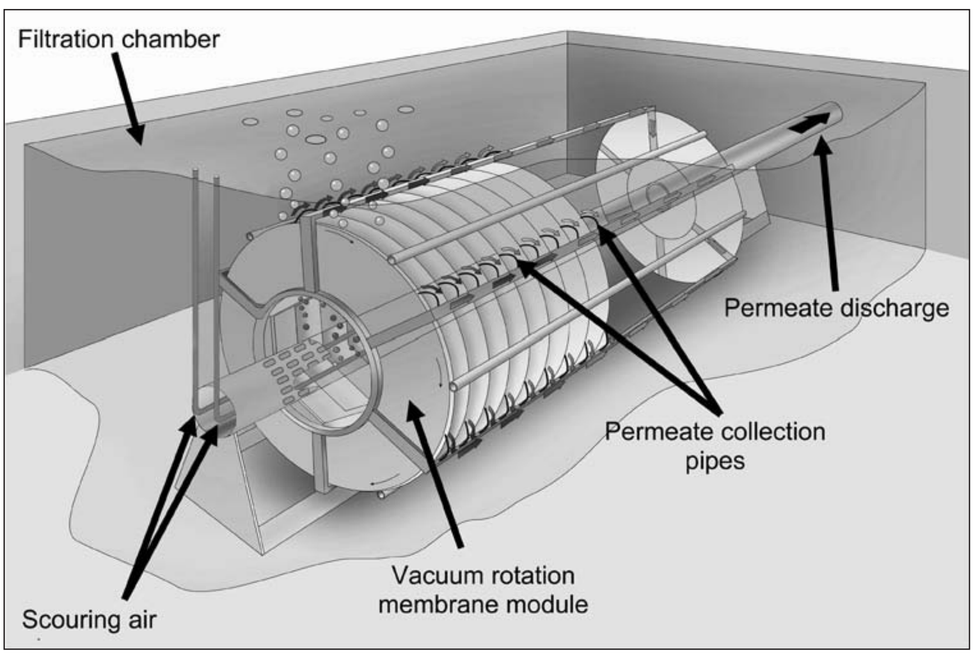

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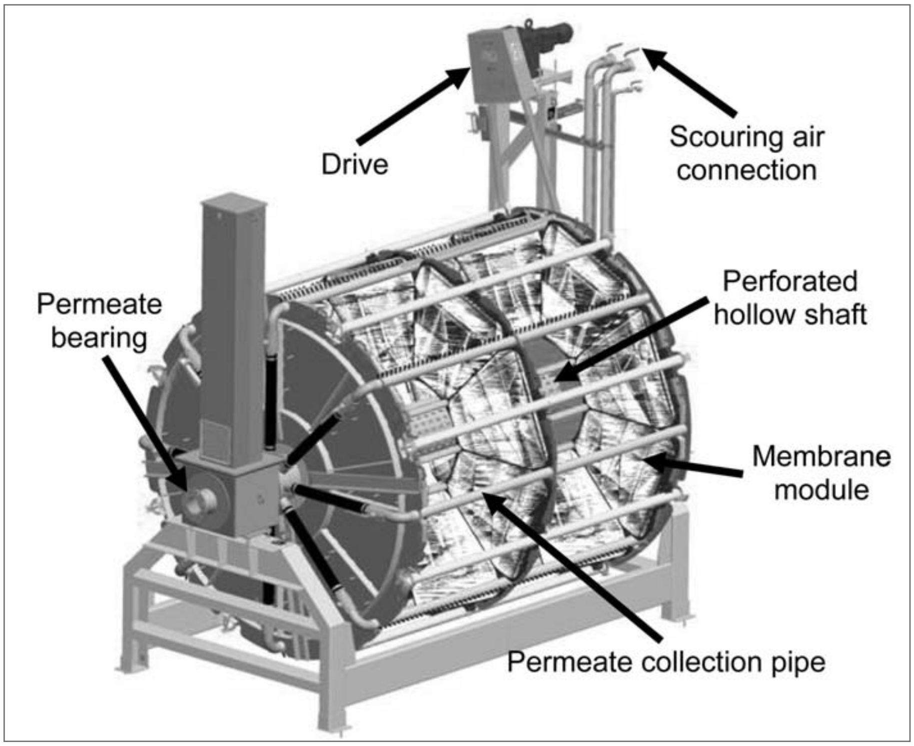
Table 1. Wastewater Parameters

	Chemical oxygen demand (mg/L)	Ammonia–nitrogen (mg/L)	Nitrate–nitrogen (mg/L)	Phosphate–phosphorus (mg/L)	pH
Minimum	675	2.12	1.27	10.11	7.67
Maximum	5517	10.44	7.13	34.25	10.53
Average	1741	5.3	4.48	19.57	9.13
85th percentile	2050	5.8	6.4	18.0	9.8

Figure 2. Detailed Drawing of a Vacuum Rotation Membrane Unit



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a low flux ensures process stability with only a few extra scouring sequences and prolonged cleaning intervals.

After startup and optimization, the operating parameters for layout and process design of the full-scale plant and expected discharge concentrations could be determined.

The MBR's COD reduction was always more than 97%. Because of this excellent performance, effluent COD averaged 20 mg/L. In the permeate, ammonia averaged 0.66 mg/L. COD and ammonia–nitrogen levels indicated that nitrification was stable, with good results. Phosphorus removal was mainly achieved in the DAF unit, but the MBR cut total phosphorus to 3.1 mg/L, on average.

Table 2. Permeate Quality

	Chemical oxygen demand (mg/L)	Ammonia–nitrogen (mg/L)	Total phosphorus (mg/L)	Total nitrogen (mg/L)
Required discharge values	75.0	5.0	2	18
Permeate (average)	22.82	0.57	0.1	4.75

Full-Scale Design

The full-scale wastewater treatment system was designed for an average daily flow of 1200 m^3/d (317,000 gal/d) and a maximum flow of 1600 m^3/d (423,000 gal/d). Temporary peak flows of up to 4800 m^3/d (1.27 mgd) may occur. A 1500-m^3 (396,000-gal) equalization tank, however, ensures that peak hourly flow does not exceed 2400 m^3/d (634,000 gal/d) during normal operations.

The new system includes coarse screening (a 15-mm multirake bar screen), fine screening (a 1-mm wedgewire rotating drum screen), an equalization tank, a 1.7-m^3/min (440-gal/min) DAF unit with chemical addition, and an MBR.

The pretreatment system reduces COD by 50% via extensive removal of fats, oils, and grease. The following aeration stage is designed for 1920 kg/d of COD and extensive nitrogen reduction. A three-line submerged membrane filtration plant with an average flux rate of 0.3 $m^3/m^2 \cdot d$ (7.1 $gal/ft^2 \cdot d$) is installed downstream of the 900-m^3 (240,000-gal) aeration tank, which operates with intermittent aeration. Each of the three membrane tanks contains one VRM unit (VRM 30/400) with an active membrane surface area of 2400 m^2 (26,000 ft^2) per unit.

Phosphorus is removed at two points in the system: the pipe flocculator before the DAF unit, and the biological treatment step. As expected, DAF reduces phosphorus by about 50%, on average. The aeration basin removes more phosphorus via simultaneous precipitation with iron chloride.

Waste activated sludge from the aeration stage is mechanically prethickened and, along with DAF sludge and screenings, trucked to a local biogas

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The pretreatment processes for the vacuum rotation membrane unit installed at a German meat processing facility include fine screens and a dissolved air flotation unit.

plant. This cost-effective disposal method is possible because it does not include sanitary wastes.

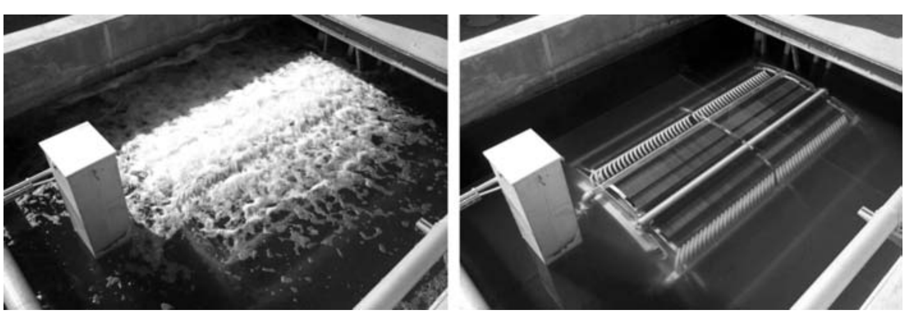
Because of its excellent quality, the permeate can be reused as service water for vapor generation or fed into the onsite storage pond for fire protection.

Excellent Results

In January 2008, the project team seeded the MBR with activated sludge from two nearby wastewater treatment plants. Extra flow from a new production line and additional nutrients soon increased MLSS to the design concentration of 8000 mg/L.

After initial startup, the full-scale MBR has consistently complied with all discharge requirements. Since March 2008, the MBR plant has consistently met its permitted limits and has since begun discharging directly into the creek.

However, the permeate meets reuse quality standards (see Table 2, p. 3; the table shows effluent quality and permitted discharge limits, not reuse standards). COD averages about 20 mg/L, which is considerably less than the required permit value (75 mg/L).



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From the top of the vacuum rotation membrane's filtration tank, it is obvious whether the unit's air scouring is on (left) or off (right).

Likewise, ammonia, nitrogen, and phosphorus are well within limits. Also, the permeate is free of suspended solids — the main reason why it is suitable for reuse.

MBRs provide constant high treatment efficiency and can significantly reduce the footprint and number of treatment steps required. This is especially useful for industrial applications, where land is at a premium and water can be reused onsite.

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