Chemical wastewater treatment applying a membrane bioreactor (MBR)

Stefan Krause; Ulrich Meyer-Blumenroth; Reinhard Voigt
Microdyn-Nadir GmbH, Rheingaustraße 190-196, D-65203 Wiesbaden

Introduction

At the current time Membrane Bioreactors (MBR) are the primary focus of wastewater treatment technologies. MBR is a combination of biological activated sludge process for the removal of nutrients and a membrane filtration for separation of biomass and treated water. In industrial wastewater treatment MBRs have proven to be a particularly reliable technique [Cornel et al., 2006]. The biological degradation is the same as in conventional activated sludge process (CAS) [DWA, 2005]. Main research in the field of MBR takes place in the understanding and minimization of membrane fouling and blocking [e.g. Judd, 2006] and in process optimization (e.g. to reduce the energy demand; Krause, 2005]. The advantages of this process is a small footprint, flexibility and solid free effluent which can be directly reused or – if purification is required – more easily conditioned compared to conventional systems. On the other hand, MBRs show a higher energy demand, require a higher level of automation and the membranes must be cleaned due to fouling and scaling.

The most energy efficient choice is submerged membrane modules, where the modules are submerged directly into the activated sludge tank. The fouling control is achieved by an air scour at the membrane surface by an additional (coarse) bubble aeration (= crossflow-aeration). The necessary shear velocity is created by the movement of the bubbles close to the membrane surface.

Microdyn-Nadir has developed a new submerged membrane module for MBR application (Bio-Cel®) with the objectives of a high operational reliability, low capital and operational cost. New Bio-Cel® Module pilot plants are in operation, one of them treating wastewater from a chemical park in Wiesbaden (Germany).

Wastewater characteristics and design of pilot plant

The wastewater at the chemical park is discharged by more than 80 companies in the pharmaceutical industry, electric chemical company, methyl-cellulose-, offset printing-, dye-, synthetic resin- and polymer membrane manufacturers. Overall the wastewater is heterogeneous and contains solvents, methyl-cellulose residues, pharmaceutical residues, pigment remainders, nitrates and nitrides and other salts. The chemical oxygen demand (COD) of the effluent is about 4,700 mg/l (± 1,000 mg/l).

The chemical wastewater is pumped after neutralisation from the primary sedimentation into the pilot plant. The treatment steps of the pilot MBR are fine screening (0.5 mm), denitrification (4 m³) and nitrification (8 m³). The total tank volume is about 12 m³. The membrane module with an active surface area of 60 m² is submerged into the nitrification tank. The plant is equipped for chemical cleaning. The permeate is discharged back into the WWTP. In Figure 1 the pilot plant is depicted schematically.
First the choice of materials was important during development, as the materials must be chemical and mechanical resistant and easy to handle. Therefore a polyethersulphone (PES) Membrane was chosen, with a pore size of about 0.04 µm. In order to prevent braiding of the membranes and to achieve best hydraulic conditions alongside the membranes, flat membrane sheets are employed. The major innovation of this newly developed module is the back-flushable flat membrane sheet. This back-flush ability is achieved by a lamination of PES membrane and polyester drainage layer. The major challenge was creating a sufficient adhesion force between the two layers and at the same time maintained high water permeability. By the usage of the developed, 2 mm thin membrane sheets instead of a plate supporting system a low specific weight and a high packing density was achieved. Within the scope of the design, the pressure loss inside the membrane must be low – therefore a new drainage scheme was developed and the permeate suction takes place from the middle of the membrane.

Results
The mixed liquor suspended solids (MLSS) content was about 12,000 mg/L during the test phase. The initial Permeability was about 280 L/(m²·h·bar) and decreased to about 50 L/(m²·h·bar) and stayed
constant at this level without any cleaning. The filterability is very low since the wastewater contains methyl-cellulose. Laboratory tests were performed for determination of the filterability. The filtration index after 10 min of filtration is about 0.17 (relating to clean water). Another pilot test sludge from a municipal application shows a filtration index of about 0.68, hence the sludge from the chemical park shows a lower filterability by factor 4 compared to municipal activated sludge. Therefore the flux is within the expected range of about 8 L/m²/h.

During the investigation the inflow COD was about 4,700 mg/L (daily load of 55 kg/d, holding high fluctuations). The pilot plant was operated at a sludge load of 0.4 kgCOD/kgMLSS·d⁻¹ at MLSS concentration of about 12 kg/m³. The volumetric loading rate is in the range of 1 to 5 kg COD/(m³·d). The average COD elimination is about 60 %, because of the low aerobic bio-degradable wastewater composition (e.g. high level of methyl cellulose). This value is comparable to the full scale wastewater treatment plant.

![Figure 3: COD Elimination](image)

The energy demand for the two aeration systems (for oxygen supply and for fouling control) can be readily calculated. According to Pöpel [1985] the specific energy demand is 5.4 Wh per m³N aeration capacity and per m depth of submergence. Hereby the energy demand for oxygen supply counts to 0.2 kWh/m³, as the crossflow aeration system is very effective regarding oxygen transfer capacity. The energy demand for fouling control is about 0.7 kWh/m³. Thus the energy demand for both of the aeration equipment results in about 1.0 kWh/m³.

Overall a successful operation of the new Bio-Cel® Module could be demonstrated in spite of complicated wastewater composition.

References:
Cornel, P., Krause, S., 2006
Membrane Bioreactors in Industrial Wastewater Treatment – European Experiences, Examples and Trends, Water Science and Technology, Vol. 53 No 3 pp 37-44, IWA Publishing

DWA, 2005
Membranbelebungsverfahren, DWA-Fachausschuss KA-7, 2. Arbeitsbericht, Fassung vom 19.01.05, (www.dwa.de)
Judd, S., 2006

Krause, S., 2005:
Untersuchungen zum Energiebedarf von Membranbelebungsanlagen, Verein zur Förderung des Institutes WAR der Technischen Universität Darmstadt, Band 166

Pöpel, H. J., 1985
Grundlagen zur Optimierung der Belüftung und Energieeinsparung, Verein zur Förderung des Institutes WAR der Technischen Universität Darmstadt, Band 23, 5-31