## Conference Program & Show Info

# FILTECH

October 22 – 24, 2019
Cologne – Germany

The Filtration Event
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Koelnmesse · Cologne · Germany

**Membrane bioreactor as polishing step in the treatment of galvanic wastewater,** B. Mayr*, T. Garstenauer, EnviCare Engineering GmbH, Austria

**Cost-optimized sustainable water management in the mining industry based on membrane processes,** T. Peters*, Membrane Consulting, Germany

## G7 Filter Test Systems I

Session Chair: tba

13:00 14:15 room 4A

**Filter media testing in accordance with ISO 16890,** M. K. Schmidt*, PALAS GmbH, Germany

**Two years of filter testing experiences according to new ISO 16890,** C. Kappelt*, A. Rudolph, C. Peters, S. Große, Topas GmbH, Germany

**Aspects of air filter testing: dust loading,** M. Stillwell*, Particle Technology Ltd, UK

## F7 Advanced Composite Fiber Materials

Session Chair: Graham Rideal

13:00 14:15 room 4B

**Sinterflo® FMC (fibre metal composite) – Development and application,** B. Allbutt*, Porvair Filtration Group Ltd, UK; A. Goux*, Bekaert Fiber Technologies, Belgium

**Bekaert Bekipor® Metal Fiber Media Filtration Solutions for Hydraulics,** M. Van Hooreweder*, A. Goux*, Bekaert Fiber Technologies, Belgium

**Methods to increase the filtration performance of metal woven wire cloths,** M. Müller*, Spörl KG, Germany

## L8 Short Oral + Poster Presentation

Session Chair: Wilhelm Höflinger

14:45 16:00 room 1A

### Characterization and Simulation of Porous Structures

**Combined porous mesh metals for filters and capillary fencing devices,** V. A. Devisilov*, Yu. M. Novikov, V.A. Bol'shakov, Bauman Moscow State Technical University, Russia,

**Geometrical model of the porous structure of the permeable material and the new experimental method of determinig its structural characteristics,** V. A. Devisilov*, A.L. Sintsov, E. Yu. Sharai, Bauman Moscow State Technical University, Russia

### Characterization of Porous Materials to Meet Regulatory Demands

**Addressing liquid filtration regulatory complexity with HACCP,** F. Lybrand*, C. Rich, T. Vest, Hollingsworth and Vose Company, USA

### Depth Filtration and Adsorption

**Metal porous filter development using additive manufacturing,** N. Burns*, D. Travis, L. Geekie, A. Molyneux, Croft Additive Manufacturing Ltd; M. Burns, Croft Filters Ltd, UK

**Design of a multi-purpose fuel filter sytem to better understand the challenges of biodiesel filtration,** B. Csontos*, H. Bernemyr, A. Christiansen Erlandsson, KTH Royal Institute of Technologies; M. Pach, H. Hittig, Scania CV AB, Sweden

**A probabilistic-statistical model of change in particle size distribution in fine filters,** A.N. Grechushkin*, V.A. Lvov, Bauman Moscow State Technical University, Russia

**Adsorption of humic acid from aqueous solution onto $Fe_3O_4$ magnetite: effect of temperature,** M.A. Zulfikar*, A. Rizqi Utami, M. Yudhistira Azis, H. Setiyanto, Bandung Institute of Technology, Indonesia

## L9 Short Oral + Poster Presentation

Session Chair: Harald Anlauf

14:45 16:00 room 1B

### Backwashing filters

**HETA smart filtration 4.0,** H. Hensel*, HETA Verfahrenstechnik GmbH, Germany

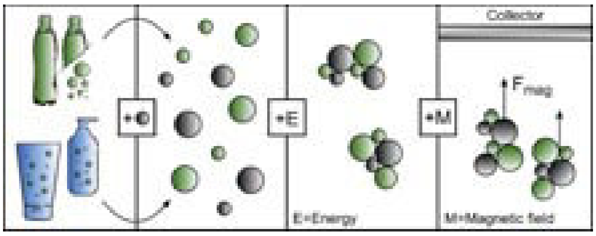
### Self Cleaning Filters

**Filtering of high solids concentration media using complex powerful to the flow,** E.Y. Sharai*, V.A. Devisilov, Bauman Moscow State Technical University, Russia

**Simulation of solid particle separation in self-cleaning filter with dynamic filtration,** E.Y. Sharai*, V.A. Devisilov, Bauman Moscow State Technical University, Russia

### Magnetic Separation

**Applied colloidal aggregation: Separation of fine polymer particles from dilute suspensions by magnetic seeded filtration (Microplastics),** F. Rhein*, H. Nirschl, Karlsruhe Institute of Technology (KIT), Germany



**A biomimetic approach for separating microplastics from water,** L. Hamann*, Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, Germany

### Electrochemical Water Treatment

**Electrodegradation of methylene blue using Ce(IV) mediated electrochemical oxidation: Effects of supporting electrolyte, potential oxidation and degradation time,** H.Setiyanto*, F.M. Sari, M.A. Zulfikar, Bandung Institute of Technology; V. Saraswaty, Indonesian Institute of Sciences; N. Mufti, State University of Malang, Indonesia

## M6 Short Oral + Poster Presentation

Session Chair: Thomas Peters

14:45 16:00 room 2

**Development of microfiltration membranes of biodegradable biomass plastics with the aid of surfactants and their application to depth filtration,** T. Tanaka*, H. Minbu, A. Ochiai, M. Taniguchi, Niigata University, Japan

**Effect of ethanol concentration on filter cake characteristics in microfiltration of yeast suspension,** N. Katagiri*, K. Tomimatsu, E. Iritani, Nagoya University, Japan

**Microsand cross flow filtration in cooling towers water circuit – a sustainable approach for hvac systems,** S. Roel Backes*, Evoqua Water Technologies GmbH, Germany

**Application of antifouling filter media based on nanofibres in liquid filtration,** I. Vincent*, D. Kimmer, L. Lovecka, M. Kovarova, L. Musilova, D. Vesela, Tomas Bata University, Czech Republic

**The effect of membrane structure prepared from carboxymethyl cellulose and cellulose nanofibrils for filtration and biochromatographic separation,** V. Kokol*, S. Gorgieva, V. Vivod, S. Vajnhandl, University of Maribor; T. Simcic, U. Cernigoj, BIA Separations d.o.o., Slovenia

**Measuring methods for nano filtration membranes and filter materials,** X. Puntigam, M. Kalmutzki, P. Pavlov, B. Arlt*, Anton Paar Germany GmbH, Germany

# MEMBRANE BIOREACTOR AS POLISHING STEP IN THE TREATMENT OF GALVANIC WASTEWATER – ABSTRACT

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In galvanic industry wastewater is formed as a byproduct in surface treatment processes of metallic compounds. The common primary treatment steps are flocculation and precipitation. Depending on the applied unit operations the filtrate of the subsequent chamber filter press usually contains significant amounts of COD, heavy metals (e.g. zinc, iron, chrome) and also filterable solids. In order to reach direct discharge quality a final treatment step is necessary.

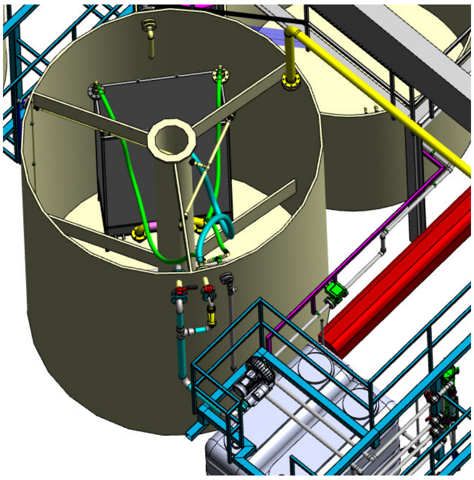
In aerated membrane bioreactors (MBR) biological wastewater treatment is combined with membrane technology. Organic compounds are degraded under aerobic conditions and the activated sludge is confined in the biological system by micro- or ultrafiltration membranes.

Of course, heavy metals cannot be degraded by microorganism, instead the metals are removed from the wastewater through various mechanism such as incorporation of precipitated metals in sludge flocs, adsorption, binding and complexation of metal ions in extracellular polymeric substances (EPS) and diffusion of metal ions into the activated sludge flocs. These heavy metals can also have inhibiting or toxic effects on the biomass in a biological wastewater treatment system.

This article deals mainly with design, construction and operation of an MBR-plant as polishing step in the cleaning of galvanic wastewater. The project started with a MBR pilot plant, which was installed and operated during a period of three months. The pilot test proofed that the MBR-process is suitable to reach direct discharge quality. Based on these results an industrial plant was implemented.

During the start-up of the industrial plant the COD-threshold value was met from right from the start. A zinc removal of 60% was achieved.

An analysis of a sludge sample showed an incorporation in the biomass of 8.4 g Zn/kg DS. In order to remove the incorporated zinc, activated sludge has to be removed regularly from the system. To achieve the necessary sludge growth dosing of an easily degradable carbon source and of a liquid fertilizer is necessary. With a high specific sludge growth, a Zn-removal of 2.5 mg Zn/l was reached.



Or experience as consulting engineers with MBR-systems starts in 1993. We realized large scale projects in communal waste water, landfill leachate, liquid waste processing, biodiesel, soft drink production and surface water treatment.

**Keywords:** galvanic wastewater, heavy metals removal, membrane bioreactor, organic contaminants, precipitation, nutrients, hollow fibre membrane

# MEMBRANE BIOREACTOR AS POLISHING STEP IN THE TREATMENT OF GALVANIC WASTEWATER – Full Paper

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## 1 Introduction

In membrane bioreactors (MBR) biological wastewater treatment is combined with membrane technology. The membranes arranged in modules are used to retain the biomass in an activated sludge tank. In the present case of submerged modules with hollow-fibre membranes (cut-off 40 nm), pressure ventilation ensures the aerobic decomposition of organic substances as well as providing the cross-flow velocity across the membrane in order to prevent fouling.

In the electroplating industry, the surface treatment of metal products generates wastewater containing chromium, iron, zinc and other heavy metals. But there are also organic ingredients from grease removal of metal surfaces in dissolved form in the wastewater, which can be described via the sum parameter chemical oxygen demand (COD).

The wastewater in the electroplating plant is commonly treated by flocculation and subsequent precipitation by addition of chemicals such as calcium hydroxide, iron (III) chloride, polysulfides, hydrochloric acid and sodium hydroxide. The resulting hydroxidic and sulfidic sludge is dewatered in a chamber filter press. Usually, the concentrations of COD, heavy metals (for example zinc, iron, chromium) and also filterable substances in the filtrate exceed the limits for direct discharge into the receiving waters or also into a municipal sewer system considerably.

To meet these quality requirements, a subsequent cleaning of the filtrate is absolutely necessary. In general, various methods such as reverse osmosis, nanofiltration, activated carbon, ion exchange or biological treatment come into consideration.

The filtrate from the chamber filter press is saturated with calcium, so reverse osmosis or nanofiltration are not suitable due to the compulsory concentrating and the accompanying exceeding of the solubility limits. If activated carbon or ion exchange process shall be applied high amounts of activated carbon or resin must be used, which not only have to be bought, but after use also have to be disposed of.

The advantage of the combined membrane-biological purification is that not only heavy metals are removed due to a post-precipitation in activated sludge flocs and complete particle retention at the membrane, but also organics are eliminated to a large extent.

Of course, heavy metals are not degraded by microorganisms but are removed from the wastewater by various mechanisms such as the attachment of precipitated metals to activated sludge flocs, binding, adsorption, and complexation of dissolved metal ions by extracellular polymeric substances (EPS), surface adsorption, and diffusion of metal ions in sludge flocs (1), (2), (3), (6).

In higher concentrations, however, these substances can also have an inhibiting or even toxic effect on the biomass of the biological wastewater treatment plant. In the literature various data on the absorption capacity and the inhibition by heavy metals in biological wastewater treatment can be found (4), (7), (8).

This article describes the design, construction and operating experience of an MBR plant for post-treatment of galvanic wastewater. The focus of this industrial installation is on the removal of zinc and COD.

# 2 Material and Methods

From May to July 2017, an MBR pilot plant was installed at the site of an electroplating production plant in order to determine the basic suitability of the process and to limit the technical and entrepreneurial risks. Based on these results the industrial plant was designed, which was then installed in September 2018.

## 2.1 Description of the Waste Water

During the operation of the pilot plant and the industrial plant, measurements were regularly carried out to characterize the wastewater. The filtrate of the chamber filter press has the following characteristics:

**Table 1: Characteristics of the MBR-influent**

| | | pilot (05-07/17) | | industrial (09-12/18) | |
|---|---|---|---|---|---|
| Parameter | unit | range | mean | range | mean |
| pH-Value | -- | 3.6 – 8.8 | 7.7 | 6.5 – 8.0 | 7.2 |
| El. Conductivity | mS/cm | 3.0 – 30.8 | 16.4 | 8.6 – 20.0 | 14.8 |
| Temperature | °C | 18.7 – 25.8 | 23.2 | 19.5 – 25.1 | 23.4 |
| COD | mg/l | 80 – 1.120 | 317 | 130 – 700 | 311 |
| Calcium – Ca | mg/l | 210 – 1.559 | 838 | 499 – 2.247 | 1.304 |
| Zinc – Zn | mg/l | 0.1 – 4.4 | 1.0 | 0.3 – 6.9 | 3.0 |
| Iron – Fe | mg/l | 0.07 – 0.70 | 0.17 | 0.10 – 0.20 | 0.14 |

Without further wastewater treatment, the Austrian limits for direct discharge into a river, i.e. COD (200 mg/l), zinc (1.0 mg/l), settleable substances (0.3 ml/l) and filterable substances (30 mg/l), as can be seen in Table 1, are not met.

For this reason, a membrane bioreactor process has been proposed as a solution for post-purification.

## 2.2 Pilot Plant

The pilot trial was conducted from May 2017 to July 2017. The following is a brief description of the key parameters for the pilot plant:

| | |
|---|---|
| - Membrane module | 3 elements á 5 m²<br>immersed hollow fiber membrane<br>material PVDF<br>cut-off 50 nm |

| | |
|---|---|
| Throughput (max) | 6 m³/d |
| MBR volume | 5.4 m³ |
| Air intake | 9 Nm³/h |
| Nutrient source | Complex liquid fertilizer |
| Carbon source | Acetic acid |

The process was started without seed sludge.

**Picture 1: MBR-Pilot plant**

## 2.3 Industrial plant

The results of the pilot test were evaluated and based on this, the industrial plant was designed and put into operation in September 2018.

The key data of the large-scale plant are:

| | |
|---|---|
| Membrane module | 400 m²<br>immersed hollow fiber membrane<br>material PVDF<br>cut-off 50 nm |
| Throughput | 120 m³/d |
| COD load | 54 kg/d |
| Volumetric load COD | 1,6 kg/(m³.d) |
| Sludge load COD | 0,10 kg/(kg.d) |
| MBR volume | 36 m³ |
| Air intake | 110 Nm³/h |
| Nutrient source | Complex liquid fertilizer |
| Carbon source | Acetic acid |

**Picture 2: MBR-Industrial plant**

## 2.4 Commissioning of Industrial plant

For the commissioning of the industrial plant, 1 $m^3$ of seed sludge from a nearby MBR plant for the treatment of liquid waste was used.

The acetic acid dosage was initially adjusted to 300 $mg_{COD}/L_{feed}$ to promote sludge growth in the MBR. After reaching full load, the acetic acid dosage was reduced to 100 $mg_{COD}/L_{feed}$. The fertilizer dosage was set to COD : P = 200 : 1.

# 3 Results

## 3.1 Pilot Plant

As a result of the pilot test, it was concluded that an MBR plant has the ability to purify the filtrate of the chamber filter press to fulfill all quality criteria for direct discharge.

The main results are:

| | |
|---|---|
| • Throughput | Ø 3.9 $m^3/d$ |
| • COD-Inlet (incl. AA) | Ø 405 mg/l |
| • Dosage Acetic Acid (AA) | Ø 100 mg COD/l |
| • Dry matter content | 10.8 g/l |
| • COD-volumetric load | 0.37 $kg_{COD}/(m^3*d)$ |
| • COD-sludge load | 0.035 $kg_{COD}/(kg_{DM}*d)$ |
| • Flux gross | 15.5 $l/(m^2*h)$ |
| • Permeability | 187 $l/(m^2*h*bar)$ |

**COD removal**

The required COD limit value of 200 mg/l was exceeded occasionally until mid-June 2017 and afterwards it was consistently well below this level. COD degradation rates of up to 90% have been recorded (see Diagram 1).

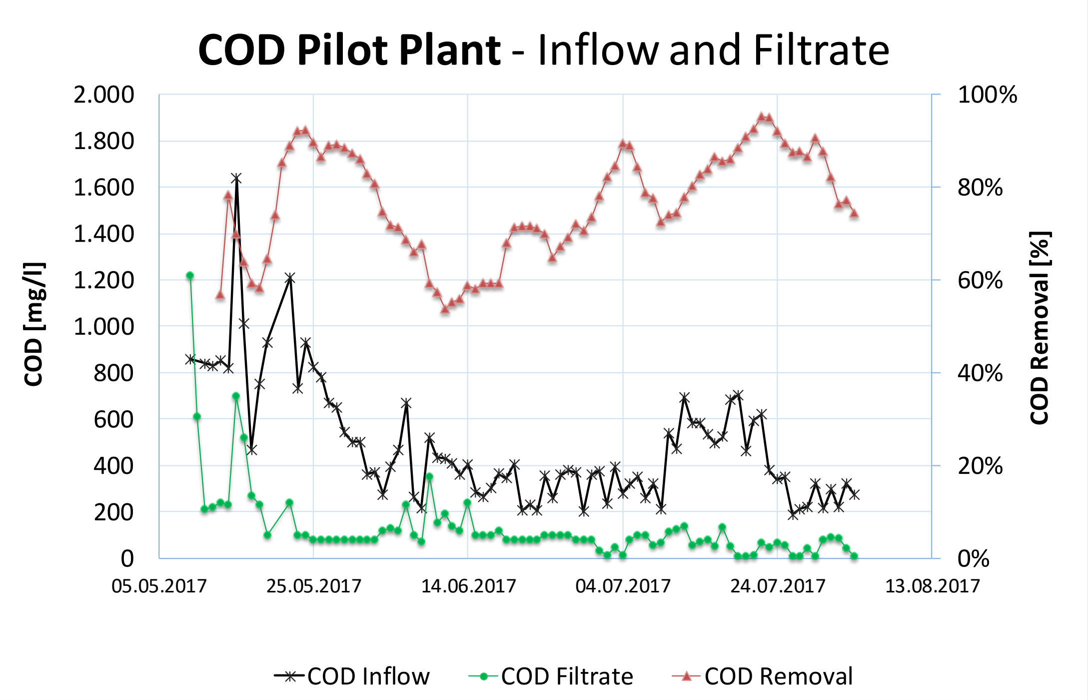

**Diagram 1: COD in inflow and filtrate and degree of degradation - Pilot plant**

## Zn removal

In a series of measurements in early July, a Zn removal efficiency of over 60% could be documented.

## Further findings

Within the first week, the formation of biomass and coupled with it a significant degradation of COD was observed, although no seed sludge was used for the start-up. After 2 weeks, the COD limit of 200 mg/l could be met, despite the increase in throughput. The Zn concentration in the filtrate was sometimes exceeding the limits when increased inflow concentrations occurred.

The Zn reduction is based on the incorporation in the activated sludge and the Zn concentration in the filtrate depends on the total Zn content in the sludge. For Zn reduction and the compliance to the given threshold value a regular withdrawal of excess sludge is therefore necessary. To guarantee the required sludge growth, the supply of an easily degradable carbon source (e.g. acetic acid) is essential.

In addition, there is insufficient phosphorus in the inflow (filtrate of the chamber filter presses), therefore a liquid fertilizer with phosphorus content must be dosed.

## 3.2 Industrial Plant

During start-up, the positive results from the pilot plant could be confirmed. The main industrial results are (period October - December 2018):

| | |
|---|---|
| Throughput | Ø 30 $m^3/d$ |
| COD-Inlet (excl. AA) | Ø 300 mg/l |
| Dosage acetic acid (AA) | Ø 100 mg COD/l |
| Dry matter content | 18,2 g/l |

| | |
|---|---|
| - COD-volumetric load | 0,39 $kg_{COD}/(m^3*d)$ |
| - COD-sludge load | 0,021 $kg_{COD}/(kg_{DM}*d)$ |
| - Permeability | 230 $l/(m^2*h*bar)$ |

## COD removal

Diagram 2 shows a stable COD degradation in the industrial plant right from the beginning. The limit value of 200 mg/l has been met since commissioning.

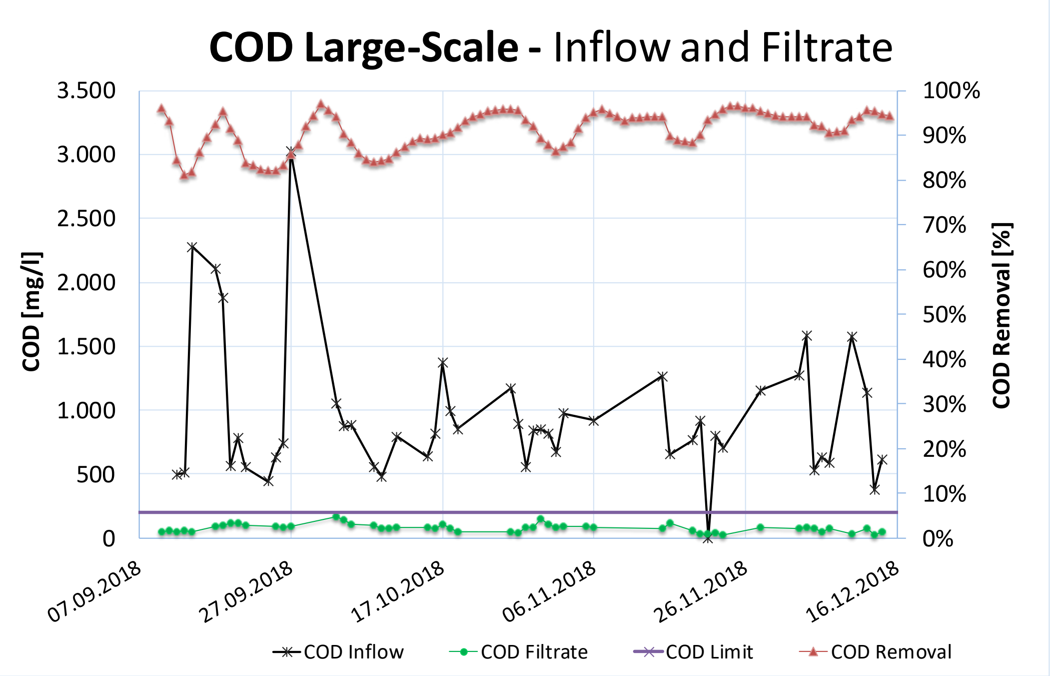

**Diagram 2: COD in inflow and filtrate and degree of degradation - Industrial plant**

## Sludge growth

To calculate the sludge growth, a three-week period starting from the 15th day of the start-up was chosen. During this time, the DM content increased by 295 kg with a COD feed load of 294 kg. This results in a specific sludge growth of 1.0 $kg_{DM}/kg_{COD}$.

The intentionally high sludge growth is aimed at the heavy metal removal and is due to on the one hand the easily degradable carbon source (acetic acid) and on the other hand the incorporation of the filterable substances of the upstream precipitation/flocculation.

**Table 3: Sludge growth - Industrial Plant**

| | | |
|---|---|---|
| Period of time | 21 | d |
| Sludge growth | 295 | $kg_{DM}$ |
| COD load | 294 | $kg_{COD}$ |
| Spec. sludge growth | 1.0 | $kg_{DM}/kg_{COD}$ |

## Zinc extraction

In January 2019 an analysis of the activated sludge was carried out. The following values could be determined:

**Table 3: Analysis results of activated sludge**

| | | |
|---|---|---|
| Dry weight content | 13.8 | g/l |
| Chromium content | 3,310 | mg/$kg_{DM}$ |
| Zinc content | 8,440 | mg/$kg_{DM}$ |

At a COD inflow concentration of 450 mg/l (including external COD) and the specific sludge growth of 1.0 $kg_{DM}/kg_{COD}$, a specific zinc-removal of 3.8 $mg_{zinc}/L_{filtrate}$ was achieved (see Table 4).

**Table 4: Zinc removal**

| | | |
|---|---|---|
| COD load | 18 | $kg_{COD}$/d |
| Spec. sludge growth | 1.0 | $kg_{DM}/kg_{COD}$ |
| Sludge growth | 18 | $kg_{DM}$/d |
| Specific zinc uptake | 8.4 | g/$kg_{DM}$ |
| Total zinc removal | 153 | g/d |
| Relative zinc removal | 3.8 | mg/l |

## Foaming

Disturbances in the upstream purification steps (flocculation, precipitation, chamber filter press) can cause short-term and severe impacts on the biology. If concentrations of heavy metals are too high, this subsequently leads to the death of the biomass (5). In MBR plants and dead biomass can lead to massive foaming.

To proof this, after an excessive foaming event 53.1 $mg_{Zn}$/l were measured in the filtrate of the MBR plant. According to Majid (2010) (5), a value of about 50 mg/l in the filtrate must be preceded by an inflow value of about 200 mg/l. The actual inflow values were not recorded during this period.

If it is assumed, however, that the concentration in the inflow was actually about 200 mg/l, the foaming process is very likely due to the death of the biomass.

# 4 Results and Discussion

The most important findings from the planning and operation of the pilot and industrial plant are briefly summarized here:

## 4.1 Importance of a pilot test

Especially in the industry, wastewater quantity and quality can fluctuate significantly due to changing operation conditions and also the ingredients are very specific to each individual plant. Carrying out a pilot test offers considerable advantages for getting to know the wastewater, the operating conditions, but also the important “human factor” in plant management. With the installation presented in this article, the basic feasibility of the MBR-process was proven with a pilot test, thereby minimizing the technical and entrepreneurial risks for the planner, supplier and client.

## 4.2 Sludge growth

In order to ensure the sludge age required for zinc removal, the addition of an easily degradable carbon source is necessary. The addition of 300 $mg_{COD}/l$ during start-up and later 100 $mg_{COD}/l$ proves to be sufficient. It should be noted, however, that the addition of the easily degradable carbon source results in an increased specific sludge growth, as in the case of the illustrated plant 1.0 $kg_{DM}/kg_{COD}$.

The accumulation of biological-physical surplus sludge of the MBR plant is quantitatively subordinate to the precipitation sludge of the chemical wastewater treatment. It is therefore not treated separately, but simply discharged into the reaction tank of the flocculation step and dewatered together with the galvanic sludge in the existing chamber filter presses.

In general, the sludge accumulation can vary considerably depending on the wastewater characteristics and the used additives. Especially in the industrial sector, the wastewater composition is very specific to the individual plant.

## 4.3 COD removal

Both the pilot and the industrial plant achieved a stable COD reduction of over 80%. Hence, it can be concluded that the COD in the inflow as well as the acetic acid as an external carbon source can be efficiently degraded by the existing biomass and the nutrient supply is sufficient. Even during excessive zinc loads, the high degree of COD degradation could be maintained.

## 4.4 Membrane suitability

The permeability shows no impairment during the pilot phase and after three months of operation of the industrial plant. However, weekly alkaline and acidic in-situ membrane cleaning is essential. In addition, from experience, a semi-annual intensive cleaning "on air" is required. If necessary, the membrane can also be submerged in a cleaning solution in an external basin.

In general, a conservative design of the membrane surface with sufficient hydraulic reserves is recommended. Thus, it is flexible even when a higher amount of wastewater must be processed and the low hydraulic load leads to a longer life-time and a relaxed plant operation.

## 4.5 Foaming

In every biological wastewater treatment plant, foaming can occur for various reasons. In the present case, foaming was caused by the death of biomass due to an extraordinary load with dissolved heavy metals.

Sufficient measures for foam detection and control such as automatic measuring probes, spray systems and a dosage of an antifoam chemical are therefore installed in the large-scale system. However, a constant antifoam dosage is not recommended, since the biology adapts and after a certain period of time the antifoam might be rapidly degraded and loses its effect. Therefore, it is also recommended to change the antifoam type periodically. The used antifoam chemical must be silicone-free for reasons of membrane compatibility.

# 5 Conclusion

The positive experience with the use of MBR technology as a post-treatment for galvanic wastewater clearly shows that MBRs can be easily adapted to different wastewater types due to the freely selectable and easily adjustable sludge age. The cost-efficient construction due to the reduced space requirement and high degradation rates are among the key advantages.

In recent years we were able to implement industrial MBRs for the treatment of wastewater in the following sectors:

- Municipal wastewater (adaptation of a pond wastewater treatment plant)
- Liquid waste (post-cleaning after evaporation and flotation)
- Surface water from waste treatment plants
- Biodiesel production
- Landfill leachate
- Beverage production (adaptation of an SBR plant)

# 6 Literature

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