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Development and evaluation of precision woven wire cloth for sieves and filters, an ultrafine woven wire cloth with a square opening size of 13 µm and mesh counts of 977 wires per linear inch, S. Nojima*, N. Hirajo, S. Shimokomaki, T. Matsumoto, Y. Mizuguchi, ASADA MESH Co. Ltd., Japan

M1 Waste Water Treatment 09:00 10:15

Membrane bioreactor for the cleaning of surface water of a solid waste treatment site, T. Garstenauer*, B. Mayr, EnviCare, Austria

Technical and economical evaluation of a membrane-based filtration process to remove micropollutants, resistant bacteria/genes and nutrients from treated wastewater, M. Werner*, D. Schreier, MICRODYN-NADIR; A. Merz, Darmstadt University of Applied Sciences, Germany

Old RO membranes end-of-life : from autopsy to reuse as NF/UF/MF or IEM in Water and WasteWater Treatments and at the end as an alternative fuel production, M. Pontié*, Angers University; S. Awad, IMT Atlantique, France; M. Shabani, Modares University, Iran; F. Seibel, V. Barbosa Briao, Universidade de Passo Fundo, Brazil

G8 Air Filtration I 09:00 10:15

One step beyond: From the experimental investigation of discharging methods to numerical optimization potential of electret filter media, M. Kerner*, S. Antonyuk, Technische Universität Kaiserslautern; K. Schmidt, IT for Engineering (it4e) GmbH; S. Schumacher, C. Asbach, Institute of Energy and Environmental Technology e.V. (IUTA), Germany

Modelling of the mechanical aging behaviour of PLA-based nonwovens and monofilaments under filter application-relevant conditions, R. Taubner*, Saxon Textile Research Institute (STFI), Germany, C. Schippers, L. Tsarkova, Deutsches Textilforschungszentrum Nord-West gGmbH (DTNW); J. S. Gutmann, University Duisburg-Essen (UDE), Germany

Changing a filter – A change of principle, T. Stoffel*, DELBAG GmbH, Germany

L14 Flotation-Adsorption-Coalescence/ Using of Boundary Surface Effects 10:45 12:00

Microscale modelling and simulation of the removal of water from diesel fuel using hydrophobic separator meshes, S. Antonyuk, Technische Universität Kaiserslautern; O. Elsayed*, R. Kirsch, S. Osterroth, Fraunhofer Institute for Industrial Mathematics (ITWM), Germany

Investigations on the process strategy of aqueous two-phase flotation (ATPF), L. Jakob*, M. Heinzmann, H. Nirschl, Karlsruhe Institute of Technology (KIT), Germany

Novel method for removal of microplastics from various waters using organosilanes, K. Schuhen*, Wasser 3.0 gGmbH, Germany

F7 Filter Media Development Supported by Simulation Methods I 10:45 12:00

Topology optimization of filters using an adjoint solver, N. Jüngling*, D. Hoch, J. Niessner, Heilbronn University of Applied Sciences, Germany

Virtual production of filter media using simulation driven design, A. Schmeißer*, S. Gramsch, W. Arne, R. Wegener, Fraunhofer Institute for Industrial Mathematics (ITWM); F. J. Hahn, T. Gose, A. Koronai-Bauer, K. Riedinger, F. Keller, MANN+HUMMEL GmbH, Germany

Filter modeling and simulation with GeoDict, M. Azimian*, A. Weber, A. Wiegmann, Math2Market GmbH, Germany

M2 Water Production 10:45 12:00

Membrane distillation for the production of pharmaceutical-grade water, F. Nellessen*, T. Klein, Wilhelm Werner GmbH; H.-J. Rapp, DEUKUM GmbH; F. Rögener, Technical University Cologne, Germany

Nanofiltration versus reverse osmosis for brackish water desalination process considering wide range of salinity: pilot scale investigation, H. Dach*, M. Pontié, Angers University, France; A. Lhassani, Fez University, Morocco

Possibilities for increasing the efficiency of decentralized production of potable water from seawater using membrane processes, T. Peters*, Membrane Consulting, Germany

G9 Air Filtration II 10:45 12:00

Test methods for indoor air cleaners with alternative test aerosols and considering ultrafine particles, S. Schumacher*, A. Banda Sanchez, A. Caspari, U. Schneiderwind, C. Asbach, Institute of Energy and Environmental Technology e.V. (IUTA), Germany

Impact of roadside filtration devices on the concentration levels of road traffic pollutants at an urban traffic hotspot, T.K. Müller, T. Warth*, MANN+HUMMEL GmbH, Germany

Using ultrafine aerosols to understand service life of air filters for gas turbine applications, A. Corradi*, G. Costa, Ahlstrom-Munksjö; J. A. Marval Díaz, P. Tronville, Politecnico di Torino, Italy

L15 Filtration and Deliquoring Analysis of Fine Particle Networks 13:00 14:15

Characterization of protein crystal sediments with microcomputer tomography, B. Radel*, H. Nirschl, Karlsruhe Institute of Technology (KIT), Germany

3D information about the multiphase processes in the pore space of a filter cake using X-ray tomography, E. Löwer*, T. Leißner, U.A. Peuker, Technical University Bergakademie Freiberg, Germany

Steam pressure filtration - Combination of water insoluble liquids and dewatering with steam, S. Esser*, U.A. Peuker, Technical University Bergakademie Freiberg, Germany

F8 Filter Media Development supported by Simulation Methods II 13:00 14:15

Simulating the microstructure of nonwovens to predict their elastic-plastic behavior in 3D, K.M. Hoess*, F. Keller, MANN+HUMMEL GmbH; S.Schmauder, University Stuttgart, Germany

Flow-induced deformation of filter media – Part 1: Experimental characterization and 3D simulation of the mechanical properties of filter media during perfusion, V. Puderbach*, S. Antonyuk, Technische Universität Kaiserslautern; R. Kirsch, R. Deshpande, Fraunhofer Institute for Industrial Mathematics (ITWM), Germany

MEMBRANE BIOREACTOR FOR THE CLEANING OF SURFACE WATER OF A SOLID WASTE TREATMENT SITE

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ABSTRACT

At solid waste treatment facilities waste is partially stored outdoor on sealed surfaces. Therefore, rainwater might be polluted with organic and inorganic compounds. If the water is going to be discharged into a receiving water body, anthropogenic polluted surface water has to be treated according to the state of the art.

High fluctuating quantities and qualities of this surface water with differing temperature cause high demands on the treatment technology. In biological wastewater treatment processes the retention of activated sludge has to be guaranteed for sudden heavy rain events as well as for longer dry periods. In membrane bioreactors (MBR) biological wastewater treatment is combined with membrane technology for the retention of biomass and particles.

An MBR pilot plant was installed at a waste treatment facility and operated for four months to evaluate the suitability of this technology. The pilot phase proofed that the MBR technology is suitable to treat the polluted surface water in order to fulfil the stipulated discharge limits. The cleaned filtrate can be discharged directly into the receiving water body. The large-scale plant was designed, constructed and put into operation based on the results from the pilot phase. Due to the previously gained experience during the pilot test, the COD limit value was met right from the start of the large-scale plant. Even longer dry periods, a cold winter and sudden hydraulic flushes showed no negative effects on the biological cleaning performance as well as the permeability of the membrane.

A pilot test offers several advantages such as becoming familiar with the wastewater, the operating conditions, but also the important "human factor" in plant management. It is recommended to design the membrane surface with sufficient hydraulic reserves. Thus, a flexibility for higher amounts of surface water can be ensured and the average lower hydraulic load extends the lifetime and generally leads to a relaxed operation mode.

The experiences gained by using an MBR as treatment for surface water at a waste treatment facility show that the technology is reliable and robust and can be adapted easily to different requirements. The main advantages include cost-effective construction works due to reduced space requirements and an unnecessary final sedimentation basin. Additionally, the freely selectable sludge age allows for high degradation rates since the sludge is completely restrained and perfectly adapted to the specific inflow.

KEYWORDS

Waste Treatment, Surface Water Treatment, Membrane Bioreactor (MBR), Activated Sludge, Aerobic Degradation, Ultrafiltration, Hollow Fibre membrane

BACKGROUND

At solid waste treatment facilities waste is partially stored outdoor on sealed surfaces. Depending on the leaching behaviour of the waste pile the rainwater might be considerably polluted with organic compounds (parameter chemical oxygen demand (COD)) and inorganic compounds (filterable substances).

By law the discharge of rainwater is only allowed into storm water or combined wastewater sewers. For direct discharge into a receiving water body, the anthropogenic polluted surface water has to be treated according to the state of the art and under consideration of the ecological status of the receiving water body.

The so-called first flush, the rainwater from the first 15 minutes during heavy rain events, has to be collected, stored and cleaned properly. Sedimentation in retention basins is not sufficient to ensure the necessary quality. After the first flush the water quality allows for direct discharge.

High fluctuating quantities and qualities of surface water with differing temperature cause high demands on the treatment technology. In the presented case the COD concentration in the inflow ranges from 50 to 1,600 mg/l and the concentration of filterable solids from 1.0 to 180 mg/l. In addition, there can also be variable and substantial nitrogen and phosphorus loads. In biological treatment plants, the retention of activated sludge has to be guaranteed for sudden heavy rain events as well as for longer dry periods. Membrane bioreactors meet both criteria while in a conventional sedimentation-based system, the activated sludge flocs will be washed out.

In membrane bioreactors (MBR) biological wastewater treatment is combined with membrane technology. Organic compounds, nitrogen and phosphorus are removed in aerobic processes. Ultrafiltration membranes prevent biomass and inert particles from wash-out. The MBR process was developed about 30 years ago (Mayr 1993) and is since then used for several industrial applications (Mayr & Garstenauer 2019) and for the treatment of communal wastewater under certain conditions (Grundestam 2015, Mayr 2017).

This paper presents the design, construction and operation of an MBR plant for the cleaning of surface water of a solid waste treatment site. In this particular case hollow fibre membranes with a cut off of 50 nm are used.

AIM AND METHODS

The surface water from sealed waste storage and manipulation sites at the waste treatment facility is collected in different infiltration structures and sewers in two areas (A and B) and drained to retention basins. After a sedimentation phase the collected surface water at least from the first flush (15 minutes) is pumped to a joint storage basin. The water is then treated in the MBR plant. When the storage basin is filled up, surface water in the two retention basins is directly discharged to the receiving water body after sedimentation. Table 1 shows the characteristic of the surface water.

Table 1: Surface water characteristics

	Area A		Area B	
	Range	Average	Range	Average
pH [-]	6.5 – 8.3	7.3	6.4 – 7.7	7.0
El. Conductivity [µS/cm]	288 – 2,080	929	340 – 2,700	1,013
COD [mg/l]	51 – 385	151	143 – 1,590	466
Filterable Solids [mg/l]	1.0 – 110	14.3	2.2 – 180	27.3

As can be seen from Table 1, the given limit values for direct discharge for COD (120 mg/l) and filterable solids (30 mg) are exceeded almost constantly.

In order to reduce the entrepreneurial risk, an MBR pilot plant in a 20''-container was installed at the waste treatment facility and operated for four months (April – July 2017) to evaluate the suitability of this technology.

Subsequently the basic information to the pilot plant is summarized:

- Membrane module 200 m² (material: polyvinylidenfluorid (PVDF); 0.05 µm; hollow fibre membrane)
- MBR Volume 12 m³ (8 m³ aerobic, 4 m³ anoxic)
- Air introduction 90 Nm³/h

The large-scale plant was designed, constructed and put into operation in July 2019 based on the results from the pilot phase.

The necessary storage volume of 750 m³ was calculated under consideration of various run-off coefficients for the different waste storage sites. The determining factor is that the higher polluted surface water of the 15-minutes first flush is collected and that afterwards the lower polluted rainwater is directly discharged in the water body.

The throughput of the MBR plant is designed to be able to process the stored surface water within 48 hours, so that the storage volume is available again for the next rain events.

Subsequently the basic design parameters of the large-scale plant are summarized:

- Hydraulic load < 16 m³/h
- COD load < 168 kg·COD/d
- MBR volume 80 m³ (aerobic)
- DS content 12 g/L
- Aeration 190 Nm³/h
- COD volumetric load < 2.10 kg COD/(m³·d)
- Membrane 800 m² (material: PVDF; 0.05 µm; hollow fibre)
- Flux < 20 l/(m²·h)

The combined biology and membrane basin is rectangular-shaped. All necessary equipment (pumps, ventilators, filters) as well as the electrical, measurement and control systems are installed in a nearby 40''-container.

Figure 1: Container and biology basin

RESULTS

The following diagram shows the different operating phases during the pilot test.

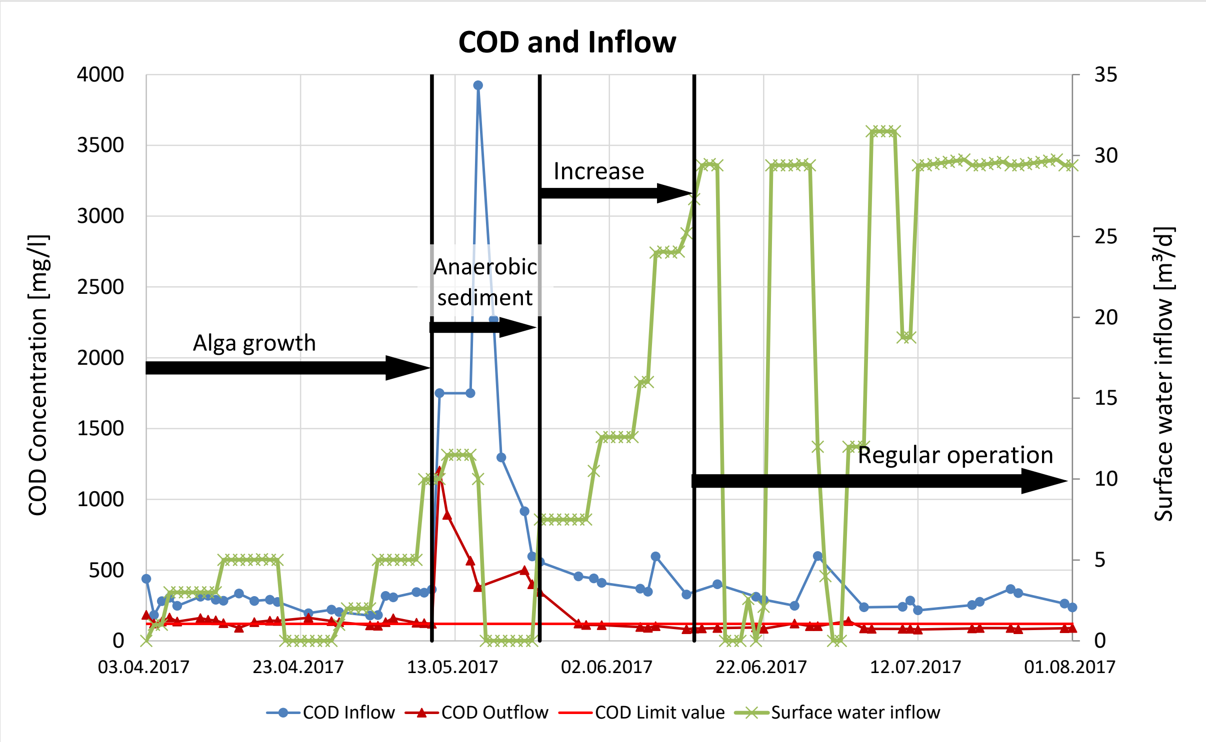

Figure 2: Operating phases MBR pilot plant

At the beginning of the pilot test strong green alga growth in the retention basin and subsequently in the MBR plant lead to considerable problems. The algae inhibited the growth of the activated sludge and had to be eliminated with different process engineering measures.

About one month after the beginning of the pilot test the level in the retention basin was decreased too much and anaerobic sediment sludge was pumped into the MBR plant. Subsequently the biological process was overloaded.

After this intensive optimization phase the inflow amount was increased over time and during the regular operation mode different settings were tested with no further disturbances.

Below the main results from the regular operating phase are summarized:

- Inflow amount Ø 22.6 m^3/d
- COD inflow Ø 304 mg/l
- COD outflow Ø 94 mg/l
- DS content 6.8 g/l
- COD volumetric load 0.5 kg·COD/(m^3·d)
- Permeability 67 l/(m^2·h·bar)

The average COD elimination was 69 %.

The pilot phase proofed that the MBR technology is suitable to treat the polluted surface water, so the clean filtrate can be discharged directly into the receiving water body.

The positive results from the pilot test could already be confirmed during the start-up of the large-scale plant. The COD limit value of 120 mg/l was met right from the start of the operation.

The start-up commenced in July 2019. The inflow amount was adjusted according to the growth of the activated sludge and the start-up phase was successfully completed in September 2019.

At the beginning of 2020 no surface water could be fed to the MBR plant due to a lack of precipitation. The biology was aerated continuously and the temperature sank to 4.5 °C. The DS content was slightly reduced due to endogenous respiration. After 47 days without inflow or any kind of nutrient dosage the feed was restarted at an inflow temperature of 10 °C. Four days later a sample of the outflow was taken and all limit values were met.

During summer 2020 a few heavy rain events led to an inflow amount of more than 300 m^3/d. These events showed no negative effects on the membrane permeability or the biology and the limit values were always met.

Figure 3 shows the amount of rain and the throughput of the MBR plant.

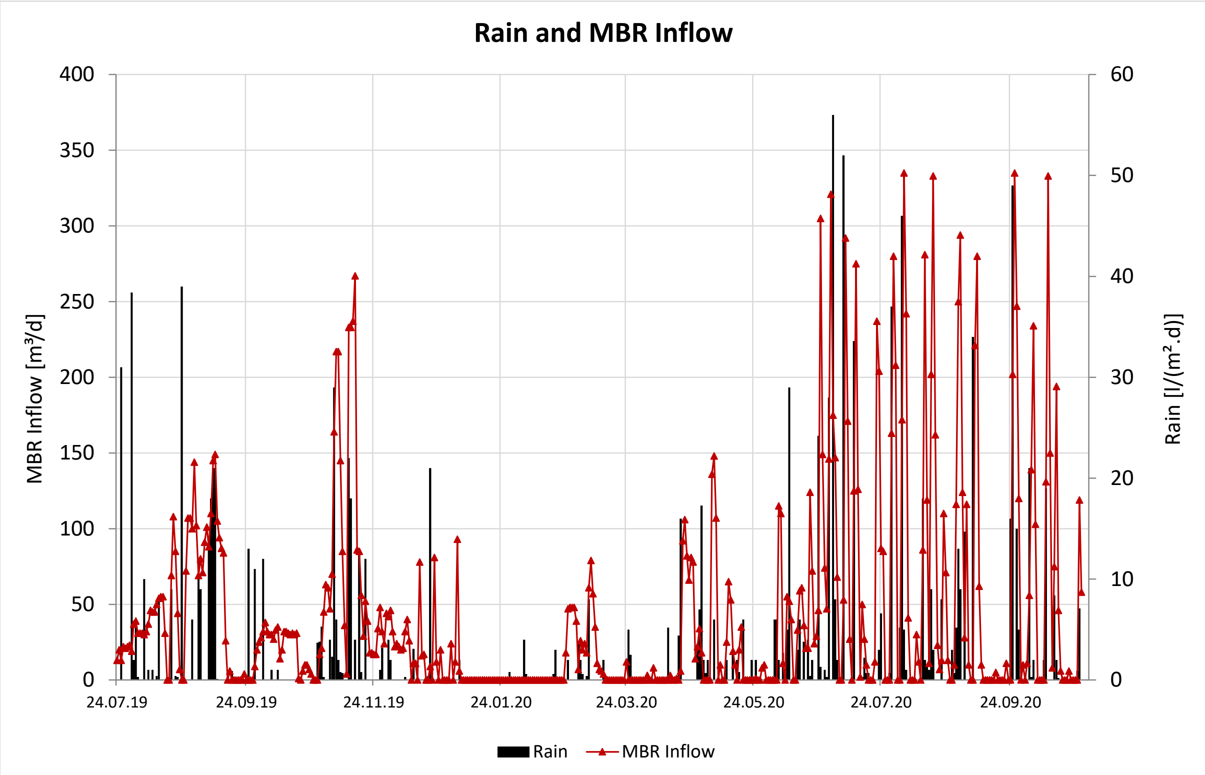

Figure 3: Rain amount and MBR inflow over time

Below some exemplary results from the large-scale plant after one year of operation are summarized:

- COD inflow — Ø 250 mg·COD/l
- COD outflow — Ø 75 mg·COD/l
- COD elimination — Ø 70 %
- Ammonia outflow — Ø 0.4 mg·NH_4-N/l
- Total phosphorus outflow — Ø 0.5 mg·P_{tot}/l
- DS content (max.) — 14.5 g/l
- Permeability after 12 months — 100 l/(m²·h·bar)

A regular acidic and alkaline cleaning of the membrane is necessary to maintain the permeability of the ultrafiltration membrane. After one year of operation no negative impact on the permeability can be observed.

The main conclusions are summarized as follows:

- Alga growth or anaerobic sedimentation sludge did not cause any problems since start-up. An emptying and cleaning of the retention and sedimentation basins is conducted yearly.
- The long period without inflow during winter (47 days) had no negative impact on the overall system and degradation performance of the MBR.
- Anti-foaming agents were not necessary so far.
- The biomass growth is stable. After longer periods with no or little inflow a stagnation or slight reduction of the biomass can be seen.

CONCLUSIONS

High fluctuating quantities and qualities of surface water from waste treatment plants cause high demands on the treatment technology. Therefore, a pilot test offers several advantages like becoming familiar with the wastewater, the operating conditions, but also the important “human factor” in plant management. In general, and especially in the presented case with a pilot test the technical and entrepreneurial risks for planner, supplier and client can be minimized.

The COD elimination was stable during the pilot test and also since start-up of the large-scale plant. Therefore, it can be concluded that the nutrient composition concerning nitrogen and phosphorus is sufficient and a dosage of surplus nutrients is not necessary, while simultaneously meeting the according limit values. Additionally, there is no need for pH adjustment.

Other organic compounds such as hydrocarbons and lipophilic substances are also removed from the surface water by degradation or adsorption on the sludge flocs and rejection at the permanent hydrophilic membrane. The limit values for these compounds were also met since the start-up.

It is recommended to design the membrane surface with sufficient hydraulic reserves. Thus, a flexibility for higher amounts of surface water can be ensured and the average lower hydraulic load extends the lifetime and generally leads to a more relaxed operation.

Foaming can occur for various reasons in any biological wastewater treatment plant. Therefore, sufficient measures for foam detection and control such as automatic measuring probes, spray systems and a dosage of an antifoam chemical should be installed. However, a constant antifoam dosage is not recommended since the biology adapts and after a certain period of time the antifoam might be rapidly biodegraded and loses its effect. In the presented case a spraying system proved to be sufficient to counteract foaming.

The operation of a MBR plant for surface water at a waste treatment facility show that this technology is reliable and robust and can be adapted easily to different requirements. The main advantages include cost-effective construction works due to reduced space requirements. Additionally, the freely selectable sludge age allows for high degradation rates since the sludge is completely restrained.

The treated water is free of particulate mater and can be re-used as industrial service water.

LITERATURE

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