Feedback from a metal processing industry MBR Plant in its 3rd Year of Operation:- An Analysis of the Flux, Effluent Quality and Membrane Lifetime Data to date

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Contents

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Note on the authors,
At the time of publication Dr Peter was the plant manager since commissioning and responsible to the process optimization. Mr Scholz's company was in charge of the process design and has acted as a technical adviser on the plant over the period to date. Mr Ferre is a technical support engineer for Kubota MBR systems.

1 Introduction

The submerged membrane bioreactor plant at Collini galvanic industries in the West of Austria is a fine example of process optimization in a complex industrial environment. The plant is owned and operated by Collini and is now in its 3rd year treating wastewater from a metal processing facility. It is sited in an industrial estate and discharges into a small waterway in an Alpine region characterized by agriculture and leisure activities. The average flow is 960m^3/d and the wastewater contains variable loads of non-biodegradable COD combined with organic additives and oils from the galvanizing process. The MBR is the final polishing step after a physical-chemical pre-treatment consisting of coagulation, flocculation, sand filtration and pH correction.

The plant is unmanned and employs a SCADA system with a PLC that controls plant operation and logs all main instruments and alarms. Key parameters are recorded and monitored daily by the factory staff.

Fig. 1. View of the Collini MBR plant and surroundings.

2 MBR plant description

The MBR plant comprises 2 identical independent treatment lanes in parallel. Each of them is divided into successive anoxic and aerobic steps. The anoxic basins (9.6m long x 4.3m wide x 5.5m deep) receive recycled sludge and wastewater feed in a 6:1 proportion. The mixed liquor overflows into integrated aerobic and filtration tanks (18.5m long x 4.3m wide x 5.5.m deep), through an area of fine bubble diffusers followed by membrane filtration. Each membrane filtration area consists of the required space for No.7 Kubota EK400 submerged membrane units. Due to lower hydraulic load only 4 units were initially supplied in each tank, thus totalling 2,560m^2 membrane filtration area. If it is required, additional 1,920m^2 can be easily installed at the readily available spaces.

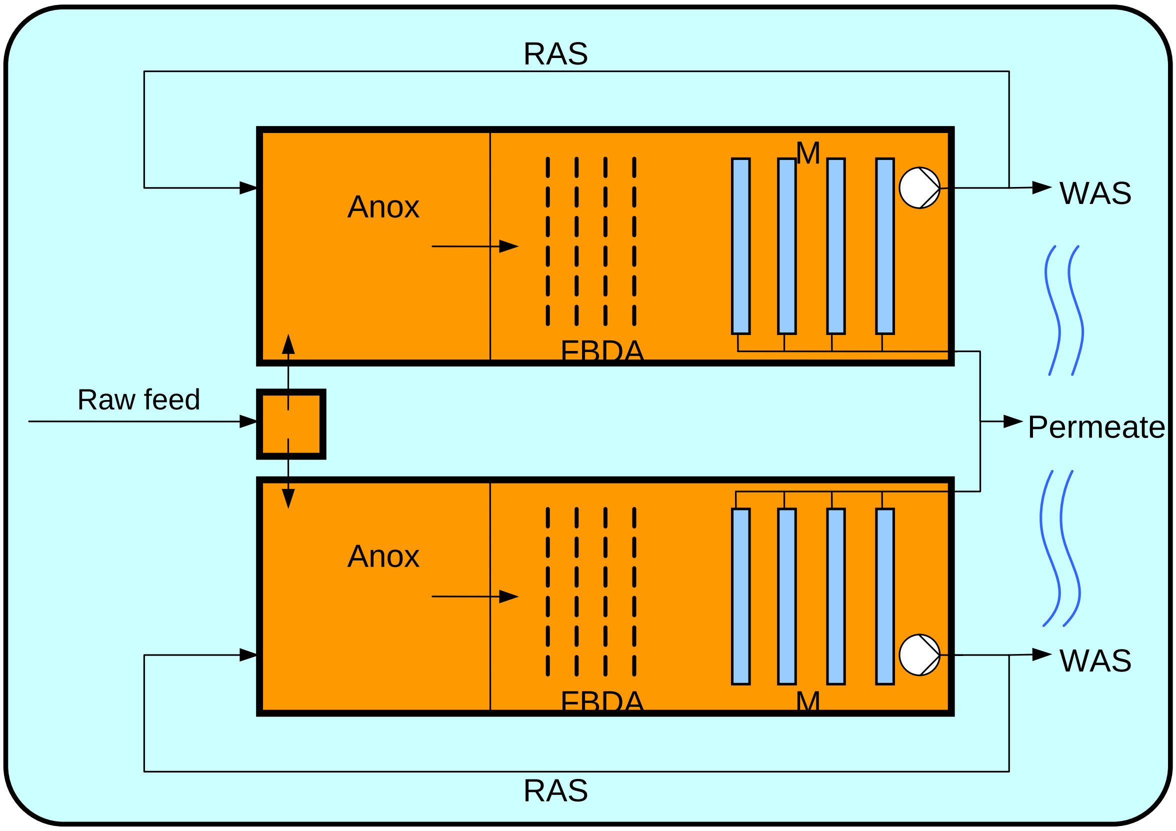

Fig. 2. Schematic showing Collini MBR plant

Both lanes permeate by gravity into a common filtrate tank. Provided that the discharge pipe is submerged, the filtration driving force is the liquid level difference between the reactors and the permeate tank. The liquid depth is variable in each lane depending on inflow. The water level at the permeate tank is maintained constant via a discharge weir. As a result of this simple and safe design, no pressure transducers were installed on the permeate lines because the maximum level difference attainable at both sides of the membranes would never exceed 2.3 metres of water column (that is, 0.23 bar). Permeate flow is targeted and controlled by means of flow meters linked to regulating valves. Permeation cycles are 8min ON/1.5min OFF when the tank liquid level is between the allowed minimum and maximum.

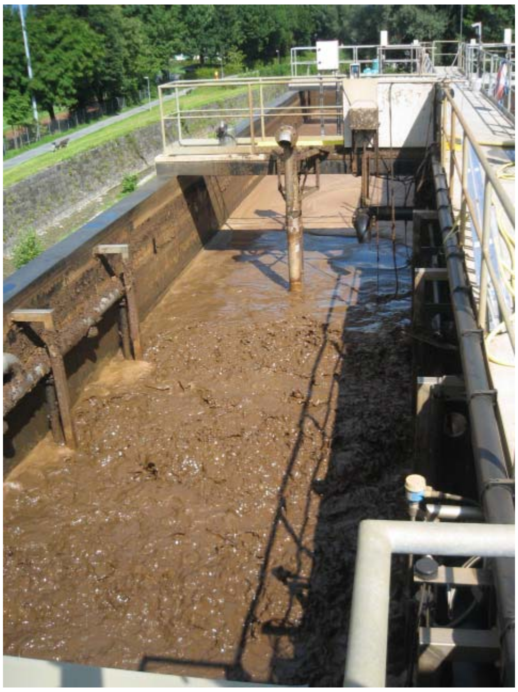

Fig.3. View of Membrane tank No.1

Given the aggressive nature of the wastewater, concrete tanks are lined with polyethylene and steel components are made of the highest stainless grade. The plant blowers are 2 duty for FBDA and 3 for membrane aeration (2 duty, 1 standby).

3 Process Data

3.1 Effluent quality

The design inlet and outlet values seen by the MBR are shown in Table 1. The discharge happens into a brook that further downstream is incorporated to a larger waterway, therefore the effluent consent provides enough safety for fresh water life. BOD limit is established at 20mg/L, nutrients must be within 10 mg/L and 2 mg/L for NH4-N and TP respectively. Also, refractory COD and heavy metals shall be retained and treated accordingly.

Table 1. Collini MBR influent and effluent design quality data

	Inflow Biological Treatment Step	Required Effluent Quality
Suspended Solids	-	30 mg/l
COD	450 mg/l	150 mg/l
NH4-N	130 mg/l	10 mg/l
Total-N	390 mg/l	-
Total-P	3,6 mg/l	1 mg/l

The historic outlet values show that the biological process combined with membranes is capable of maintaining constant and excellent permeate quality as follows:

Table 2: Collini MBR influent and effluent quality data from 2006 to August 2008

Parameter	**Number of samples**	**Feed average**	**Permeate average**	**Typical detection limit**
BOD - mgO_2/l	3	70	< 10	6
COD - mgO_2/l	260	220	70	10
NH_4-N – mg/l	260	100	< 0,5	
Total P – mg/l	260	0,6	0,8	
Total S – mg/l	3	1000	1000	

3.2 Biodegradability of the influent

The galvanizing process adds BOD to a wastewater that is generally characterized by non-biodegradable COD. BOD comes in the form of oils, surfactants and long-chained polymers, which usually are non-readily biodegradable. Also, the wastewater is rich in chlorides (max 4,000ppm), sulphates (max. 8,000ppm), and there is presence of aluminium, boron and silicon.

In order to allow biomass growth it is necessary to ensure the right level of nutrients. Nitrogen is ubiquitous as ammonium, however phosphorus has to be dosed as phosphoric acid.

Process temperature is usually around 25°C, which facilitates an even biological activity throughout the year. Wastewater pH is corrected upstream the MBR in order to maximize the acclimation of microorganisms. A slightly basic pH is targeted as to counter the acidic effect of nitrification.

The plant manages to completely nitrify the influent. This is achieved with periodical addition of carbon sources; the most cost-effective of which have proved to be the waste productions from a well-known energy drink and commercially available wooden pellets for wood-fired boilers.

The anoxic zone is just large enough to ensure cracking of nrbCOD and small enough not to de-nitrify so that anaerobic cultures are inhibited. If anaerobic digestion took place H_2S would be generated thus intoxicating the process and posing hazards to human health. As a consequence, the permeate presents combined nitrate values around 100 mg/L, which are de-nitrified downstream in the major waterway.

3.3 Mixed Liquor Suspended Solids

Kubota's MBR design recommends MLSS figures around 12,000mg/L as to obtain optimum biological and membrane filtration performances. However, due to the difficult treatabilities of both the wastewater and the waste sludge it has been favoured to operate at long sludge ages (above 1 year) thus very sparse de-sludging routines.

Sludge ages have ranged from 300-600 days, well above the designed 50 days. F:M ratios are low and have generally ranged 0.02-0,03 kgBOD/kg

MLVSS, far from the proposed 0.10 kgBOD/kgMLVSS. As a consequence, sludge production figures are low and have been estimated in the range 0.35 – 0.50 kgDS/kgBOD.

Over 2 years' continuous operation MLSS values have averaged 20,000mg/L. Peaks have reached 40,000mg/L, especially before de-sludging, with sustained instantaneous flux around 12LMH (net flux 10LMH). Due to the presence of sulphur in the sludge the operator avoids mechanical or gravity thickening as it could create anaerobic conditions, thus generating H_2S and toxicity on the returned sludge supernatant into the reactor.

Such high MLSS concentration does not affect oxygen transfer and nitrification, finding DO figures as high as 15mg O_2/L in the activated sludge.

Despite the excessive range, the plant has proved very tolerant of the high MLSS, provided the aeration is maintained.

3.3 Flux rates and permeability over time

The design provided a conservative flux rate as a consequence of lack of piloting stage, the unpredictable nature of sludge condition and the potential for inorganic fouling. The design net flux 15.6LMH has been consistently achieved.

3.4 Chemical cleaning

Chemical cleaning is performed in-situ, in sludge, as a backwash of sodium hypochlorite at 0.5% concentration by weight as free chlorine or citric acid at 4 % concentration by weight. An average interval between cleans of 3 months was recorded over the first 2 years. Chemical cleans take approximately 5 hours per tank from taking off-line to re-start, allowing for a 2 hour soaking time.

4 Operation and Maintenance

To the date of this paper, membranes at Collini have not yet been removed. Every year there is a maintenance week during which tanks are alternately emptied and inspected. Sludge is kept in the operational tank, therefore any possible grit cumulated in the reactor is not really eliminated.

4.1 Operational problems

Overall the plant has performed well with membranes proving exceptionally robust. Operational issues encountered during the 2-year period have been:

- Very high MLSS; although no problems were detected up to 25 g/l using aeration in excess
- Uneven aeration; although it was optimised with more frequent diffuser flushing
- Foaming; it was solved with sludge jets on the surface induced with big pumps
- Blower breakdowns were tolerable due to standby capacity.
- Sludge condition; chemical cleaning was never the reason for flux-problems; the reason was always biological stress

4.2 Maintenance tasks

The main maintenance tasks associated with the membranes on this site are:

- Diffuser water flushing to maintain aeration (automatic, 3 times a day)
- A visual check on effluent quality and aeration pattern (daily)
- MLSS check every 1 – 2 weeks
- Chemical cleaning (target once per 3 months)
- Annual drain down of the tank for a visual check on membrane units and tanks, for signs of screenings, sludge caking or grit build-up.

5 Conclusions

Collini industrial MBR was designed conservatively due to lack of pilot testing period. Two years after commissioning the process has been optimized and the plant has proved robust. Effluent quality is consistently better than the requirements and the level of operation and maintenance is well within the expectations of the owner. Overall the Collini case constitutes a success for MBR technology and proves the capabilities of biological treatment in aggressive industrial environments.

References

Churchouse, S., Warren, S., Floyd, M. *Feedback from the Porlock MBR plant in its 10th year of operation:- An analysis of the flux, effluent quality and membrane lifetime data to date.*

Acronym	Definition
BOD	Biochemical oxygen demand (mgO_2/l)
COD	Chemical oxygen demand (mgO_2/l)
DS	Dry Solids
FBDA	Fine Bubble Diffused Aeration
F/M ratio	Food to biomass ratio (kg BOD_{in} / kg MLSS)
LMH	L / m^2 / h
MBR	Membrane Bioreactor
MLSS	Mixed liquor suspended solids (mg/l)
MLVSS	Mixed liquor volatile suspended solids (mg/l)
nrbCOD	Non-readily-biodegradable COD
PLC	Programmable Logic Controller
RAS	Recirculated Activated Sludge
SCADA	Supervisory Control And Data Acquisition
TMP	Transmembrane Pressure in mm water head or sometimes mb
WAS	Waste Activated Sludge