Submerged membrane bioreactor and reverse osmosis technology for tannery effluent treatment and water recycling

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Abstract: The combination of Membrane bioreactor (MBR) and Reverse Osmosis (RO) treatment has shown to be highly effective in the removal of organic pollutants and salts from tannery effluent providing for high quality water recycling.

Membrane bioreactors (MBRs) combine an activated sludge process with membrane Ultrafiltration to facilitate complete retention of the biomass. This combination results in high biomass concentrations leading to an increased removal of organic pollutants and suspended solids from tannery effluent. The MBR permeate is then polished with Reverse Osmosis (RO) membranes to remove salts, which enables high quality water re-use for leather processing. Recycling RO water for leather processing gives excellent results without causing any detrimental effects on leather quality. This combination of MBR and RO technology shows to be a technical and economical feasible option for effluent treatment and high quality water recycling. An average reduction of 89% COD and 96% BOD and a stable membrane performance was achieved. The effluent quality complies with the Chinese discharge consents for tannery effluents.

Simona Tanning Inc is a pioneer in implementing this novel hybrid concept of MBR and Reverse Osmosis. The Chinese tannery is retanning bovine leather processing up to finished product for high performance and specialized leathers for the shoe business. Simona Tanning is giving a special emphasis to environmental protection and safety and is very innovative in respect of new environmental techniques. W_2O Environment has assisted Simona Tanning in the successful implementation of MBR and RO technology, which is one of the first industrial scale applications of it's kind in Asian tanneries.

Keywords: Membrane Bioreactor, MBR, Reverse Osmosis, RO, tannery water recycling

1 Introduction

The effluent treatment plant consists of screening, pre-settlement, balancing, floatation and sedimentation. This follows biological treatment with anaerobic, facultative and aerobic treatment steps. The aerobic biological treatment is being operated as an MBR system with submerged membranes, to treat the effluent for subsequent RO membrane filtration. The MBR and RO plant are designed to provide for up to 67% water recycling. The RO concentrate is further treated applying Primary and Biological treatment in the former effluent treatment plant following final polishing using a Fenton process. This treatment concept achieves 67 % water recycling and a final discharge quality according to the Chinese discharge limit permission.

2 Effluent Treatment and water recycling plant

Tannery effluents contain many types of pollutants, which are present in all forms from large solids through colloids to dissolved salts. The flow and composition of the effluent also varies considerably during the day and from the various stages of the tanning process [1].

2.1 Screening and Pre-settlement

Pre-treatment is especially important in the treatment of tannery wastewater to remove coarse solids and to equalise flow variations in order to protect and optimise the subsequent processes. Particles, which can be easily abstracted by physical and/or mechanical means, are usually removed from the liquid effluent at the earliest possible stage. This prevents the problems of blockage and wears in pumps, pipework and other subsequent treatment equipment [2].

Photo 1: A fully automatic self-cleaning screen with 1mm slot size provides for adequate pre-treatment

Two automatic self-cleaning screens with a slot size of 1 mm are installed to efficiently remove coarse solids. In the following the effluents flow into a series of 5 small sedimentation tanks, where `natural´ settlement occurs. This Pre-settlement is being operated without any addition of coagulants and flocculants and can be applied to remove suspended solids before balancing. A small proportion of the solids in suspension are settling in this stage.

2.2 Balancing Tank

The main task of balancing is to equalise flows and concentrations. A steady uniform effluent flow can be achieved by sizing the equalisation tank to a volume of 70 to 100% of the tannery daily flow. In addition to flow balancing, the equalisation tank provides for neutralisation and precipitation. It is necessary to provide effective mixing by mechanical stirring or air injection to achieve equalisation, prevent anaerobic conditions and settling of suspended solids.

Photo 2: Self-entrained Jetox venturi aeration provides for efficient mixing and prevents sludge settlement

The tannery has two Balancing tanks installed, which offer high flexibility for operation and maintenance. Each of the balancing tanks have a volume of 1,000 m^3 and provide for 20 hours retention time offering sufficient balancing provision at peak production. Each tank has a centralised jetox venturi unit installed to provide for sufficient aeration and mixing.

2.3 Primary treatment with DAF and settlement

Primary sedimentation is a physical and chemical separation, which leads to settlement of suspended solids and colloidal substances. Sedimentation occurs, when the velocity of effluent is reduced below the point at which it can transport the suspended solids matter. The suspended solids settle and can be removed as sludge.

The physical removal of the suspended solids and colloidal substances from the wastewater is enhanced by chemical conditioning of the wastewater. The effluent is pre-treated by dosing of a coagulant, such as alum or ferric salts, followed by polyelectrolyte flocculants, which aid the phase separation. The dosing of these chemical conditioners requires prior pH adjustment of the feed streams for optimum chemical dosage [3].

Photo 3: Concrete Dissolved air floatation with sludge scraper

The Primary treatment involves Dissolved air Floatation (DAF treatment), were mainly oils and fats are removed. Following coagulation with Ferric sulphate fine air bubbles are injected to lift suspended solids to the surface from where they are removed by an automatic scraper. The facilities for chemical conditioning for the Primary settlement consist of 3 reaction tanks to mix Polyaluminium chloride (PAC), NaOH and Polymer with the effluent. Following the coagulation larger flocks are formed, which are settled in a conical settlement tank, achieving a good reduction of suspended solids. The effluents gravity flow through a static screen to the following biological treatment.

2.4 Biological treatment

The biological plant comprises of three treatment steps with a mixed anaerobic zone, with growth media, a facultative zone, operated at low oxygen, and an activated sludge aerobic zone, with fine bubble diffusers to provide for BOD removal and nitrification.

The anaerobic treatment comprises of 15 communicating tanks. The effluents are mixed with submerged mixers to keep the anaerobic bacteria in suspension. During this treatment step anaerobic processes occur, which reduce the major pollution load. In general anaerobic systems have certain advantages in terms of lower energy consumption, reduced sludge production, reduced operating and maintenance costs and overall stability, especially during power failure and breakdowns. However, anaerobic processes are slower than aerobic systems and therefore require larger sizes and volumes. The anaerobic treatment achieved an average COD reduction of 37% (daily sampling May-October 2008).

The facultative treatment comprises of 12 communicating tanks. To improve the facultative treatment, plastic growth media are installed in the tanks on frames to provide for the formation of bacteria films. Holed piping is installed to provide for mixing and light aeration to maintain the oxygen levels in between 0.1 and 0.5 mg/l, achieving an average COD reduction of further 38%(daily sampling May-October 2008). Both treatment tanks are covered to reduce smells.

Photo 4: Growth media to promote biofilm formation for facultative treatment

The facultative system is commonly applied for tannery effluent treatment as a facultative lagoon and also in the highly efficient Pasveer ditch. Low-load activated sludge systems, like the Pasveer 'oxidation' ditch, are particularly suitable for tannery effluents and have been extensively adopted by tanneries. Due to a reasonable retention time of 2-4 days and lower organic loading after the anaerobic treatment, the facultative treatment is more suitable to cope with the variable effluent composition and shock loads from the tanning process. A further advantage is that a facultative treatment tends to produce less wasted sludge. Anaerobic and Facultative treatments are used successfully in tannery effluent treatment. According to reported data 25% reduction of COD can be achieved in the anaerobic treatment stage and a further 25% in the facultative treatment stage. The anaerobic and facultative treatment performance has shown a COD reduction from average 1,748mg/l to average 1,104mg/l outlet anaerobic stage to average 690 mg/l at the inlet of the activated sludge system.

2.5 Membrane bioreactor (MBR)

Membrane bioreactors combine the activated sludge process with a membrane separation unit for biomass retention. Main advantages of MBRs over conventional wastewater treatment plants are a smaller footprint due to higher biomass concentration and the absence of a clarifier, but also the production of a highly quality disinfected effluent.[4-5]. Submerged or integrated membrane systems can be operated at significantly lower pressures and hence energy consumption. In this case membranes are submerged into the bioreactor and permeate is pumped under negative pressure of only 0.1-0.3 bars. [6] The Membrane bioreactor comprises of aerated activated sludge tanks and the membrane tank with submerged membrane filtration. Fine bubble diffusers to maintain DO levels between 2 to 4 mg/l provide aeration. The membrane bioreactor tank has 18 submerged hollow fiber membrane units, which are operated at –0.1 – 0.3 bars continuously over 13 minutes with a break interval of 2 minutes. The cross flow is provided by coarse bubble aeration, which clean the outer surface of the membranes. The membranes have to be cleaned periodically (every 3 months) with cleaning chemicals. Each membrane stag is then transferred to a cleaning tank to carry out the cleaning with Sodium Hydroxide and Hypochloride.

Table 1: Biological and MBR performance with average reduction of COD and BOD (May – October, 2008)

Parameters (mg/l)	Primary	Anaerobic	Facultative	MBR	(%)
COD (mg/l)	1748	1104	690	199	89
BOD (mg/l)	350			21	94

Photo 5: Membrane Bioreactor tank with submerged membranes

The MBR tank is being operated at 6,000- 10,000 mg/l MLSS, which is regulated by the volume of return sludge to the facultative treatment. Four pumps return the concentrated MBR sludge with 100m^3/hr capacity each to the facultative tank or the anaerobic tanks and the surplus sludge is transferred to the sludge thickener.

2.6 Water recycling plant with Reverse Osmosis

Reverse Osmosis treatment is considered as BAT, Best available technology, to remove salts from tannery effluents. The high quality RO water can be re-used as process water in the tannery. However the operation of Reverse Osmosis requires an efficient pre-treatment and a feed water quality with no suspended solids and a minimum of BOD[7]. Membrane bioreactor technology is the preferable pre-treatment for Reverse Osmosis plants due to the complete elimination of BOD and suspended solids. Even small concentrations of BOD after conventional treatment can cause bio-fouling of RO membranes and residual suspended solids physically block the spacer of a spiral RO module. The combination of a Reverse Osmosis plant applied as a polishing step after MBR treatment allows recycling of desalinated water back into the tannery process [8]. The RO pre-treatment comprises of a multilayer bed filter with sand and activated carbon. Following this pre-treatment, UF membrane filtration using Hollow Fibre membranes provide for final polishing before RO treatment. The UF membrane plant comprises of 44 units with 110 m^3/hr capacity.

Photo 6: Reverse Osmosis permeate with low salinity

The RO plant is designed in 'Christmas tree' configuration, with 6 membrane modules in series is being operated at 12-16 bars. The material of the installed membranes is a cross-linked fully aromatic polyamide composite. The RO plants are designed to be operated at a permeate recovery of 66 % and produces up to 67 m^3 permeate and 33 m^3 concentrate per hour. The RO concentrate is then further treated in a separate effluent treatment plant.

2.7 Fenton process for Reverse Osmosis concentrate treatment

The Reverse Osmosis concentrate is composed of mainly recalcitrant compounds, which are hardly biodegradable. Advanced oxidation processes (AOPs) have shown to be suitable for the chemical oxidation of residual COD with up to 90% removal achieved as reported in literature [9]. The Fenton process was selected as the most suitable technology to reduce residual COD for final discharge. The Fenton process is based on the formation of hydroxyl radicals ($^{\bullet}OH$), which due to their strong oxidation potential destroy organic pollutants. The hydroxyl radicals are formed by interaction of H_2O_2 with ferrous salts. In the first oxidation step the RO concentrate is mixed with H_2O_2 under $FeSO_4$ addition and the pH is adjusted to 4. In the following coagulation step, pH is corrected to 7 using NaOH and suspended solids are settled. The application of the Fenton process has shown to efficiently reduce the residual COD to the discharge limit of 90 mg/l.

3 Conclusions

The application of anaerobic, facultative and aerobic biological MBR treatment is a promising treatment concept for low cost industrial wastewater treatment. This unique combination has shown high reductions of COD and a reduction of energy consumption and aeration requirements. The combination of MBR with Reverse Osmosis has shown to achieve maximum recovery of high quality desalinated water at lowest costs. The RO water is now being steadily used for leather processing achieving a constantly good leather quality. This treatment and recycling concept can be easily adapted to local requirements and offers a treatment scheme, which is operated exactly at discharge consent. Treatment in any case represents a pure cost, with no return, while this recycling scheme actually achieves cost savings due to reduction of fresh water consumption, discharge costs and disposable sludge generation. This hybrid system is capable to meet both criteria easily of efficient treatment at low costs and high quality water recycling. The development of a suitable RO concentrate treatment using beside conventional treatment (Primary and Biological) also the Fenton process achieves a solution to the concentrate issue that is both legal and cost effective. The Outlook for further treatment cost reduction will be RO concentrate treatment by using Reedbeds.

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