Membrane Bioreactor Treatment of Tannery Effluents with Nitrogen Removal and Low Cost Sludge Drying

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Abstract

Measurements to improve discharge quality to fulfil the requirements of new regulations such as nitrogen limits and to reduce treatment and sludge disposal costs have become increasingly important to improve the competitiveness of tanneries. Biological treatment of tannery effluents is an essential step to reduce soluble organic compounds as well as nitrogen. A combined de-nitrification and nitrification stage oxides ammonia to nitrate, which is recirculated to an anoxic stage where nitrate is denitrified releasing molecular nitrogen. In practice denitrification/nitrification systems have shown greater stability and performance of biological plants with complete ammonia removal achieving low nitrate concentrations of 5 ppm in the effluent. Membrane bioreactor (MBR) treatment in combination with a denitrification / nitrification loop has shown to increase significantly the biological plant performance compared to conventional treatment with average removal rates of 92% COD, 98% BOD and 93% total nitrogen. A further benefit of longer sludge retention times and higher temperatures associated with MBR treatment, is the reduction of surplus sludge generation compared to 50% of metabolised COD in conventional activated sludge plants down to 10%. Tanneries strive to reduce disposable sludge volumes as landfill is becoming increasingly expensive. Primary and Biological sludge is commonly mixed and de-watered with a decanter centrifuge achieving a dry matter content of 30-35%. The filtercake can be further dried in a low cost sludge dryer, where the sludge is macerated and dried with steam- heated screws, resulting in 90% cake dryness, which reduces the overall sludge volumes for disposal by 60%.

Keywords: tannery effluent, denitrification, nitrogen removal, membrane bioreactor, sludge drying.

Introduction

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 (Buljian and Kral 2011). Fine screening at 1 mm is especially important for the pre-treatment of tannery wastewater to remove coarse solids in order to protect and optimise the subsequent processes.

The effluents gravity flows to a Balancing tank to equalise flows and concentrations. A steady uniform effluent flow can be achieved by sizing the balancing tank to a volume of 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 and aeration by using self entrained jetox venturis to achieve equalisation, prevent anaerobic conditions and settling of suspended solids.

The following Primary treatment involves Dissolved air Floatation (DAF treatment), were suspended solids and colloidal substances are removed. The physical removal of the suspended solids and colloidal substances from the wastewater is enhanced by chemical conditioning of the wastewater (IPPC 2009). The effluent is pre-treated by dosing of a coagulant, such as alum or ferric salts, followed by polyelectrolyte flocculants with pH adjustment, which aid the phase separation. Dissolved air flotation works on the reverse principle to sedimentation, employing fine air or gas bubbles to lift suspended solids to the surface, where the flocks form a sludge layer, which is removed by a scraper. A DAF system achieves high levels of pollution removal with 98% of SS and up to 75% of the COD (Scholz et al. 2009). A further advantage is that the floated sludge has higher solids content, up to 10% dry material, which is much easier and cost effective to handle.

Following Primary effluent treatment the effluent gravity flows to the biological treatment with anoxic and aerobic treatment steps with ammonia oxidation and nitrate removal. 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.

Primary sludge after Dissolved Air Floatation has a dry matter content of 8 - 10 % and the secondary MBR sludge of 1–1.5%. Primary and secondary sludge is mixed and de-watered using a decanter centrifuge, beltpress or filterpress and then dried in a sludge drier reducing the disposable sludge volume by 2/3.

Biological treatment

After Primary treatment soluble COD, BOD and ammonia remain in the effluent, which can be removed efficiently by the means of biological activated sludge treatment. Biological processes are based on the fact that micro-organisms can use the organics (BOD) and nutrients (N &P) to build up their cell mass as well as provide their energy requirements. The soluble organics are converted to CO2 and wasted sludge from the biomass.

Ammonia can be removed from the effluent during biological wastewater treatment by the process of nitrification - the conversion of ammonia to nitrate by specialised micro-organisms. This process is relatively sensitive and requires suitable conditions and good control of the biological process. In biological systems, the solids and hydraulic loadings, temperature, pH, dissolved oxygen and the sludge age are important factors for nitrification to occur and have to be adjusted to induce nitrification. Beside that inoculation with nitrifying bacteria can accelerate to induce nitrification.

Photo 1: Pre-denitrification and aerobic biological treatment

Similar as for municipal effluents also tannery effluent treatment, the biological systems is being designed to achieve complete nitrification. All available Ammonia is then completely converted to nitrate, which in the following can be reduced by biological denitrification. If a nitrified effluent is mixed with a non aerated or respirating sludge, dissolved oxygen is rapidly exhausted and further supplies of oxygen are obtained by the reduction of nitrate, resulting in the liberation of gaseous nitrogen. To maintain respiration of the sludge at an adequate rate an additional carbonaceous substrate is usually required. The necessary BOD is supplied by mixing fresh effluent in the anoxic zone with the nitrate-enriched effluents after aerobic treatment. This form of using the anoxic step as the initial treatment is called Pre- denitrification and has the additional advantage of reducing BOD loads without any aeration requirements. The denitrification/ nitrification systems are operated in sequence with effluents recirculating in between the aerated zone and the anoxic zone.

Membrane Bioreactor

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 (Scholz 2005).

MBRs provide a relatively compact alternative to conventional biological treatment options, producing a high quality effluent even at high and varying organic loading rates. The process relies on membrane filtration to effectively retain all the biomass in the bioreactor as opposed to conventional treatment, where the biomass is continuously lost during clarification. As a consequence, the MBR process is operated at 3 folds higher mixed liquor concentrations of up to 10 g/l MLSS, than conventional biological treatment. A major benefit of MBR, resulting from increased sludge retention times and operating temperatures, is the reduction of surplus sludge generation. The MBR process is well suited for tannery effluents, which generally require long retention times for the effective biological treatment of the less degradable organic pollutants present achieving an effluent quality, which is in many cases far better than the required discharge standard (Scholz 2011).

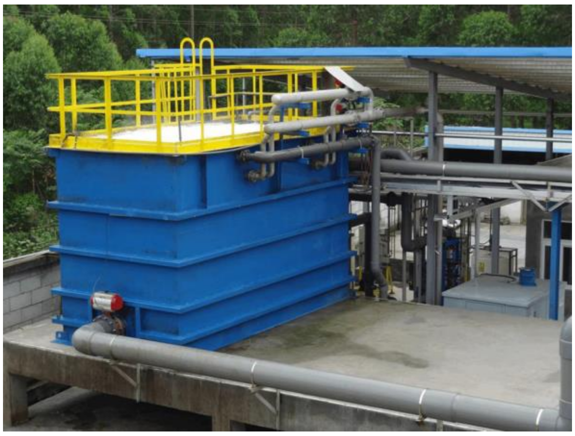

Photo 2: Membrane Bioreactor with submerged membranes of 60m3/hr capacity installed in China

Membrane bioreactor technology is an excellent pre-treatment for Nanofiltration or Reverse Osmosis plants due to the complete elimination of BOD and suspended solids. Small concentrations of BOD after conventional treatment would cause bio-fouling of NF/RO membranes and suspended solids would physically block the spacer of a spiral RO module. The combination of a Nanofiltration plant applied as a polishing step after MBR treatment allows high quality water recycling back into the tannery process. The advantage of this is a reduction of fresh water and effluent costs. The use of consistent high quality process water will also have a positive influence in regards of saving process chemicals and improving the leather quality. The Membrane Bioreactor system achieves 92% COD, 99% BOD removal and a suspended solids free and transparent permeate.

Sludge Handling and Drying

Mixed Primary and secondary sludge have a dry matter content of 6 % and is de-watered using a decanter centrifuge, beltpress or filterpress. The filtercake with 30-40% dryness is further de-watered with a sludge dryer to a dryness of 85 - 90%. The sludge falls through a hopper and is conveyed into the stainless steal chamber of the dryer, where the sludge is macerated and dried with steam-heated screws, which transport the sludge to the outlet of the sludge dryer. A heat exchanger provides for heat recycling from the outlet conveyor back to the inlet, where the sludge is pre-dried. The condensate is collected in steam traps and recycled back to the dryer. The exhaust steam and dust is cleaned in a washing tower.

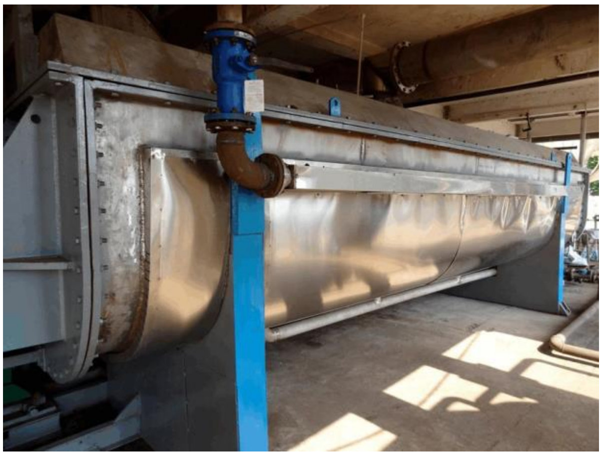

Photo 3: Low cost sludge dryer made in China

Results

Effluent treatment plants implemented in China, Dominican Republic and Norway have shown the following results.

Table 1: Effluent treatment plant performance of a Chinese Tannery processing retan to finishing with average wastewater concentrations of COD, BOD, ammonia and Suspended Solids (June 2012)

Treatme	COD	BO	Ammo	S
Balancin	3150	7	4	13
DAF	2020	2	4	3
MBR	180	20	0.6	1.

The implementation of modern effluent treatment and sludge handling using BAT technology improves significantly the effluent quality, reduces energy costs and reduces significantly sludge disposal volumes and costs. The plant is fully automatic and requires the minimum of supervision.

Conclusions

The combination of jetox venturi aerated Balancing and Dissolved Air Flotation has shown high removal rates of suspended solids of average 98% and COD removal rates of up to 75%.

DAF effluent containing soluble COD is then treated in an anoxic pre-denitrification followed by aerobic treatment which, which removes completely ammonia and reduces total nitrogen to < 5 mg/l.

The activated sludge is then filtered with submerged membranes resulting in a membrane bioreactor permeate with low COD of average 180 mg/l and BOD of < 20 mg/l.

Primary and Biological sludge is mixed in a sludge holding tank, de-watered and then dried in a sludge dryer achieving a reduction of disposable sludge volume by 2/3 with 90% dryness.

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