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Improved Membrane Bio-Reactor (MBR) performance delivers superior effluent quality and major capital savings at Latte Trento Dairy in Italy

Environmental Results	eROI	Economic Results
Plant average flow capacity increased by 47% (15 m^3/hour to 22 m^3/hour) and by 25% for peak flows (from 20 m^3/hour to 25 m^3/hour) eliminating any requirement for MBR plant expansion	asset protection	Preventative impact eliminating €150,000 in capital expenditure projects and €10,000 in annual operational and maintenance costs by delivering enhanced plant capacity
Increase in oxygen transfer efficiency of 18% Membrane permeability increased by up to 600%	earth	Reduction in industrial oxygen demand and associated production and transportation impacts through increased plant operational efficiencies
COD in plant effluent reduced by 30%	water	Overall lower waste treatment costs and increased protection of the local environment and the receiving water course

Introduction

One of the biggest challenges with the MBR process is membrane fouling, which results in higher operational and maintenance costs, and which can seriously impair system performance. This in turn limits the amount of wastewater which can be treated, and can negatively impact effluent quality. Although this problem was alleviated by the invention of submerged-type membrane modules in the late 1980's, today membrane fouling still remains a significant and largely unsolved problem. With respect to the biological process itself, it is not possible to solve this problem by making a conservative design or spending more money on chemical cleaning of the membrane surface. The goal is to give technology to the operator which can ensure a quick and reliable solution.

Various approaches have been tried in order to reduce membrane fouling. These include:

- Intermittent suction
- Back flushing
- Module design improvement
- Optimisation of aeration
- Higher frequency of chemical cleaning

Combinations of these methods have reduced the cost of MBR operation, but additional significant cost reduction can only be achieved through further decreases in membrane fouling.

It has been shown that soluble microbial products (SMPs) and micro particles (< 1µm) are the major contributors to membrane fouling in the MBR process. Therefore the target must be to include especially the very fine SMPs in bigger flocs to reduce membrane fouling.

Fouling is especially troublesome during periods of peak influent flow for all types of MBR system. In addition, in the case of municipal MBR plants, cold weather decreases operating temperatures and increases the production of membrane fouling by Extra Polymer Substances (EPS). This increased EPS causes additional membrane fouling, especially during peak flows. To combat fouling, the frequency of cleaning of the membrane system is usually increased, and if necessary, filtration rate has to be decreased. During severe fouling, the full influent flow cannot be treated properly, and this can have a major impact upon system performance, especially during intermittent episodes of peak flow and operating conditions which place stress on the biomass.

It is not cost-effective to design MBR plants that use additional membranes and ancillary equipment in order to handle these peak flow events which occur for perhaps less than 20% of the annual operating time.

To provide a solution to the problem of membrane fouling, Nalco launched its Membrane Performance Enhancer (MPE) technology in 2004. Since then the technology has been used successfully in over 100 MBR plants. This innovative programme is designed to react with the SMP (colloidal EPS, micro particles) and reduce the frequency of chemical cleaning. The use of MPE technology has consistently shown that membrane fouling is significantly reduced even at higher flows and lower transmembrane pressures. In addition, permeate COD is reduced by ~30% with no negative effect on bio-activity. The oxygen transfer efficiency (α-factor) shows a slight increase (as shown in Figure 1).

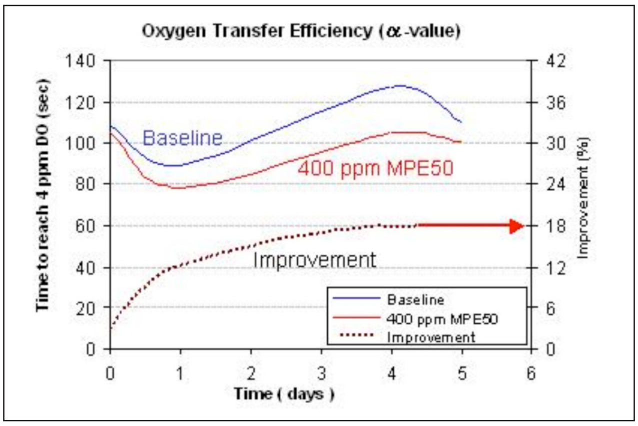

Figure 1 – *Improvement in oxygen transfer efficiency (α-value) achieved by using MPE technology at an MBR plant*

Background

The dairy plant operated by Latte Trento in Italy installed an MBR plant in 2006 to treat effluent from the manufacturing process. This was designed to treat an average flow of 15m³/hour (flux rate approximately 15 l/m² per hour) and a peak flow of about 20 m³/hour. However, in 2009, as a result of increased demand for the company's products, production volumes were increased, generating wastewater flows of up to more than 400 m³/day (average >18m³/hour, peak flows up to 22 m³/hour). The goal of the customer was to be able to operate the MBR plant to continuously treat 22 m³/hour, and to accommodate an intermittent peak flow of 25 m³/hour. Wastewater quality was similar to that found in many other diary plants, including high organic load and high calcium concentration. The high level of aeration required to clean the membrane modules very often resulted in an increase the pH-value of the solution, leading to the precipitation of calcium salts onto the membrane surface. This clogged the membranes still further, necessitating intensive cleaning with acid and sodium-hypochlorite solutions.

Figure 2 – *View of the MBR plant*

Figure 3 – *View of flat sheet membrane modules*

Having established the customer goals (increase in MBR capacity from 15 m³/hour (peak flow 20 m³/hour) up to 22 m³/hour (peak flow 25 m³/hour), two options were reviewed:

Option 1 – Physical expansion of the plant structure

Installation of:

- Additional MBR module
- Additional pipe work
- Replacement of the blower with a larger model
- Installation of larger permeate pumps
- Installation of alternative control systems

The total capital expenditure (CAPEX) was estimated to be €150,000 with an increase in the annual operational costs (OPEX) of €10,000/year. The additional OPEX was attributable to higher replacement costs for the membranes, and increased maintenance and energy costs. This would also increase the environmental footprint and energy-related emissions from the plant.

The enlargement would take a minimum of 2 months to complete. During this period the plant would need to be taken out of use, and wastewater either discharged untreated, or shipped to another treatment plant by tanker. These costs would be in addition to the amounts shown above. Based on the scale of this effort and the consequent disruption to dairy operations, the plant manager wanted to examine the other options.

Option 2 – Optimisation of existing membrane system

For an MBR system, design flow is based in part upon the projected impact of fouling and scaling upon flow rate. In addition, operational conditions are always expected to change due to variations in production activity. This impacts MBR plant performance and can lead to unstable operation and variable efficiency. However, with the MPE technology it is possible to achieve consistently higher average and peak flow conditions without mechanical intervention. At the dairy plant, the incoming organic loading in the wastewater stream was relatively high. As a consequence, the Mixed-Liquor Suspended Solids (MLSS) concentration in the MBR was also high (16,000 – 18,000 mg/l), in order to ensure efficient bio-degradation performance. Figure 1 shows the higher oxygen transfer efficiency required to supply sufficient oxygen in the case where the MLSS concentration is increased due to higher organic load. Before starting a full-scale trial with MPE at the plant, filterability tests were carried out in order to evaluate the relationship between the dosage of MPE and a potential increase in filterability. Figure 4 shows that a 70% increase in filterability/filtration was achieved in bench tests using MPE. One advantage of using MPE technology is the ability to obtain a quick test result. In this case, 70-80% of the sludge was filtered within the first 2.5 minutes of the test.

The reduced filtration time results from the rapid reaction with, and agglomeration of, fine particles. In general very fine particles eventually combine into a compact layer and eventually clog filter paper. Without MPE, filter paper gets clogged very quickly. With MPE technology the very fine particles are combined into bigger flocs, and this results in a higher porosity. As a result of these tests, the customer asked Nalco to conduct a full-scale trial for three months.

Plant data

VBB + VMBR	=	427 m³
MLSS	=	16,000 mg/l to 18,000mg/l (Design 12,000 mg/l)
Design flow	=	15 l/m²/hour (average)
Target flow	=	22 l/m²/hour (average)
Installed membrane	=	960 m² flat sheet membranes
MPE concentration	=	Dosage based upon bench tests then optimised

During the trial several problems were experienced with measurement, the blower and control systems, and intermittent planned shutdowns, such that conditions were not representative of normal plant operation. However operational data showed that the membrane flow increased from ~ 20 l/m²/hour up to 35 l/m²/hour almost immediately, whereas the trans membrane pressure (TMP) decreased to a level which was continuously below 100 mbar. Based on these early results permeability increased by 300%.

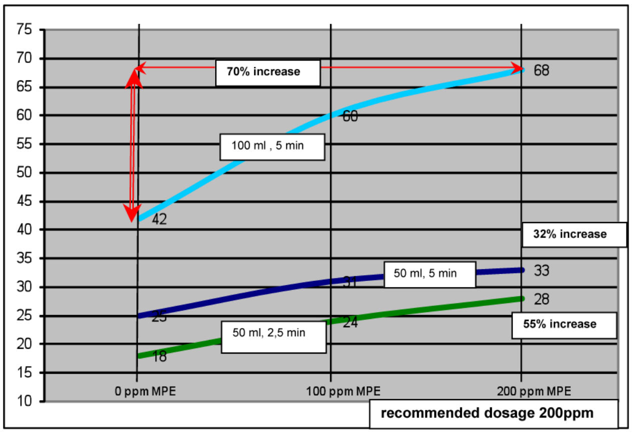

Figure 4 – *Filtration rates with and without MPE50 in filterability tests (performed on site)*

In addition to all these early challenges, excess wasting of surplus sludge reduced the MLSS down to less than 10,000 mg/l, leading to a marked deterioration in sludge quality and an increase in stress on the biological system. Despite this, the MPE technology was still able to ensure stable filtration efficiency, ensuring that the inflow could be adequately treated. The dosage of MPE was varied according to the various changes encountered in system operation. Filtration tests were carried out regularly to optimise the programme performance. After this first trial ended, the plant was operated without MPE, during which a marked deterioration in plant performance was observed.

Operational results

Based on the consistent performance of the programme during the first trial, the customer asked Nalco to conduct a second trial, initially for a further four months. The treatment programme was then re-started, and since then the plant has been treated continuously with the MPE technology and has operated successfully, meeting the goals set for flow enhancement. The conduct of the second trial and its impact on plant performance is shown in Figure 5.

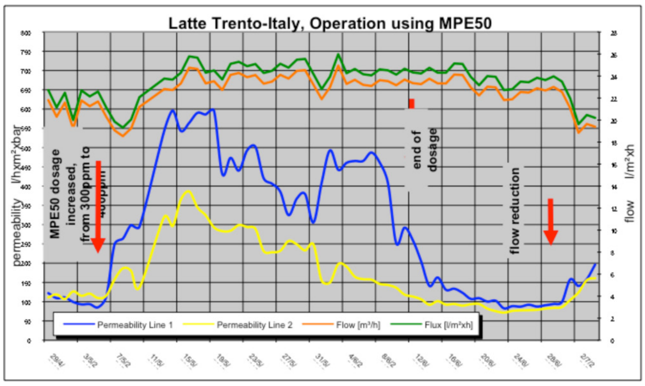

Figure 5 – *MBR performance during the second trial period*

During the application of MPE technology, the COD level in the effluent decreased significantly. This effect has also been seen in other similar cases, where the level of COD in the effluent has been reduced by up to 50%.

The target of 22m³/hour average flow was achieved. During the whole time the permeability was at a high level, between 250 and 600 l/m² x hour x bar. Compared to the operation performance before and after dosing, permeability improved by approximately 200-500%. Based on the dosage of MPE used during the trial, fouling was significantly reduced and the targets achieved. The calcium level in the inlet was approximately 130 – 190 mg/l, yet it was found that calcium precipitation had no significant impact on MBR performance.

(Option 1) was cancelled, avoiding the unnecessary allocation of €150,000 for the capital expense, and a further €10,000 per year in operational costs.

In summary, the following operational parameters were recorded:

- Target for 22 l/m²/hour average flow achieved
- Target for 25 l/m²/hour peak flow achieved
- Permeability increased between 200 – 600 %
- Reduction in COD levels in the effluent by 30%
- Avoidance of €150,000 CAPEX project and €10,000 annualised operational costs
- Reduction in chemical cleaning
- Longer membrane lifetime (expected to increase by 20-40%)

Conclusion

The application of the advanced MPE technology delivered enhanced performance of the existing MBR system. This was significant to the point where goals for increased capacity to meet above-design average and peak flows were met. This eliminated the need for the costly construction and operation of an extended plant footprint, delivering significant savings in capital and operational expenditure, and avoiding the emissions and other environmental impacts associated with plant expansion. In addition significant improvements were made to the quality of the effluent. Overall this improved the sustainability performance of the plant and assured continuity of expanding production demand and profitability for the dairy operation.

Nalco reports Environmental Return on Investment (eROI) values to customers to account for contributions in delivering both environmental performance and financial payback.

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