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Review

Treatment of textile wastewater with membrane bioreactor: A critical review

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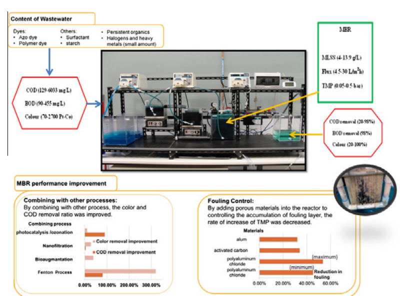
HIGHLIGHTS

- Suitability of MBR for dye wastewater treatment is reviewed.
- MBR is suitable for end-of-pipe treatment compared to other processes.
- MBR combined with MF, UF, NF, MD can assist to recover dyes and reuse treated water.
- When RO is added to MBR, salts can be recovered.
- When FO/RO system is added to MBR, brine discharge from RO can be minimised.

GRAPHICAL ABSTRACT



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ABSTRACT

Membrane bioreactor (MBR) technology has been used widely for various industrial wastewater treatments due to its distinct advantages over conventional bioreactors. Treatment of textile wastewater using MBR has been investigated as a simple, reliable and cost-effective process with a significant removal of contaminants. However, a major drawback in the operation of MBR is membrane fouling, which leads to the decline in permeate flux and therefore requires membrane cleaning. This eventually decreases the lifespan of the membrane. In this paper, the application of aerobic and anaerobic MBR for textile wastewater treatment as well as fouling and control of fouling in MBR processes have been reviewed. It has been found that long sludge retention time increases the degradation of pollutants by allowing slow growing microorganisms to establish but also contributes to membrane fouling. Further research aspects of MBR for textile wastewater treatment are also considered for sustainable operations of the process.

1. Introduction

1.1. Textile industry and its generation of wastewater

Increasing industrialisation has led to severe environmental pollution and it has now become a global issue. It is recorded that more than 100,000 commercially available textile dyes are present in the market and approximately 700,000–1,000,000 tons of dyes are produced while 280,000 tons are discharged (Ali, 2010) via effluents generated from the textile industry to the global environment annually. Thus, textile industry is one of the most significant manufacturing sectors that produce large volumes of highly polluted and toxic wastewater. The World Bank estimates that 17–20% of industrial water pollution is contributed by the textile industry (Kant, 2012). Increasing the discharge of such effluents

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without proper and adequate treatment has impacted the water bodies, soil and ecosystems adversely. The current water usage in the Indian textile industry is around 830 million m^3/year and subsequent wastewater discharge is around 640 million m^3/year; treating this wastewater and discharging into receiving water bodies could cost over a billion dollars every year. This is in addition to the cost involved in the initial treatment of water that is consumed in various processes.

The composition of effluent from the textile factories are quite complex because of the variation in machines, techniques, type of fibres, and chemicals. Textile wastewater is often rich in colour and also of extreme pH with various types of chemicals (persistence and toxic). Due to this reason, many countries have now introduced more stringent discharge standards for textile wastewater.

1.2. Technologies available for textile wastewater treatment

During the past two decades, different treatment technologies have been studied to evaluate the sustainable treatment of textile wastewater. The selection of a suitable type of technology depends on the production process and chemical usage of the textile mill, constituents of effluent, discharge standards and location, capital and operating costs, availability of land area, options of reusing/recycling the treated wastewater and skills and expertise available. In some textile mills effluent generated from different processes can be separated as concentrated (fillings of padders-dyeing/finishing, printing and dye-baths), medium polluted (washing and rinsing) and low/zero polluted (cooling and floor washing) wastewater (Bechtold et al., 2006). This separation of effluents assists in designing efficient treatment processes. However in most cases, effluents generated from different processes are mixed with each other and discharged from the final outlet as composite wastewater.

Treatment technologies for textile wastewater can be divided mainly into three: separation and concentration processes, decomposition and degradation processes and exchange processes (Bechtold et al., 2006). In full scale treatment systems, suitable combinations of these technologies are used to achieve the final discharge or recycle treated water quality standards. In most cases, anaerobic biodegradation is incorporated (*as a pretreatment technique*) in the treatment of high strength effluents such as textile wastewater. While aerobic processes consume energy (1 kWh/kg of BOD degraded), anaerobic processes yield 0.5 to 1.5 kWh/kg of BOD degraded and comparatively produce less volume of waste-sludge than aerobic processes. In general, installation of anaerobic reactors/digesters is expensive but they can absorb higher shock loads in addition to the advantages mentioned above.

The research in this area is still being actively conducted due to the lack of information and data available to design and establish a suitable full-scale treatment technology which would be applicable for different textile manufacturing processes. Membrane bioreactor (MBR) technology has shown a superior performance in the treatment and operation of domestic and a wide spectrum of industrial wastewaters (including wastewater containing micropollutants) compared to other conventional treatment technologies (Lin et al., 2012). An analysis using Web of Science (retrieved on the 10th November 2015) indicates that there are 2041 research articles available on textile wastewater treatment from 1996 to 2015 with 56,379 citations. However, when filtered using the keyword "Membrane Bioreactor", those number of articles subsided to 43 with 537 citations (the above data included herein are derived from the Web of Science® prepared by Thomson Reuters Scientific, Inc. (Thomson®), Philadelphia, Pennsylvania, USA: © Copyright THOMSON REUTERS® 2015. All rights reserved). The articles were mostly specific to certain types of dyes or MBRs and some were comparisons between two processes rather than reviews. Thus, the potential of MBR to treat textile wastewater has not been explored fully. Therefore, this review focuses on the perspectives of textile wastewater treatment using MBR systems under different conditions.

2. MBR for the treatment of textile wastewater

MBR is a hybrid process which has two interdependent treatment processes; biological treatment and membrane filtration. MBR has become an attractive wastewater treatment technology which produces very high quality recyclable treated water. MBR process delivers several advantages such as small footprint, low maintenance, consistency in final treated water quality independent of sludge conditions in the bioreactor, lower sludge production, and higher removal of nutrients, organic and persistent organic pollutants (POP) over conventional activated sludge processes. However, fouling of membrane is the main drawback of MBR process (Chang et al., 2002) as it leads to decline in the permeate flux or increase in the trans-membrane pressure (TMP) with processing time, resulting in higher operating costs for membrane cleaning and eventually decreases the life span of membranes. The composition of wastewater and biomass grown in the MBR are directly related to fouling. MBR fouling can occur due to organic fouling, inorganic fouling, particulate fouling, bio-fouling, as well as combinations of those fouling. However, bio-fouling generally occurs over a long period of operation and inorganic fouling mainly occurs in high pressure membranes (nano-filtration and reverse osmosis). Therefore, this review highlights the mechanism of organic fouling of MBR and possible fouling control strategies during the treatment of textile wastewater.

The objective of this review is to collate the results, data and information from research studies conducted in the recent past on the treatment of textile wastewater using MBR technologies. The results will be critically compared and analysed to establish some important recommendations and conclusions. This review therefore would be a useful source to obtain important design information to construct/install pilot and full scale MBR treatment systems for textile processing plants.

2.1. Organic fouling in MBR

Organic fouling in MBRs refers to the deposition of organic molecules onto the membrane and these organics are generally forming a colloidal layer on the membrane surface. A Study has found that MBR fouling can largely attribute to extracellular polymeric substances (EPS) (Rosenberger and Kraume, 2002). In the biological process, EPS are released by microbes during substrate metabolism, biomass growth and biomass decay (Jarusutthirak and Amy, 2006). However, Liu and Fang (2003) noted a different observation during MBR operation where EPS matrix in wastewater played an important role in the hydrophobic interaction among microbial cells and in the floc formation. This indicates that a low concentration of EPS in feed water might have negative impact on its performance for floc deterioration. Hence, a minimum level of EPS should be present in the wastewater for sustainable performance of MBR process. In addition, Rosenberger et al. (2006) found that organic substances caused increase in sludge viscosity and thus increase in filtration resistance is attributed to the attachment of EPS onto the membrane surface.

EPS are generally categorised into two types namely bound and soluble EPS. Bound EPS consists of capsules, sheaths, loosely bound polymers and attached organic materials and soluble EPS are referred to soluble microbial products (SMPs) which mainly consists of low to high molecular weight (MW) proteins, protein-like