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Report on research literature related to Moving Bed Biofilm Reactor wastewater treatment

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for Barwon Water

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**Introduction**

This report is an investigation of the research literature on Moving Bed Biofilm Reactor (MBBR) wastewater treatment, in particular examining the available literature relating to retrofitting MBBR technology to existing treatment plants and the operating costs of MBBR plants. A primary literature review was conducted using relevant online research databases, and the references listed in the first round of discovered documents were also examined to identify any other useful literature.

This report presents:
- a literature review based on the discovered relevant documents;
- a summary of the main findings; and
- a list of references.

The research literature on the topic of interest was found to be relatively limited. Apart from the research literature documented here, there is large amount of commercial/promotional literature (the independence of which is hard to verify), a significant amount of historical literature relating to the development of the MBBR process, and a significant amount of literature describing the application and optimisation of MBBR systems to various specific waste stream treatment applications. Some of this additional literature is identified in the references listed in the documents reviewed.
Literature review

Andreottola et al. (2003) present an experimental study to evaluate the application of an MBBR system for the upgrading of an overloaded municipal wastewater treatment plant (MWWTP). The MBBR solution was considered to offer several advantages including good potential in nitrification process, easiness of management and the possibility to use the existing tank with very few modifications. A pilot-scale experiment was undertaken to develop the design parameters for the full-scale upgrade. The final configuration was a two-stage MBBR system. The upgraded was able to handle a 60% increase in flow rate with good performance. (Andreottola et al., 2003)

Rodgers & Zhan (2003) present a review of four types of moving medium biofilm reactors for the treatment of wastewater. Their review is based on published case studies and covers:
1. the rotating biological contactor (RBC);
2. the moving bed biofilm reactor (MBBR);
3. the vertically moving biofilm reactor (VMBR); and
4. the fluidized-bed reactor (FBR).
They conclude that the MBBR is a good process for upgrading existing wastewater treatment systems. (Rodgers & Zhan, 2003)

Weiss et al. (2005) present an evaluation of the use of an MBBR system for the enhancement of nitrogen removal in a secondary treatment wastewater plant. They conclude that the MBBR process is capable of achieving desired nitrogen removal requirements in a smaller overall bioreactor volume. However, the advantages of the MBBR system have to be weighed up against the capital cost of purchasing the proprietary MBBR attached growth media and the increased energy costs for the aeration. (Weiss, Alvarez, Tang, Horvath & Stahl, 2005)

Verma et al. (2006) present a survey of aerobic bio-filtration processes for wastewater treatment. They assess a range of conventional and advanced bio-filtration systems, including MBBR systems. They conclude that the MBBR process is a good one for upgrading existing wastewater treatment systems. However, they note that for fluidised systems generally (including MBBR systems), while capital costs are comparatively low, operating costs are higher due to pumping/aeration requirements. (Verma, Brar, Blais, Tyagi & Surampalli, 2006)

Brinkley, Johnson & Souza (2007) note that many existing wastewater treatment facilities are being upgraded to cater for increased effluent flows, and that many such existing facilities have constraints on space for expansion. They identify MBBR as one wastewater treatment technology that has been developed which addresses both of these issues. They suggest that MBBR systems provide more treatment capacity within a given reactor volume compared to a conventional activated sludge (AS) process. They present a case study of a full-scale MBBR system that was installed on a space-constrained site to treat a planned increase in wastewater from a pharmaceutical production facility. They state that the MBBR system was the most cost-and space-effective treatment solution. The MBBR system is smaller than the existing aeration basin and can treat wastewater with a significantly higher organic load. They expect good performance from the MBBR system and less operator invention than the original AS process. They conclude that the MBBR process is ideal for expanding or upgrading existing treatment plants that have space constraints. (Brinkley, Johnson & Souza, 2007)
Falletti & Conte (2007) present a pilot-scale performance comparison of an AS treatment process and the same plant after the aerated tank was converted to an MBBR format. Following excellent results in the pilot phase, a full-scale AS wastewater treatment plant was converted to MBBR operation. The existing plant had been designed to service 3000 PE (person equivalent), but over time the waste stream had grown to 5800 PE, causing the system to be overloaded. Following successful operation of the converted plant, they conclude that MBBR is a suitable technology for upgrading overloaded AS plants without building new tanks. They report that the conversion of existing tanks to MBBR format can be done quickly, and that the main capital cost is related to the purchase of the proprietary MBBR attached-growth media. They note that no cleaning or replacement of the media growth media is required in normal operation, and that the excess sludge produced is similar to that from conventional AS plants. They observe that the aeration requirement for MBBR systems is somewhat higher than for an AS tank of the same volume, and that this contributes to higher operating costs, but that this is offset by the higher treatment flow rate possible with an MBBR system, and that automatic control of aeration based on pollutant concentration can optimise aeration costs. They make other observations about the practical operation of MBBR plants, and recommend that a pilot-scale test be performed to identify the optimal design parameters for a particular application. (Falletti & Conte, 2007)

Hait & Mazumder (2008) identify the growing need to construct new wastewater treatment facilities, or to upgrade the capacity and/or performance of existing facilities, to treat increased effluent loads and/or to meet more stringent environmental requirements. They indicate that the conventional strategy of constructing additional treatment basins is technically sound, but expensive. They note the development of hybrid technologies that supplement the AS process with highly porous suspended support media (including MBBR systems), and that these systems offer the potential for realising the same waste water treatment objectives as conventional plant expansion, but at significantly lower capital cost. They cite a number of case studies documenting a range hybrid treatment systems. They conclude that hybrid treatment processes are well suited to retrofitting and upgrading existing facilities to meet increased effluent treatment requirements. They note that hybrid treatment processes have been adopted into existing plants with minimal interruption to operations, and have successfully extended the asset life of existing facilities. (Hait & Mazumder, 2008)

Di Trapani et al. (2010) present a pilot-scale comparison between a conventional AS treatment system and a MBBR treatment system. The aerobic reactor in both systems was the same size. The MBBR system was able to treat twice as much waste water as the AS system while maintaining similar performance in organic and nitrogen removal. They conclude that the higher treatment capacity of the MBBR system demonstrates that it is an effective technology for the upgrading of overloaded wastewater treatment plants. (Di Trapani, Mannina, Torregrossa & Viviani, 2010)

McQuarrie & Boltz (2011) provide an up-to-date overview of MBBR process design considerations. They observe that MBBR systems can be used for a wide range of waste water treatment applications, and that they offer a range of benefits, including similar treatment performance as AS systems, and being a continuous flow process that does not require a special operational cycle. (McQuarrie & Boltz, 2011)

Barjenbruch & Exner (2012) report on a 14 month evaluation project conducted by the Berlin Centre of Competence for Water (Kompetenzzentrum Wasser Berlin) to compare 12 different pilot-scale wastewater treatment plants – the COMPAS project. The aim of the
The project was to fill a perceived lack of information about performance, operation reliability and maintainability of the different types of small wastewater treatment plant (SWWTP) under real operating conditions. The 12 types of SWWTP evaluated included:

1. combination rotating disc and activated sludge
2. moving bed
3. rotating disc
4. trickling filter
5. trickling filter (textile material)
6. submerged bed
7. bed filter
8. constructed wetlands
9. filter with coconut material
10. membrane bioreactor
11. sequencing batch reactor I
12. sequencing batch reactor II with control panel

The test program for all treatment plants was in accordance with the European Standard EN 12566-3 (Small wastewater treatment systems for up to 50 PE–Part 3: Packaged and/or site assembled domestic wastewater treatment plants), and includes a predefined sequence of varying operating conditions over a period of 56 weeks. Because of the volume of test data generated by the trial, this paper generally reports only summary results, but the relative performance of the moving bed treatment plant was good, and it was reported as recording the lowest mean total maintenance time of all the treatment plants tested. (Barjenbruch & Exner, 2012)

The full report on the COMPAS project does not appear to be publicly available, but an extended summary of the test results is available – see: Kompetenzzentrum Wasser Berlin (2010). This extended summary report provides detailed operational performance data for all 12 wastewater treatment plants included in the trial, including energy consumption. Based on kWh/(PE.a), a wide range of energy consumption was reported across the 12 plants, with the moving bed plant performance being mid-range. (Kompetenzzentrum Wasser Berlin, 2010).
Summary findings

MBBR systems are reported in the research literature as having a range of desirable characteristics, including:

- good pollutant removal performance;
- being suitable for a wide range of effluent sources and types;
- ease of management – good stability and no sequencing;
- can be retrofitted relatively easily into existing tanks to extend asset life and performance;
- requiring a smaller tank volume compared to AS systems for the same treatment flow rate;
- higher effluent treatment flow rates compared to similar capacity AS plants; and
- lower capital cost compared to an AS plant with similar performance characteristics.

Particular capital costs of MBBR systems include the purchase of proprietary attached growth media, which may be offset against the typically reduced overall cost for the smaller plant size required compared to traditional treatment plant technology.

MBBR systems generally have an increased energy requirement for aeration on a tank unit volume basis, which may be offset against the typically smaller tank unit volume required for the same flow rate of effluent treatment compared to traditional treatment plant technology.

Many authors identify MBBR technology as appropriate for upgrading the performance and/or treatment capacity of existing plants, particular if plant expansion is constrained by space limitations.

Many authors recommend the use of a pilot-scale evaluation to determine suitable design and operating parameters for full-scale plant developments.
References


