The use of wood-polymer composites in a Moving Bed Biofilm Reactor Technology (*Rapid Communication*)

Izabela Kruszelnicka[1),*)], Dobrochna Ginter-Kramarczyk[1)], Michał Michałkiewicz[1)], Stanisław Zajchowski[2)], Arkadiusz Kloziński[3)], Jolanta Tomaszewska[2)]

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Abstract: Moving Bed Biofilm Reactor (MBBR) systems are increasingly used for municipal and industrial wastewater treatment. Innovative wastewater treatment technologies are developed to respond to changing regulatory requirements, increase efficiency, and enhance sustainability or to reduce capital or operating costs. Extensive research on how to use new materials in a moving bed technology is currently being carried out. An interesting solution in this area due to the large active surface (above 1200 m^2/m^3) for biofilm is employment of wood-polymer composites (WPC). The elements of moving bed made of WPC may be an interesting option for treatment plants that are difficult to access, where the applied technology should be characterized by flexibility that is the ability to adapt the technology to the changing sewage flow, so as not to worsen the quality of treated wastewater.

Keywords: wood-polymer composites, WPC, composites in the moving bed biofilm reactor technology, MBBR, industrial wastewater, biological treatment.

Wykorzystanie kompozytów polimerowo-drzewnych w technologii złoża ruchomego

Streszczenie: Innowacyjna technologia złoża ruchomego (MBBR), stosowana do oczyszczania ścieków, została opracowana w odpowiedzi na zmieniające się wymogi prawne oraz w celu zwiększenia wydajności i stabilności procesu oczyszczania, a także zmniejszenia kosztów eksploatacji. Obecnie prowadzone są badania nad wykorzystaniem nowych materiałów w technologii złoża ruchomego. Interesujące rozwiązanie, ze względu na dużą powierzchnię czynną dla błony biologicznej (powyżej 1200 m^2/m^3), mogą stanowić kompozyty polimerowo-drzewne (WPC). Opracowana technologia, wykorzystująca kompozyty na bazie PE-HD lub PP napełnianych mączką drzewną lub włóknami drzewnymi, charakteryzuje się elastycznością w dostosowywaniu do zmiennego natężenia dopływających ścieków, bez pogorszenia jakości oczyszczonego strumienia.

Słowa kluczowe: kompozyty polimerowo-drzewne, WPC, technologia złoża ruchomego, kompozyty w technologii MBBR, technologie oczyszczania ścieków, oczyszczanie biologiczne.

The article deals with the use of polymeric materials in the technology of suspended moving bed bioreactors (MBBR), which are currently used as one of the effective methods of wastewater treatment. The advantages of the use of polymeric materials, principles of operation and technical solutions which function are use in the type of reactors will be presented. Our preliminary research of the innovative use of wood-polymer composites (WPC) as a moving bed in MBBR will also be described.

The Moving Bed Biofilm Reactor (MBBR) is used in wastewater treatment processes such as nitrification, denitrification and BOD-removal. The Moving Bed Biofilm Reactor (MBBR) was constructed in the mid-eighties by Professor Hallvard Ødegaard's basic research at the Norwegian University of Science and Technology and was further developed by a small Norwegian company, Kaldnes Miljøteknologi (now AnoxKaldnes AS) with financial support from the Norwegian government (Royal Norwegian Council for Scientific and Industrial Research) [1]. It was initially oriented to obtain nitrification and nitrogen removal from cold wastewater on constrained sites. The first MBBR was installed at Steinsholt, in Norway in 1989. Although it is a relatively new technology in the United

1) Poznan University of Technology, Faculty of Civil and Environmental Engineering, Department of Water Supply and Environmental Protection, Piotrowo 3A, 60-965 Poznań.

2) University of Technology and Life Sciences in Bydgoszcz, Faculty of Chemical Technology and Engineering, Department of Polymer Technology, Seminaryjna 3, 82-326 Bydgoszcz.

3) Poznan University of Technology, Institute of Chemical Technology and Engineering, Department of Polymers, M. Skłodowskiej-Curie 2, 60-965 Poznań.

*) Author for correspondence; e-mail: izabela.kruszelnicka@put.poznan.pl

States (first introduced in 1995), there are now over 500 installations worldwide in both the municipal and industrial sectors with over 36 in North America [2—4].

The MBBR process uses small plastic carrier elements to provide sites for bacteria attachment in a suspended growth medium. The carrier elements allow a higher biomass concentration to be maintained in the reactor compared to a suspended growth process, such as activated sludge. This increases the biological treatment capacity for a given reactor volume. The carrier elements can be installed in either an anoxic reactor or an aeration basin. In aerobic processes the biofilm carriers are kept in suspension by the agitation created by air from aeration diffusers, while in anoxic processes a mixer keeps the carriers in movement. A schema of the principle in an implementation of the MBBR technology is shown below (Fig. 1).

Fig. 2. High Performance Carrier Elements for MBBR [5]

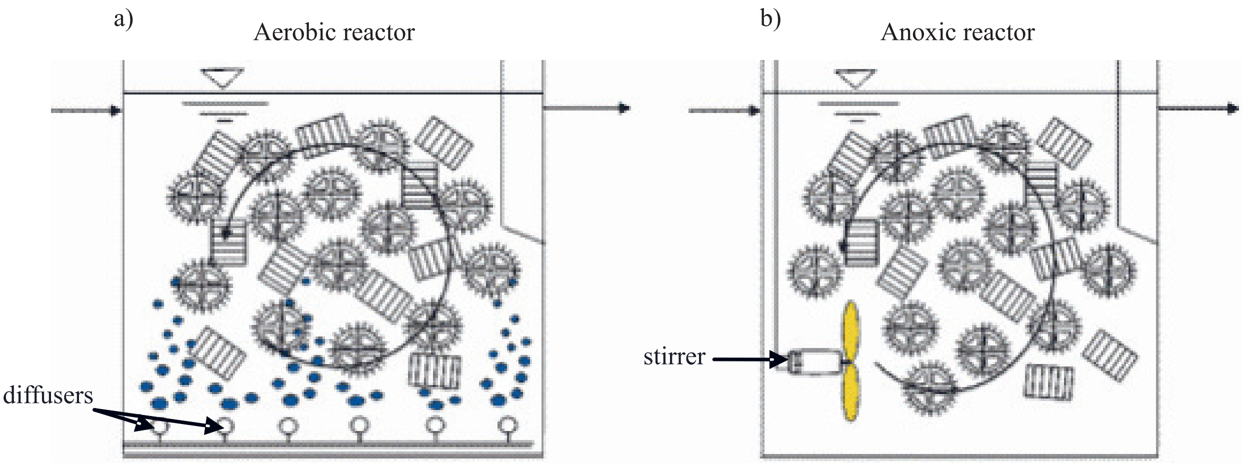

Fig. 1. Scheme showing the principle of MBBR [5]

A large surface area of the plastics provides abundant surface for bacterial growth. Biomass grows on the surface as a thin film whose thickness usually varies between 50 and 300 mm. There are several different sizes and designs of carrier elements used in the MBBR process. These carriers are cylinders constructed of high density polyethylene (PE-HD) or polypropylene (PP) [5, 6]. The carrier elements have a specific gravity of 0,96 g/m^3 and provide an effective surface area for biofilm growth of 500 to 1200 m^2/m^3 [5—7]. Biofilms primarily develop on the protected surface inside of the plastic biofilm carrier [8]. The free-moving carriers rotate freely within these bioreactors (Fig. 2).

MBBR technology has become the preferred biological treatment technology because it offers several advantages over the traditional Activated Sludge Process, the most popular technology [9]. Also, because of its lower costs and high treatment quality, MBBR technology is preferred to Membrane Bio Reactor (MBR) technology in most cases. The MBBR technology application in reactors with high BOD load gives tangible result. The MBBR reactor removes 60—80 % of BOD and significantly reduces the load to downstream activated sludge process, resulting in a very efficient treatment with a lower footprint. Some of the key features of MBBR process are provided below:

— Robust — it is stable under load variations, insensitive to temporary limitation and provides uniform treatment results;

— Efficient — it generates low amount of solids and requires no or minimum polymer for solid/liquid separation;

— Compact — it requires a small footprint. Typically it requires 1/3rd of the space required for Activated Sludge Process;

— Cost – it requires a low capital cost and is comparable to cost of Activated Sludge Process. It is cheaper than the MBR process;

— Flexible – existing plants can be upgraded easily with MBBR. New MBBR plants can be upgraded to handle higher loads with no or minimum cost and construction [2—8].

APPLICATION OF MBBR TECHNOLOGY

The MBBR technology has been successfully used for treatment of many industrial effluents, including pulp and paper industry waste, poultry processing wastewater, cheese factory wastes, refinery and slaughter house wastes, phenolic wastewater, dairy wastewater and municipal wastewater. Moreover, a sequencing batch operation of MBBR has been attempted for biological phosphorus removal [7—9].

INNOVATIVE MATERIALS IN THE MBBR TECHNOLOGY AND THEIR EXPECTED IMPACT

The aim of the current research is to investigate the possibility of using molded wood-polymer composites (WPC) [10—12] as a moving bed MBBR (Moving Bed Biofilm Reactors) support. In the literature review there are no reports on the use of WPC as filling in the moving bed technology, therefore, the following objectives of the presented research project seemed to be appropriate. The accomplishment of the research will allow to examine and ultimately obtain the polymer-wood composite [10—15]. That will be used to manufacture elements of the moving bed with a large active surface area (over 1200 m^2/m^3). These elements will be the substrate for a biofilm, while providing optimal conditions for life for the diverse cultures of microorganisms.

WPC material can be used to make carriers of various shapes including spheres, rosettes, and cylindrical forms. The elements can be produced using polypropylene, polyethylene and poly(vinyl chloride) filled with wood flour in varying amounts from 20 to 70 %. The filler used to prepare the WPC is present in different forms: splinters and chips. It comes from conifers (pine, spruce) and deciduous trees (oak, maple). Particles or fibers having a length from 0.05 mm to 3.0 mm and a thickness of at least 0.03 mm are obtained in the result of wood crumbling. The filler can come from waste generated during the felling of coniferous and deciduous trees or their subsequent treatment (after sawmilling waste) postconsumer waste wood, such as furniture, pallets, and even chipped MDF may also be used [12—15].

There is ongoing interdisciplinary research by combined teams of the Faculties of Civil and Environmental Engineering and Chemical Technology, University of Technology and the Faculty of Technology and Chemical Engineering, UTLS Bydgoszcz, which is aimed at predicting the optimal composition of the polymer composite for the use as a moving bed in a bioreactor.

In preliminary studies, commercial polypropylene (PP Moplen HP648T) Basell Orlen Polyolefins was used as a matrix for polymer-wood composites. The second component (filler) of the composites was sawdust. There were used two types of sawdust from J. Rettenmeier & Söhne GmbH Co KG Germany, originating from conifers: Lignocel type C120 and L9, with particle size of 0.07 mm — 0.15 mm and 0.8 mm — 1.1 mm, respectively. Homogenization of polypropylene with wood flours was carried out in single screw extrusion process, the composite pellets were obtained with the filler content of 30 and 40 wt %. The samples for testing in the form of standard dumbbells, according to EN ISO 527-2 (dumbbell of type 1A), were prepared by injection molding. The composite dumbbells were suspended in the aeration chamber bioreactor with known technical and technological parameters. Every two months some samples were taken (dumbbells) for microbiological and endurance tests. Microbiological tests were to evaluate the quantity and quality of the microorganisms that resided in the composite beds and the reference of the obtained results to the biofilms formed on a bed made of a conventional material (polypropylene dumbbells). The strength tests, carried out under static tension, were conducted to determine the effects of prolonged exposure of the activated sludge on mechanical properties of the composites (strength, elongation, Young's modulus).

The studies revealed that there is a close correlation between the type of the used filler (wood flour), and its amount and the impact of the activated sludge on the properties of the tested samples. In each case considered, a higher Young's modulus with a period of stay in the bioreactor of 24 months was obtained for WPC samples with respect to the pure polypropylene. Given the qualitative and quantitative analysis of biofilms formed on the composite fittings and those made of unfilled polypropylene, numerous agglomerates of microorganisms were forming on WPC fittings with both L9 and C120 flour, in contrast to the molded polypropylene. The most frequently observed were ciliates (*Ciliata*) and rotifers (*Rotifera*) and amoeboid (*Amoebozoa*). The studies have also shown a direct effect of the composition of WPC (the amount of filler, the filler particles' size) on the quality of the produced biofilm.

SUMMARY

On the basis of the study it can be concluded that the advantage of the proposed solution is a significant increase in the density of microorganisms population in the reactor on the surface of filling and reducing vulnerability of the living population to adverse environmental conditions. Specific conditions for the growth of bacteria (and other microorganisms) will ensure that more contaminants in a day will be removed than in conventional activated sludge wastewater treatment plants, in which the typical moldings of pure polymeric materials are used.

The moving biological bed technology with WPC can be used in municipal and industrial sewage treatment plants. It could be also applied to pretreatment plant in order to relieve the existing treatment plant or to a final cleaning of the wastewater discharged from treatment plant, especially in case of increasing of the quality requirements. The proposed material, due to its properties, will also be suitable for use in home sewage treatment plants, and it will perform particularly well in areas with poorly developed infrastructure (in rural and mountain areas). This solution will allow a very high reduction of biogenic compounds. On the other hand, a major advantage of the described technology will be a high resistance to fluctuations in the flow of waste water, resistance to a variable external temperature (both high and low), and a small area (footprint) required for installation of the biological bed. Reactivation and modernization of many wastewater treatment plants with the use of the bed based on the moldings of polymer-wood composites will be much cheaper than construction of new facilities.

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