APPLICATION OF NANOFIBRES FOR BIOLOGICAL TREATMENT OF INDUSTRIAL WASTEWATERS *

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Introduction

Nanofibers are prepared using the method of electrospinning called "Nanospider", when fibers are formed by the effect of electrostatic field from a thin layer of a polymer solution and are put on a collector in the form of unwoven textile. Common fibres prepared by this method have diameter between 200-500 nm. They have a number of extraordinary properties such as a large specific fibre surface, big porosity of the fibre layer and small pore diameter. These characteristics play crucial role in the formation of natural biofilm, especially in the first stages of immobilization. Nanofibers offer a innovative solution for wastewater treatment using biofilm as a tool for retention of slowly growing microorganism in bioreactor. These slow-growing microorganisms are essential in some cases of industrial wastewater treatment where the content of inherent compound leads to use of specially selected microorganism or where the composition of wastewater strongly influence the growing rate of common biomass (high salinity, toxic compounds or extreme temperatures). The core of the technology lies in the immobilisation of slowly growing microorganisms in natural biofilm which is easily created in structure of nanofibres layer, consequently on their surface. The immobilisation of bacteria inside the porous matrix of biofilm also enhances robustness of the immobilised biomass towards chemical shocks and other negative environmental effects. This application has proven its efficiency for the case of removal of aniline, diphenylguanidine (DPG), phenylurea and cyanides (hundreds of ppm) from industrial wastewater generated by DPG production (vulcanization agent in process of tires manufacturing). The carrier was prepared as a polyester thread which was covered by a layer of polyurethane nanofibres. The stability of this layer was bonded by another fixation yarn. Developed type of threads can be processed in subsequent common textile technologies for creation of woven or weaved textiles. Evaluation of this type of biomass carrier was realised in long-term comparative experimental study where nanofibre-based carrier was compared with commercial carrier developed by AnoxKaldnes. AnoxKaldnes technology was chosen due to their proven successful full-scale application for treatment of wastewaters from DPG production.

Experimental

Materials and Methods

Bioreactors were simulated using a continuous completely mixed glass reactor with a working volume of 2 litres. Contaminated water and the selected microorganisms were mixed in the reactors. Flow of waste water was implemented through flow peristaltic pumps. In all bioreactors was the same bacterial population, a microorganism of the genus *Rhodococcus*. These bacteria were proved to be able to adapt to chemical stress and physiological conditions. They are able to produce a natural biofilm, which allows a much higher resistance to pollutants. Oxygen was fed through the aeration device placed on the bottom of reactor. The aeration device also ensures uniform mixing of reactor, thanks to medium-sized bubbles. The air-conditioned room was used for conditions setup. One of bioreactors was filled with commercial plastic carrier AnoxKaldnes K3, in the form of "rings". The second reactor was filled with an experimentally developed nanofiber carrier spherical shape, which was covered with an incoherent layer of nanofibers, called "Nano-knob." Each type of carriers was inserted into the separate reactor in amounted to 30% of its volume, which correspond to the real deployment of wastewater treatment plants. These first two reactors were implemented as a fluidized bed. The third reactor was built as a fixed bed. The nanofiber covered threads were wound on the metal grid. The grids are fixed to each other, to ensure uniform conditions for all threads. In this case, was an effort to determine the optimal size of nano-layer on surface that would be best for maximum growth of microorganisms. Three forms of nano-surface and one without nano-layer were used.

Experimental Setup

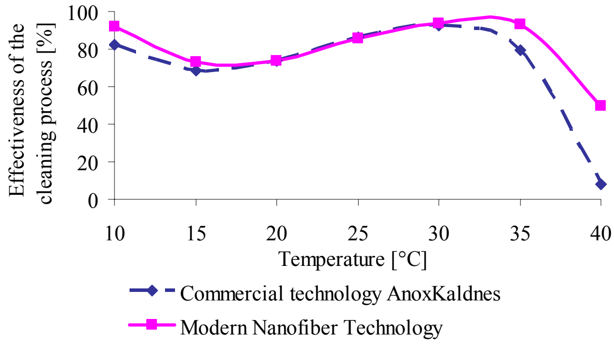
The basis of this work was to reproduce the conditions of real application (technological parameters of biological wastewater treatment plant with AnoxKaldnes). Furthermore, these conditions realize in laboratory experiment and determine the limit conditions (e.g. minimum retention time, maximum temperature), while maintaining efficiency of the

* This result is realized under the state subsidy of the Czech Republic within the research and development project "Advanced Remediation Technologies and Processes Center" 1M0554 - Programme of Research Centers PP2-DP01 supported by Ministry of Education.

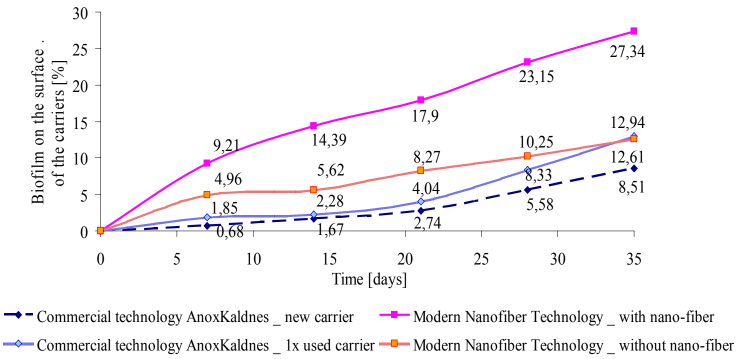
process. The system was undergoing through the stressful situations and was verifying by its response (whether the micro-organisms can adapt to severe conditions). The aim was to confirm the suitability of the nanofiber carriers (theirs stability, the ability to colonize them, regeneration capacity, and others).
Reactors were operated on the principle of continuous cultivation. Bacterial suspension was taken from the chemical-biological wastewater treatment plant Lučební závody Draslovka a.s. Kolín (for this company was originally adapted by AQUATEST). Initially the flow rate was set for optimal growth of microorganisms (retention time 10 days). With time the flow rate increases to the highest possible (retention time 2 days).

Results and discussion

The effectiveness of technology based on nanofibers was slightly higher compared to commercial technologies, an average of 10 % to 42 % (in the long-term, depending on temperature and other conditions). These results show higher resistance of immobilized microorganisms on surface of nano-layers. Nanofiber technology allows faster creation of microbial biofilm and so reduction of the cultivation time in the first phase of biofilm forming.
The minimum tested temperature was 10 °C, this temperature had not caused any major problems (process efficiency of commercial technology was 82%, efficiency of nanofiber technology was 92%, and retention time was 48 hours). The maximum recommended temperature at which the reactor can still operate is 40 °C (process efficiency of commercial technology was only 9%, efficiency of nanofiber technology was 50%, and retention time was 64 hours). Thanks to laboratory experiment has been shown that the microbial biofilm on the nanofiber carrier takes over the function of degradation processes, for the immobilized bacteria of commercial technology at the same stage of growth does not apply it. The slightly lower suspension growth in presence of nanofiber carrier confirmed the better incorporation and colonization of this carrier and higher activity of microorganisms bound to the carrier. To assess the development of immobilized microbial population (biofilm) is used determining of dry residue (on the carrier). The complete (steady state) colonization of the commercial carrier (AnoxKaldnes) was determined by 362 days, for nanofiber technology was it already in 167 days. These results confirm the much faster colonization of nanofibrous layers (up to twice faster), especially in the early stages of colonization.
Another way to determine the state of microorganisms on the carrier's surface (biofilm) was the microscopic observations and subsequent image analysis. This monitoring was performed during the first month in the reactors. The biomass will stain the surface in darker shades, so it can by use the image analysis. It is a nondestructive method of carrier and biomass as well. They can be again put back into the reactors.



The bacterial biofilm attach the surface very slowly, for the commercial carrier AnoxKaldnes (which is caused by lack of adhesion to the surface). For the nanofiber carrier, micro-organism sit down directly on the nano-layer. The presence of these layers is a necessary for rapid colonization. Incorporation of biofilm to nano-carriers is more than six times faster than with use of commercial technology AnoxKaldnes (for the same carrier but without the nano-layer twice faster as the commercial technology). The microorganisms replicate mainly places with nano-layer. They are growing outside the area and fill the rest space on the carrier with time. All samples were measured six times in same time for the same carrier, in graphs are given the average values.



Conclusion

The long-term comparative experimental study evaluate new type on nanofibre-based carrier of biomass with the real industrial wastewaters. The comparison was carried out for the wide range of possible operational conditions. Nanofibre-based carrier is fully comparable with commercial type, in addition allows faster biofilm forming especially in the first stages of immobilization. This advantage is important in the case of industrial wastewater treatment, where the potential of biostatic or toxic effects and subsequent needs of regeneration is high.

References

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