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ORGANIC MATTER REMOVAL FROM MEAT PROCESSING WASTEWATER USING MOVING BED BIOFILM REACTORS**

Conventional, biological wastewater treatment technologies with suspended biomass have several drawbacks, and this is why new, efficient technologies should be developed and implemented. Moving bed biofilm reactors (MBBRs) guarantee a close contact of the biomass with the substrate, which leads to their high capacity and efficiency. This paper presents the results obtained in testing the MBBR process for removal of organic matter from meat processing wastewater. The experiments were performed in three laboratory-scale moving bed biofilm reactors connected in series, using meat processing plant wastewater taken from the outlet of the Imhoff settler. The tests showed that in the first reactor, which worked under high loads, with the HRT of about 4 hours and COD loading to 10 kg/m^3, the removal of organic matter ranged from 50 to 75% of TCOD. In two reactors connected in series, the organic matter removal reached 64–75% of TCOD and 70–88% of SCOD, with total HRT from 4 to 13 hours. Organic matter removal proved to be almost a linear function of organic load for all the loads tested. The Kaldnes process being stable and competitive under conditions of high loads can be applied to organic matter removal from meat processing wastewater.

1. INTRODUCTION

Conventional biological technologies with suspended biomass have several negative aspects and this is why new and efficient technologies should be developed. Implementing technologies and processes, which can improve wastewater treatment, is especially important in rural areas, where there is a necessity to establish small, but highly compact and efficient plants. Moving bed biofilm reactors (MBBRs) would be competitive in this case [6], [7] because of a close contact of the biomass with the substrate which leads to their high capacity and efficiency. Other advantages of these reactors are as follows: high biomass concentration, improved phase mixing, better oxygen transfer and better phase separation [2], [9]. These advantages could be fully used for treating wastewater with high concentration of organic matter. This paper presents the results obtained in testing the MBBR process for removal of organic matter from meat processing wastewater.

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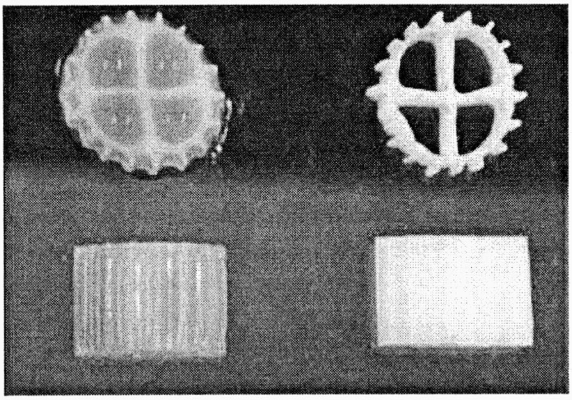
2. DESCRIPTION OF THE KALDNES PROCESS

The patented moving bed biofilm process has been developed by the Norwegian company Kaldnes Miljoteknologi (KMT), in cooperation with the SINTEF research organisation. In this process, biomass grows on small carrier elements floating in wastewater. The carriers (figure 1) are made of polyethylene whose density ranges from 0.92 g/dm^3 to 0.96 g/dm^3. They are shaped like small cylinders, about 9 mm in diameter and 7 mm in height, with a cross inside the cylinder and longitudinal fins on the outside. The reactor can be filled with carrier elements up to 70% of its volume, which corresponds to the potential specific growth area of biofilm approaching 500 m^2/m^3. Because there is no biofilm growth on the outside of the carriers, the maximum, practical specific growth area is about 350 m^2/m^3.



a b

Fig. 1. The Kaldnes carriers: a – with biofilm, b – without biofilm

The carriers are kept in suspension either by air (in aerobic processes) or by mixers (in anoxic processes). In order to keep the biofilm carriers in the reactors, sieves are placed at each outlet. The agitation is maintained by mixers so the carrier elements are constantly moved upwards over the surface of the sieve. This creates scrubbing action that prevents clogging of the sieve.

MBBRs work under very high loads, have a simple construction and are easy to operate [3], [10]. They have several advantages compared with conventional fixed bed systems. In MBBRs there is no reactor clogging, no need to wash the carriers, low head losses, the total reactor volume is effectively used and the volumetric efficiency is the same as for submerged biofilters.

Compared with the activated sludge process there is no need to recycle the biomass, a much smaller area is required and the process is more stable. The change in the degree of filling may alter the capacity of the reactor. In many cases, the existing non-nitrifying activated sludge plants may easily be upgraded to nitrogen removal, without expanding the existing reactor volumes [11], [12].

3. EXPERIMENTAL ARRANGEMENT

3.1. DESCRIPTION OF THE LABORATORY-SCALE SET

The experiments were performed in three laboratory-scale moving bed biofilm reactors connected in series, each of 14.5 dm^3 volume, followed by an activated sludge contact tank of 7.4 dm^3 volume and a settler of 14 dm^3 volume (figure 2). Each reactor was filled with the Kaldnes carriers to 48% of its volume. Fine bubble diffusers aerated the reactors. The airflow was measured by rotameters and regulated with manual valves. The carriers in the reactors circulated due to aeration or a work of mechanical mixers, which were used when the aeration was insufficient. The wastewater was supplied to the reactors by a peristaltic pump.

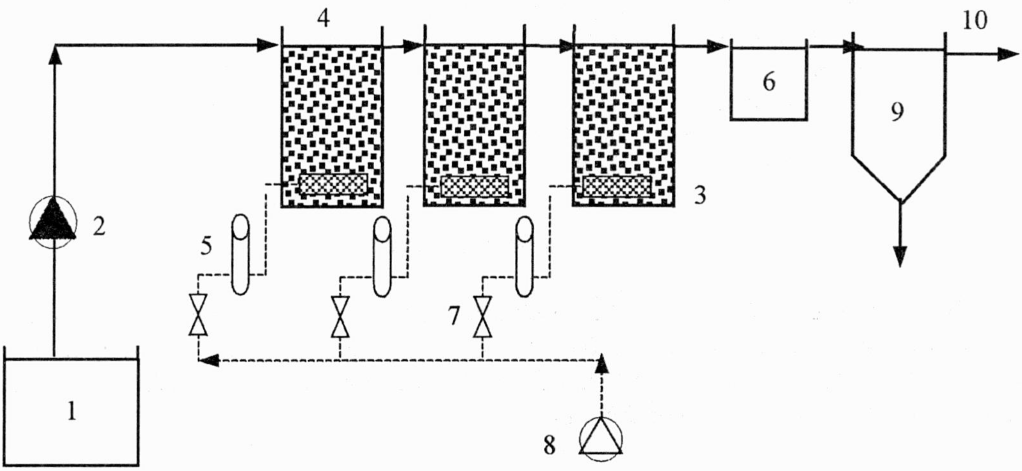


Fig. 2. Laboratory-scale set: 1 – tank with wastewater, 2 – peristaltic pump, 3 – membrane tube diffuser, 4 – the Kaldnes reactor, $V = 14.5$ dm^3, 5 – rotameter, 6 – activated sludge contact tank, $V = 7.4$ dm^3, 7 – manual valve, 8 – air blower, 9 – settler, $V = 14$ dm^3, 10 – effluent

3.2. WASTEWATER CHARACTERISTICS

This study was carried out using meat processing wastewater taken from the outlet of the Imhoff settler. Wastewater characteristics are given in the table.

3.3. SAMPLING AND ANALYSIS

The laboratory set worked in June 1998. During the test, manual grab samples were taken from the effluent of each reactor once or twice a day, three times a week. Dissolved oxygen (DO) was continuously measured by one DO probe, which was immersed in one of the three reactors. Total COD (TCOD) was measured according to the Polish Standards. For soluble COD determination (SCOD) samples were filtered before analysing through filter paper (slow filtering of the finest deposits).

Table

Wastewater composition

Constituent	Unit	Concentration		
		Average	Max	Min
Temperature	°C	18	–	–
pH		7.5	7.7	7.2
TCOD (total COD)	mg O_2/dm^3	1158	1678	487
SCOD (soluble COD)	mg O_2/dm^3	1028	1536	348
Suspended solids	mg /dm^3	1700	1960	1570
Dissolved solids	mg /dm^3	1630	1910	1470
Ammonia nitrogen	mg N/dm^3	237	281	199
Total nitrogen	mg N/dm^3	248	287	208

3.4. OPERATING CONDITIONS

The test was carried out with the concentration of dissolved oxygen in the first reactor ranging from 1.4 mg/dm^3 to 6.4 mg/dm^3 (average 4.3 mg/dm^3), a temperature from 19 to 25 °C and pH from 8.0 to 8.7. Hydraulic retention time (HRT) in one reactor varied from 2.4 hours to 6.7 hours.

4. RESULTS AND DISCUSSION

4.1. EFFECT OF SCOD CONCENTRATION ON SCOD REMOVAL RATE

The dependence of SCOD removal rate on the SCOD concentration in the first reactor is shown in figure 3. The results were tested using a simplified kinetic modelling according to HARREMOES and HENZE [4] and a model of the following type:

$$r = a \times \mathrm{SCOD}^b,$$

where:

r – removal rate in the first reactor, g/m^{2}d,

SCOD – concentration of SCOD in the first reactor, g/m^3,

a, b – constants.

The highest correlation was found for the equation $r = 0.12 \times \mathrm{SCOD}^{0.99}$. The value of the constant b proves that the reaction order is close to 1, which means that diffusion is responsible for a limiting reaction rate. This results from a thick liquid film on the biofilm surface caused by weak turbulence in the reactor and the growth of biofilm on the inner surface of carrier elements.

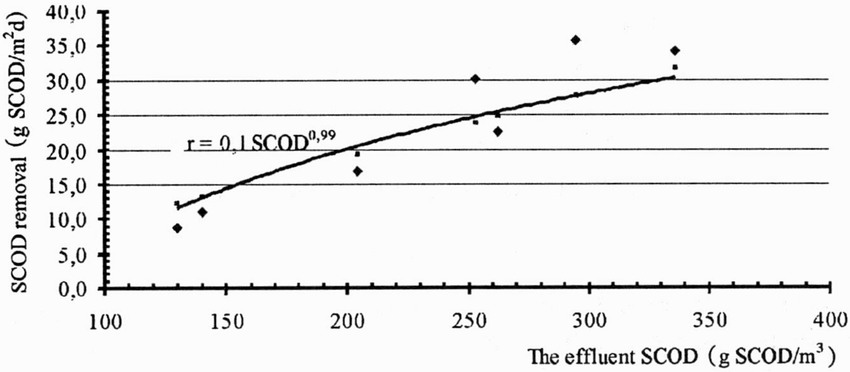


Fig. 3. SCOD removal rate in the first reactor as a function of the SCOD concentration

4.2. EFFECT OF COD LOAD ON REACTOR PERFORMANCE

The rate of SCOD removal in the first reactor versus SCOD load is shown in figure 4. This rate reached 35 g SCOD/m^{2}d for SCOD load close to 45 g/m^{2}d (9 kg SCOD/m^{3}d). The curve that represents the dependence in figure 4 is nearly a straight line for all loads tested in the range of 25–45 g SCOD/m^{2}d. A dependence of loading on removal rates was also reported by PASTORELLI [8], but for the loads smaller than 8 g SCOD/m^{2}d.

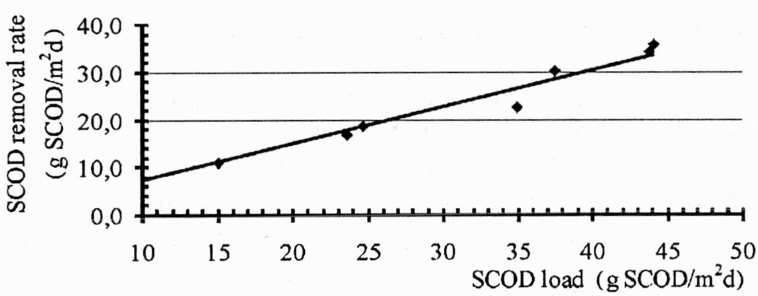


Fig. 4. SCOD removal rate in the first reactor as a function of the SCOD load

Figure 5 shows the effluent TCOD concentrations in the first reactor as a function of the TCOD load. In order to keep the effluent TCOD below 450 g/m^3, the load has to be smaller than 40 g TCOD/m^{2}d. A similar dependence was observed by RUSTEN [9], who found that for dairy wastewater the effluent TCOD was below 400 g/m^3 when organic load was smaller than 35 g TCOD/m^{3}d.

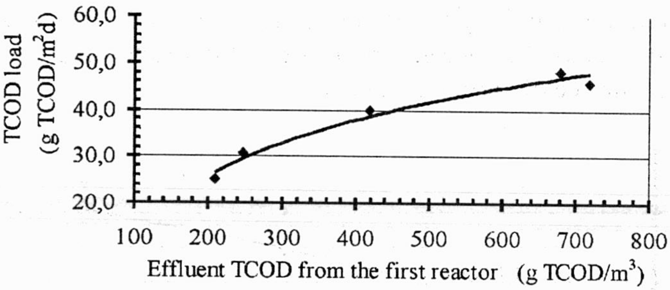


Fig. 5. Effluent TCOD as a function of the TCOD load

4.3. PROCESS EFFICIENCY

The efficiency of organic matter removal in the first reactor versus organic load is shown in figure 6. Removal efficiencies over 70% of TCOD were obtained in the first reactor at organic loads up to 30 g TCOD/m^2d. BROCH-DUE [2] achieved the same

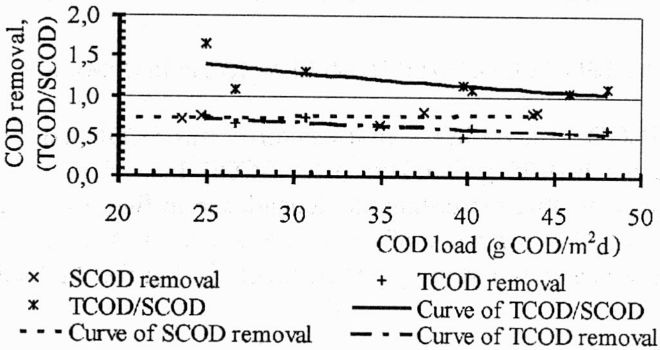


Fig. 6. COD removal, TCOD/SCOD as a function of COAD load

result (66–82%) for newsprint mill wastewater, but for a greater load (up to 51 g TCOD/m^2d). For the SCOD load tested in this experiment the process efficiency increased slightly from 71 to 81%. The reverse dependence was obtained for the TCOD, whose removal decreased from 76 to 55%. It is supposed that the increasing trend towards the SCOD removal is caused by wastewater characteristics. For low loads with low TCOD concentration, TCOD was composed of 66% SCOD and up to ca 30% of inert or hardly biodegradable organic matter. In the case of high loads with high TCOD, the TCOD concentration contained up to 91% of SCOD and only up to 10% of inert or hardly biodegradable organic matter.

4.4. EFFECT OF HYDRAULIC RETENTION TIME

The organic matter removal was affected by HRT. For an empty bed and the HRT approaching 4 hours 75–85% SCOD removal was reached. Longer HRT (up to 8 hours) slightly increased (by ca. 5–10%) the process efficiency. A similar dependence was claimed by RUSTEN and BROCH-DUE [2], [9], [10].

4.5. ORGANIC MATTER REMOVAL IN SUBSEQUENT REACTORS

The rates of SCOD removal and process efficiency in each reactor for the loads of 5 kg SCOD/m^{3}d and 9 kg SCOD/m^{3}d are as follows: over 70% of SCOD were removed in the first reactor and only 4–10% in the second reactor. In the third reactor and in the contact tank, the organic matter removal was insignificant. BROCH-DUE [1] and HEM [5] achieved similar results treating NSSE wastewater and forest industry wastewater, respectively. All researchers reported that the contribution of the second reactor to SCOD removal was about 3–10%.

4.6. SLUDGE PRODUCTION

During the test it was observed that the concentration of suspended solids in the wastewater increased in the subsequent reactors and varied from 180 to 530 mg/dm^3 in the first reactor and from 240 to 840 mg/dm^3 in the second reactor. It depended on the reactor load.

5. SUMMARY AND CONCLUSIONS

The study showed that in the first reactor, which worked under conditions of a high load, at the HRT of about 4 hours and COD loading approaching 10 kg/m^3, the removal of organic matter was 50–75% of TCOD (60–80% of SCOD). In the second reactor, only 5–15% of TCOD were removed (4–10% of SCOD). In the two reactors connected in series, the organic matter removal reached 64–75% of TCOD and 70–88% of SCOD, with a total HRT from 4 to 13 hours. In the next elements of the laboratory set, the organic matter removal was insignificant. Two reactors connected in series, with the HRT of 4 hours and the load to 14 kg TCOD/m^{3}d, could achieve 60–75% TCOD removal from meat processing wastewater.

Organic matter removal appeared to be almost a linear function of organic load for all the loads tested. The organic matter removal was nearly the first-order reaction, which meant that liquid film diffusion limited the reaction rate.

The Kaldnes process, being applied to very high loads, is a stable and competitive process which can allow organic matter removal from meat processing wastewater.

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USUWANIE ZWIĄZKÓW ORGANICZNYCH ZE ŚCIEKÓW Z MASARNI W REAKTORACH Z RUCHOMYMI NOŚNIKAMI BIOMASY

Konwencjonalne technologie biologicznego oczyszczania ścieków z biomasą zawieszoną mają kilka wad. Dlatego należy szukać nowych, skutecznych technologii, które powinny być rozwijane i stosowane. Reaktory z ruchomymi nośnikami biomasy zapewniają dobry kontakt biomasy z substratem, dzięki czemu są wydajne i skuteczne. Przedstawiono wyniki zastosowania procesu MBBR do usuwania związków organicznych ze ścieków z masarni. Eksperymenty prowadzono w trzech reaktorach MBBR w skali laboratoryjnej. Reaktory te pracują w układzie kaskadowym. Ścieki pobierano w masarni z wylotu osadnika Imhoffa. Badania wykazały, że w pierwszym reaktorze, pracującym jako wysoko obciążony stopień, dla czasu zatrzymania 4 godziny i obciążenia do 10 kg ChZT/m^{3}d sprawność usuwania substancji organicznych wynosiła 50–75% ChZT. W dwu reaktorach pracujących w kaskadzie sprawność usuwania substancji organicznych wynosiła 64–75% ChZT, a frakcja filtrowana ChZT była usuwana w 70–88% dla czasu zatrzymania od 4 do 13 godzin. Usuwanie substancji organicznych było liniową funkcją obciążenia ładunkiem dla wszystkich testowanych obciążeń. Proces MBBR jako wysoko obciążony stopień jest stabilny i odpowiedni do usuwania substancji organicznych ze ścieków z masarni.

technologie oczyszczania
biomasy
substrat