



UNIVERSITI PUTRA MALAYSIA

**PERFORMANCE OF MEMBRANE BIOREACTOR IN THE
TREATMENT OF HIGH STRENGTH MUNICIPAL WASTEWATER**

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OF HIGH STRENGTH MUNICIPAL WASTEWATER**

By

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PERFORMANCE OF MEMBRANE BIOREACTOR IN THE TREATMENT OF HIGH STRENGTH MUNICIPAL WASTEWATER

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In some parts of Malaysia, wastewater treatment plants (WWTPs) are located in industrial areas. These WWTPs receive wastewater mostly from these industrial activities regularly or occasionally. Therefore, their biochemical oxygen demand (BOD), chemical oxygen demand (COD) and ammonia nitrogen (NH₃-N) are very high. Conventional biological treatment processes are incapable of producing desirable effluent quality with the increasingly stringent discharge requirement.

In this study, a laboratory-scale membrane bioreactor (MBR) was used for treating high strength municipal wastewater. Prepared synthetic wastewater samples which represent a high strength municipal wastewater as well as the actual high strength municipal wastewater were used in the study. The developed MBR was operated under different conditions using statistical experimental full factorial design with three factors and three levels. The factors were sludge retention time (SRT), feed temperature (T_f) and organic loading rate (OLR) and their respective levels were 25, 30 and 35 days; 20, 30 and 40 °C; and 1.73, 4.03 and 6.82 kg COD/m³ .d .

To evaluate the performance of MBR under the different operating conditions, ten trials were carried out using the prepared synthetic wastewater samples. The MBR could cope with the different operating conditions with high accuracy on the experimental results. Permeate COD, BOD, NH₃-N and total suspended solids (TSS) varied from 0 to 32, 0.3 to 13.1, 0.004 to 0.856 and 0 to 26 mg/l respectively. The pH in the aeration tank increased significantly compared to that of the feeding tank. In addition, the increasing pH of the aeration tank was well correlated to that in the feeding tank. ($R^2 = 0.8336$ for low OLR trials and 0.9106 for high OLR trials).

To investigate the effects of the different operating conditions on membrane fouling, sustainable time (t_{sust}) was used as a measure to compare the different trials. Within the same OLR level, t_{sust} increased as SRT and T_f increased. Sustainable time was found to decrease as the ratio of mixed liquor volatile suspended solids to mixed liquor suspended solids (MLVSS /MLSS) increased with a correlation coefficient (R^2) of 0.808.

When MBR was used to treat the actual high strength municipal wastewater, the respective average removal efficiencies of COD, BOD and NH₃-N were 98.4, 99.7, and 99.9%. These were found to be comparable with those values obtained from the synthetic wastewater treated by MBR .

Empirical models were developed to predict the concentrations of permeate COD, BOD and NH₃-N. The predicted values were highly correlated with the observed values (R^2 of 0.9188, 0.9111 and 0.9899 respectively for the three parameters

mentioned). However the models of COD and BOD were found to be more accurate than the $\text{NH}_3\text{-N}$ model.

Future work on the optimization of MLSS concentration and aeration rate as well as the improvement on the techniques for reducing the membrane fouling is recommended.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PRESTASI BIOREAKTOR MEMBRAN DALAM MENGOLAH AIR SISA
DOMESTIK BERKEKUATAN TINGGI**

Oleh

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Di sesetengah tempat di Malaysia, loji olehan kumbahan airsisa terletak di kawasan industri. Loji-loji olehan kumbahan airsisa ini kebanyakannya menerima air sisa daripada aktiviti-aktiviti industri secara berterusan atau berkala. Oleh itu, tahap keperluan oksigen biokimia (BOD), keperluan oksigen kimia (COD) dan ammonia nitrogen ($\text{NH}_3\text{-N}$) adalah sangat tinggi. Proses olehan biologi konvensional tidak mampu menghasilkan kualiti effluen yang dapat memenuhi piawai kumbahan yang semakin ketat.

Di dalam kajian ini, satu bioreaktor membran skala makmal (MBR) telah direkabentuk, dibina dan diaplikasikan dalam mengolah air sisa domestik berkekuatan tinggi. Penyediaan air sisa sintetik yang mewakili air sisa domestik yang berkekuatan tinggi dan juga air sisa domestik sebenar yang berkekuatan tinggi telah digunakan di dalam kajian. MBR yang telah dibangunkan beroperasi di bawah keadaan yang berbeza dengan menggunakan rekabentuk faktorial penuh eksperimen statistik dengan tiga faktor dan tiga tahap. Faktor-faktor itu ialah masa tahanan enapcemar (SRT), suhu suapan makanan (T_f) serta kadar bebanan organik (OLR)

dan nilai-nilai tersebut ialah 25, 30 dan 35 hari; 20, 30 dan 40 °C; dan 1.73, 4.03 dan 6.82 kg COD/m³ .hari masing-masing.

Untuk menguji prestasi MBR di bawah keadaan operasi yang berbeza, sepuluh ujian telah dijalankan dengan menggunakan sample air sisa sintetik tersedia. MBR tersebut berupaya beroperasi di bawah keadaan operasi yang berbeza dengan ketepatan tinggi ke atas keputusan eksperimen. Turasan dengan nilai COD, BOD, NH₃-N dan Jumlah Pepejal Terampai (TSS) adalah berjulat dari 0 sehingga 32, 0.3 sehingga 13.1, 0.004 sehingga 0.856 dan 0 sehingga 26 mg/l masing-masing. Nilai pH di dalam tangki pengudaraan meningkat dengan ketara jika dibandingkan dengan tangki suapan makanan. Tambahan pula, peningkatan pH di dalam tangki pengudaraan dapat dikorelasikan dengan tangki suapan makanan ($R^2 = 0.8336$ untuk ujian OLR rendah dan 0.9106 untuk ujian OLR tinggi).

Untuk menyiasat kesan-kesan keadaan operasi yang berbeza ke atas penyumbatan membran, masa mampan (t_{sust}) telah digunakan sebagai sukatan bandingan bagi ujian-ujian yang berbeza. Di dalam lingkungan tahap OLR yang sama, t_{sust} meningkat apabila SRT dan T_f meningkat. Masa mampan telah didapati menurun apabila nisbah pepejal terampai meruap likuor campur kepada pepejal terampai likuor campur (MLVSS/MLSS) meningkat dengan pekali korelasi (R^2) 0.808.

Apabila MBR digunakan untuk mengolah air sisa domestik sebenar yang berkekuatan tinggi, purata keberkesanan penyingkiran untuk COD, BOD dan NH₃-N ialah 98.4, 99.7, dan 99.9% masing-masing. Keputusan ini didapati sejajar dengan

nilai yang telah diperolehi terlebih dahulu daripada model air sisa yang diolah dengan MBR.

Model empirikal telah dibangunkan untuk meramal kepekatan turasan COD, BOD dan $\text{NH}_3\text{-N}$. Nilai yang telah diramal adalah sangat berkorelasi dengan nilai sebenar (R^2 dengan 0.9188, 0.9111 dan 0.9899 masing-masing untuk tiga parameter yang telah disebut). Walaubagaimanapun, model untuk COD dan BOD didapati lebih tepat dibandingkan dengan model $\text{NH}_3\text{-N}$.

Kajian masa hadapan ke atas pengoptimuman kepekatan MLSS dan kadar pengudaraan di samping pembaikan ke atas teknik untuk mengurangkan penyumbatan membran disarankan.

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I certify that an Examination Committee met on October 24th 2008 to conduct the final examination of Ahmed Hussien Birima on his doctor of philosophy thesis entitled “Design and Development of Membrane Bioreactor for Treating High Strength Municipal Wastewater ” in accordance with Universiti Pertanian Malaysia (higher degree) Act 1980 and Universiti Pertanian Malaysia (higher degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

AHMED HUSSIEN BIRIMA

Date:

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LIST OF ABBREVIATIONS

| | |
|--------------------|--|
| BOD | Biochemical Oxygen Demand |
| COD | Chemical Oxygen Demand |
| TOC | Total Organic Carbon |
| NH ₃ -N | Ammonia Nitrogen |
| NO ₂ -N | Nitrite Nitrogen |
| NO ₃ -N | Nitrate Nitrogen |
| TKN | Total Kjeldahl Nitrogen |
| TS | Total Solids |
| TSS | Total Suspended Solids |
| ML | Mixed Liquor |
| MLSS | Mixed Liquor Suspended Solids |
| MLVSS | Mixed Liquor Volatile Suspended Solids |
| TMP | Trans-Membrane Pressure |
| CASP | Conventional Activated Sludge Process |
| MBR | Membrane Bioreactor |
| SMBR | Submerged Membrane Bioreactor |
| MSBR | Membrane Sequencing Batch Reactor |
| UF | Ultrafiltration |
| MF | Microfiltration |
| SRT | Sludge Retention Time |
| T _f | Feed Temperature |
| OLR | Organic Loading Rate |
| VLR | Volumetric Loading Rate |

| | |
|-----------|---|
| F/M | Food To Microorganism Ratio |
| FC | Fecal Coliforms |
| CFV | Cross Flow Velocity |
| EPS | Extracellular Polymeric Substances |
| UBIS | Ultra Biological System |
| HRT | Hydraulic Retention Time |
| EBPR | Enhanced Biological Phosphorus Removal |
| Q_r | Recycling Flow Rate |
| E_c | Efficiency of Substrate |
| RMBR | Recirculated Membrane Bioreactor |
| CMF | Critical Membrane Flux |
| PAC | Powdered Activated Carbon |
| RBCOD | Readily Biodegradable Organic Substances |
| SMP | Soluble Microbial Products |
| DOE | Department of Environment |
| PE | Population Equivalent |
| DO | Dissolved Oxygen |
| TMP | Transmembrane Pressure |
| SP | Suction Pressure |
| J_c | Critical Flux |
| J_p | Permeate Flux |
| t_{sus} | Sustainable Time |
| SVI | Sludge Volume Index |
| FSIP | Flux- Suction Pressure Intersection Point |