DEVELOPMENT OF ATTACHED GROWTH MICROBIAL FUEL CELL (AG-MFC) FOR TREATMENT OF SPENT CAUSTIC WASTEWATER AND ENERGY RECOVERY

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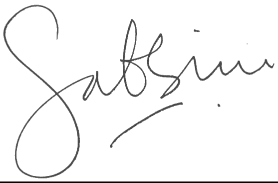

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ABSTRAK

Sisa air yang tidak dirawat dengan baik dan kebergantungan terhadap bahan api fosil sebagai sumber tenaga yang utama membawa kepada masalah pencemaran air dan kekurangan sumber tenaga yang serius. Sisa air kaustik merupakan sisa air yang sangat beracun dihasilkan oleh perkilangan petroleum kimia. Dengan ciri-ciri berbahayanya, pelupusannya memerlukan pengurusan yang istimewa. Industri biasanya menggunakan kaedah perawatan menggunakan bahan kimia atau haba yang menghasilkan oksidasi separa dalam sisa air kaustik. Kajian ini bermatlamat untuk menghasilkan perawatan sisa air kaustik yang efektif dan penghasilan tenaga menggunakan sel bahan api mikrob berasaskan pertumbuhan terlekat pada sesuatu medium (AG-MFC). AG-MFC adalah satu sistem integrasi antara antara aplikasi MFC dengan penggunaan butir am karbon aktif (GAC) terampai sebagai medium pelekatan bakteria. Penambahan GAC ke dalam sistem membenarkan kehadiran bakteria terlekat yang mempunyai kadar ketumbesaran yang lebih tinggi meningkatkan jumlah mikroorganisma. Bakteria terlekat juga lebih berdaya tahan terhadap tekanan fizikal dan kimia. Ciri-ciri ini menambah baik daya penyesuaian bakteria terhadap sisa air kaustik. Kajian ini dimulakan dengan penentuan dos GAC optimum dengan sejumlah 0 g hingga 25 g dos GAC telah dikaji. Kemudian, keadaan operasi yang optimum iaitu campuran cecair pepejal terampai (MLSS), masa tahanan pepejal (SRT) dan kadar beban organik (OLR) ditentukan dengan variasi operasi berbeza iaitu pada MLSS dari 2500 ke 4000 mg/L, pada SRT dari 10 ke 30 hari dan pada OLR dari 700 ke 900 mg COD/L.d. Prestasi AG-MFC dinilai berdasarkan penyingkiran keperluan oksigen kimia (COD) dan sulfida dan keluaran voltan. Bakteria dominan yang terlekat dikenalpasti secara molekular dan morfologi bakteria diperhatikan menggunakan analisis mikroskop. Akhir sekali, pecahan COD sisa kaustik ditentukan menggunakan analisis respirometri dan parameter rekaan yang menerangkan proses biologi dalam AG-MFC ditentukan dengan menggunakan Model No.1 Enapcemar Aktif (ASM1). Hasil kajian menunjukkan 10 g GAC adalah optimum dengan peyingkiran COD dan sulfida tertinggi masing-masing sebanyak 97.25% dan 96.25% dan keluaran voltan tinggi sebanyak 583 mV. Peningkatan GAC dari 0 g ke 10 g telah meningkatkan penghasilan bakteria terlekat. Namun, mikroorganisma berlebihan pada dos GAC melebihi 10 g tidak digemari oleh operasi AG-MFC. Keadaan operasi optimum AG-MFC adalah pada MLSS 3500 mg/L, SRT 20 hari dan OLR 700 mg COD/L.d memandangkan AG-MFC memperoleh penyingkiran COD yang tinggi melebihi 90% pada keadaan ini. MLSS dan SRT tinggi digemari oleh AG-MFC kerana MLSS tinggi meningkatkan jumlah mikroorganisma dan SRT tinggi memanjangkan masa untuk penghasilan semula bakteria. OLR yang tinggi telah menurunkan kadar penyingkiran oleh AG-MFC kerana substrat berlebihan melebihi kebolehan degradasi bakteria. Biojisim AG-MFC didominasi oleh Proteobacteria, yang merupakan Gram-negatif dan mempunyai flagella untuk pelekatan mekanikal pada GAC. Peningkatan OLR juga telah meningkatkan pecahan COD mudah biodegradasi (Xs) yang menjelaskan penurunan kecekapan penyingkiran AG-MFC pada OLR tinggi. Daripada simulasi dinamik, didapati peningkatan OLR menurunkan kadar ketumbesaran spesifik heterotrofik mikroorganisma (μmaxH) dan meningkatkan kadar pereputan heterotrofik (bH). Keadaan ini menunjukkan peningkatan pecahan larut yang tidak boleh dibiodegradasi yang terhasil daripada pereputan biojisim yang menyebabkan penyingkiran yang rendah pada OLR yang tinggi. Kajian ini telah menunjukkan AG-MFC berkapasiti dalam memberikan degradasi penuh terhadap sisa air kaustik dan sesuai untuk dijadikan sebagai perawatan kedua dalam perawatan sisa air kaustik di industri perkilangan.

ABSTRACT

Insufficiently treated wastewater and dependability to fossil fuel as the main source of energy led to serious water pollution and depletion of energy resources problem. Spent caustic wastewater is a highly toxic wastewater generated by the petroleum chemical plants. Due to its noxious properties, it required special management for its disposal. Chemical and thermal treatment methods which produced partial oxidation of spent caustic of wastewater are the common industrial practice. This study aims to produce effective treatment of spent caustic wastewater and energy recovery using Attached Growth Microbial Fuel Cell (AG-MFC). AG-MFC a system integrating the MFCs application with suspended GAC as bacterial attachment medium. The GAC addition into the system allowed the presence of attached biomass which has higher growth rate leading to a higher amount of microorganism. Attached biomass are also more resistant to physical and chemical force. These features improved the biomass adaptability in spent caustic. The study began with determination of optimum GAC dosage whereby 0 g to 25 g of GAC dosage was tested. Then, its optimum operating conditions in terms of Mixed Liquor Suspended Solid (MLSS), Solid Retention Time (SRT) and Organic Loading Rate (OLR) were determined by varying the operating conditions of MLSS from 2500 to 4000 mg/L, SRT from 10 to 30 days and OLR at from 700 to 900 mg COD/L.d. The AG-MFC performance was evaluated based on chemical oxygen demand (COD) and sulfide removal and voltage output. The dominant bacteria attached was identified using the molecular method and their morphology was observed using microscopic analysis. Finally, the COD fractionations of spent caustic wastewater were determined using respirometric analysis and the design parameters that described the biological process in the AG-MFC were determined using Activated Sludge Model No. 1 (ASM1). The finding demonstrated 10 g of GAC its optimum dosage since it produced the highest COD and sulfide removal of 97.56% and 96.25% respectively and high voltage output of 583 mV. Higher GAC addition from 0 to 10 g increased the biomass attached. However, there was excessive microorganisms at GAC dosage of higher than 10 g which was not favourable for the AG-MFC operation. The optimum operating conditions of the AG-MFC were at MLSS of 3500 mg/L, SRT of 20 days and OLR of 700 mg/L.d as AG-MFC possessed highest COD removal trend of beyond than 90% at these conditions. High MLSS and SRT were favourable for AG-MFC operation since a higher MLSS increased the amount of microorganisms and higher SRT prolonged the time for bacteria to reproduce. Higher OLR reduced the AG-MFC removal efficiency due to excessive substrates beyond the degradation capacity of the microorganisms. The AG-MFC biomass was dominated with Proteobacteria, which are Gram-negative and have flagella for mechanical attachment on GAC. Increasing OLR has also increased the slowly biodegradable COD (Xs) fraction which explained the low removal efficiency of AG-MFC at high OLR. From the dynamic simulation, it is found that increasing OLR reduced the maximum specific growth rate of heterotrophic microorganisms (μmaxH) and increased heterotrophic decay (bH). This condition indicated higher new soluble and non-biodegradable fractions generated from the decaying biomass which caused low removal at high OLR. This study has demonstrated AG-MFC capacity in producing complete degradation of spent caustic wastewater and is most suitable to serve as the secondary treatment of spent caustic wastewater in the refinery industry.

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