A STUDY ON HYBRID PHOTOCATALYTIC PRE-TREATMENT FOR SEAWATER DESALINATION BY USING OIL PALM FIBRE ASH

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We hereby declare that we have checked this thesis and in our opinion this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

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I hereby declare that the work in this 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 Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Pelbagai rancangan dan strategi telah dibangunkan untuk penyediaan sistem penyahgaraman ini yang mana ianya amat diperlukan pada masa ini dengan langkah-langkah dalam mengurangkan kos yang berkaitan seperti kos pelaksanaan, kos operasi dan kos penyelenggaraan teknologi penyahgaraman ini. Dalam perkara ini, pra-rawatan air laut dengan teknik penyahgaraman fotokatalitik boleh menjadi satu alternatif yang cekap yang mana proses ini hanya memerlukan kos operasi dan pelaksanaan yang rendah. Pembasmian kuman secara fotokatalitik ini semakin popular sebagai satu kaedah yang mudah dan kos yang rendah untuk rawatan air. Dalam proses kerja ini, fotomangkin yang berasaskan kepada TiO_2 hibrid yang cekap dan mesra alam telah disediakan dan digunakan sebagai fotomangkin. Fotomangkin dengan nisbah yang berbeza menggunakan TiO_2 dan abu gentian kelapa sawit (OPFA) telah disediakan dengan menggunakan teknik impregnasi kebasahan. Kesan doping logam Fe dan Ce pada 5% dan 10% juga telah diuji dan diselidiki. Bahan yang digabungkan dan dicirikan oleh pembelauan serbuk sinar-X (XRD), pengimbasan mikroskop elektron dengan spektroskopi sinar-X penyebaran tenaga (SEM dan EDX), kajian penjerapan-desorpsi N_2 (BET), spektroskopi fotoelektron sinar-X (XPS), dan spektroskopi serapan UV-vis pantulan meresap. Selain itu, bekalan sumber air laut telah desediakan dan dicirikan melalui penganalisis XPS fotoelektron sinar-X untuk diselidiki unsur-unsur dan oksidanya. Eksperimen ini telah dilakukan didalam reaktor Borosilikat 1000 mL dengan kehadiran sinaran cahaya UV atau cahaya nampak dengan panjang gelombang 365 nm, dan 420 nm masing-masing. Keputusan kajian telah menunjukkan bahawa aktiviti TiO_2 untuk pra-rawatan air laut didapati bertambah baik dengan amat ketara apabila pemangkinnya adalah hibrid dengan menggunakan abu gentian kelapa sawit (OPFA) (Ti:Ash 40:60 dan Ti:Ash 60:40 fotomangkin) di bawah penyinaran cahaya UV. Didapati juga bahawa pemangkin Ti:Ash 40:60 dan Ti:Ash 60:40 telah merendahkan 45% asid humik dengan amat ketara manakala Ti:Ash 40:60 pula telah merendahkan 41% asid humik. Ion logam doping telah meningkatkan penyerapan cahaya tampak fotomangkin di mana jalur tenaga berkurangan. Dapat diperhatikan bahawa pemuatan Fe sebagai pemangkin telah menunjukkan berprestasi yang lebih baik daripada Ce di bawah cahaya UV, cahaya nampak dan cahaya nampak semula jadi. Pemangkin foto yang terbaik adalah Ti:Ash:Fe 40:55:5 dan Ti:Ash:Ce 40:55:5. Ti:Ash:Fe 40:55:05 yang mana menunjukkan bahawa aktiviti fotomangkin yang tertinggi adalah sebanyak 49% manakala Ti:Ash:Ce 40:55:05 mempunyai 45% aktiviti fotokatalitik selama 240 minit penyinaran di bawah cahaya yang boleh dilihat. Parameter terbaik untuk tindak balas fotomangkin boleh diperolehi dengan menggunakan Ti:Ash:Fe 40:55:5 dan Ti:Ash:Ce 40:55:5 apabila nisbah pemangkin kepada air berada pada tahap nisbah1:300 selama 120 minit. Didapati juga bahawa Ti:Ash:Fe 40:55:05 telah merosot dengan ketara pada tahap 58% asid humik selepas 120 minit di bawah sinaran cahaya UV. Walau bagaimanapun, pada tahap 42% dan 28% didapati kemerosotan pada tahap asid humik telah diperhatikan apabila Ti:Ash:Fe 40:55:05 masing-masing terdedah kepada cahaya nampak buatan (420 nm) dan cahaya semula jadi. Mekanisme kajian secar kinetik telah dilakukan untuk mendapatkan tindak balas fotokatalitik HA dengan menggunakan ungkapan kadar kinetik Langmuir-Hinshelwood ke atas fotomangkin yang menggunakan fotomangkin hibrid yang mana boleh meningkatkan tahap kualiti air. Kadar pemalar yang diukur selepas 240 minit di bawah cahaya dilihat Ti:Ash:Fe 40:55:05 adalah 0.0028 min-1, manakala Ti:Ash:Ce 40:55:05 dalam keadaan yang sama adalah 0.0025 min-1. Oleh itu, proses fotomangkin boleh dijadikan sebagai pra-rawatan alternatif yang cekap dalam proses penyahgaraman air laut

ABSTRACT

Owing to the scarcity of portable water sources and humic acid contamination, the desalination of saline water can be an alternative solution to meet its growing demand. Although several desalination methods already exist, there is a pressing need to create approaches that minimize the expense of their setup, operation, and upkeep. In this aspect, the pre-treatment of seawater by photocatalytic desalination technique can be an efficient and alternative way that requires low operational and implementation costs. Photocatalytic disinfection is gaining popularity as a simple and low-cost method for water treatment. In this work, cost-efficient and environmentally friendly hybrid TiO_2-based photocatalysts were prepared and utilized. The photocatalysts with different ratios of TiO_2 and oil palm fibre ash (OPFA) were prepared using wetness impregnation technique. The effect of metal doping of Fe and Ce at 5% and 10 % were also investigated. The incorporated materials were characterized by X-ray powder diffraction (XRD), scanning electron microscope with energy dispersive X-ray spectroscopy (SEM and EDX), N_2 adsorption-desorption studies (BET), X-ray photoelectron spectroscopy (XPS), and diffuse reflectance UV–vis absorption spectroscopy. Moreover, X-ray fluorescence was used to determine the element and oxides of OPFA. The experiments were done in a 1000 mL Borosilicate reactor in the presence of either UV-light or visible light irradiation with wavelength 365 nm, and 420 nm respectively. Besides that, the hybrid system was equipped with a glass pyramid cover to collect the evaporated water. The results show that the activity of TiO_2 for seawater pre-treatment improved significantly when the catalyst was hybrid with oil palm fiber ash (OPFA) (Ti:Ash 40:60 and Ti:Ash 60:40 photocatalysts) under UV light irradiation. It was found that the humic acid was significantly degraded after using Ti:Ash 40:60 and 60:40 by 45% and 41%, respectively under UV light. Doping metal ions significantly improved the photocatalyst visible light absorption where the band energy was reduced. It can be observed that Fe loading in the catalyst performed better than Ce under UV light, visible light, and natural visible light where Ti:Ash:Fe 40:55:05 and Ti:Ash:Ce 40:55:05 photocatalyst performed well. The Ti:Ash:Fe 40:55:05 and Ti:Ash:Ce 40:55:05 showed the best photocatalytic activity compared to other synthesized photocatalyst. The degradation rate of humic acid was achieved at 49% for Ti:Ash:Fe 40:55:05 and 45% for Ti:Ash:Ce 40:55:05 after 240 min of irradiation under visible light. The best parameters for the photocatalytic reaction were achieved by using Ti:Ash:Fe 40:55:5 and Ti:Ash:Ce 40:55:5 when catalyst to water mass ratio was set at 1:300 and tested for 120 minutes. Meanwhile, the Ti:Ash:Fe 40:55:05 degraded effectively 58% of humic acids after 120 minutes under UV light. However, 42% and 28% of humic acid degradation were observed when the Ti:Ash:Fe 40:55:05 was exposed to artificial visible light (420 nm) and natural light, respectively. The mechanism of the kinetic studies was performed for Humic acids photocatalytic reaction by using Langmuir-Hinshelwood kinetic rate expressions over the photocatalysts were adopting a hybrid photocatalyst. The specific reaction rate constant measured after 240 min under visible light of Ti:Ash:Fe 40:55:05 was 0.0028 min^{-1}, whereas of Ti:Ash:Ce 40:55:05 under the same conditions, was 0.0025 min^{-1}. Thus, the photocatalyst process has huge potential as an efficient alternative pre-treatment for seawater desalination.

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