Photocatalytic restoration of liquid effluent from oil palm agroindustry in Malaysia using tungsten oxides catalyst

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A B S T R A C T
In the current work, the photocatalytic treatment of palm oil mill effluent over tungsten oxides photocatalyst under ultraviolet-irradiation was evaluated. Characterization of fresh and used tungsten oxides photocatalyst was accomplished via X-Ray Diffraction, Scanning Electron Microscopy with Energy Dispersive X-Ray Analysis, Ultraviolet–Visible Light Diffuse Reflectance Spectroscopy, and Fourier Transformed-Infrared Spectroscopy. Photocatalytic treatment of palm oil mill effluent was conducted to determine the effects of catalyst loading, longevity, and recyclability of the tungsten oxides photocatalyst, as well as the effect of pH alteration on palm oil mill effluent. During the photocatalytic reaction, the collected liquid sample was tested for chemical oxygen demand, pH, and colour intensity while the gaseous sample was analyzed via gas chromatography. The optimum catalyst loading was 0.5 g/L, corresponds to highest photocatalytic degradation (51.15%) and decolourization (96.21%). The pH alteration on palm oil mill effluent has negligible effect on its photocatalytic degradation with UV/WO3 system. For longevity study, the optimum reaction time was 16 h, which achieved 84.70% photocatalytic degradation and 98.28% photocatalytic decolourization. From the recyclability study, it can be concluded that the tungsten oxides photocatalyst is suitable for photocatalytic decolourization of palm oil mill effluent, but not suitable for photocatalytic degradation. In addition, analysis of the gaseous product showed that the photocatalytic treatment has successfully degraded the organic pollutants in the liquid effluent into methane and carbon dioxide.

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1. Introduction

According to Malaysian Palm Oil Council (MPOC, 2016), the oil palm industry in Malaysia presently accounts for 39% of production and 44% of exports for palm oil in the worldwide. Malaysia is the largest exporter of refined palm oil despite that it is the second-largest contributor to world production of the oil, behind only to the Indonesia. Although oil palm industry appears as one of the most structured agro-industry in Malaysia, the milling process can generate massive colloidal wastewater often known as palm oil mill effluent (POME). This is because a traditional milling process employs steam for sterilization process. Unfortunately, this process is a precursor to the formation of POME waste that is less environmentally-benign (Law et al., 2016). From the previous study, it was discovered that the processing of every ton of crude palm oil would produce approximately 2.5–3.75 tons of POME (Ahmad et al., 2003).

POME is a viscous, thick brownish and colloidal liquor that mainly consists of water (95–96%), total solids (4–5%, included 2% suspended solid) and oil (0.6–0.7%) (Wongfaed et al., 2015). Raw POME is acidic with pH ranging from 4 to 5, and is hot, as the milling process occurs at 80 °C–90 °C (Tabassum et al., 2015). POME is brownish as it contains appreciable amounts of lignin, tannin, humic acids, lipids and fatty acids that originate from industrial steam extraction (Saeed et al., 2015). A rapid expansion of palm oil production in Malaysia is generating large volume of POME wastewater. Without proper treatment, POME will inflict serious environmental pollution. Although POME is non-toxic, it possesses high chemical oxygen demand (COD) ranging from 15,000 to 100,000 ppm and high biochemical oxygen demand (BOD) that ranged from 10,250 to 43,750 ppm (Madaki and Lau, 2013). Indeed, COD and BOD are parameters that reflect the number of organic pollutants present in wastewater. Therefore, prior to discharge, the raw POME must be treated by POME treatment facility in order to