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Polluted River Water Treatment Via Membrane Photocatalytic Reactor (MPR) Incorporated ZnO-Kaolin

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Abstract

Rivers provide essential resources for human use both in agriculture and aquatic ecosystems, which are particularly vulnerable to contamination. The polluted river water was treated using MPR incorporated Zno-Kaolin. The ZnO-Kaolin was synthesized through precipitation method and calcined at 550C. The characterization of the ZnO-kaolin was done using FTIR and XRD. It was found no impurities occurred during the synthesis. The Zno-Kaolin was then incorporated with MPR to investigate the reduction performance under different conditions, i) effect of initial pH, ii) effect of dosing and iii) effect of initial concentration. it was found that the optimal pH for the reduction is at pH 5, and at dosage 0.05 g/L. It was found the 100% concentration gave the highest reduction for all water quality index (salinity,TDS, conductivity). It can be concluded that MPR incorporated Zno-kaolin effectively treat polluted river water.

1. Introduction

Water pollution is a huge environmental problem that creates considerable obstacles for both the well -being of humans and the long-term viability of ecosystems. The pollution of rivers, which may be caused by a variety of activities including industrial, agricultural, and household, makes it necessary to design water treatment systems that are both effective and environmentally friendly. In recent years, membrane photocatalytic reactor (MPR), have emerged as a potentially useful technique for the treatment of contaminated river water by [1]. MPR have the ability to successfully remove a broad variety of contaminants from water sources by combining the processes of photocatalysis with membrane filtration. The use of ZnO-Kaolin as the photocatalyst, a composite material consisting of ZnO nanoparticles and kaolin clay, may significantly improve the effectiveness of MPR in the treatment of river water. The ZnO nanoparticles have high photocatalytic capabilities, which means they are capable of decomposing organic pollutants and lowering the concentration of pollutants. On the other hand, kaolin clay offers adsorption sites for the contaminants, which makes it easier to remove them from the aqueous matrix [2]. The performance of the MPR system is improved because of the combination of photocatalytic and adsorptive characteristics offered by ZnO-Kaolin, which is included in the system. The purpose of this research is to investigate the capability of ZnO-Kaolin as photocatalyst in treating polluted river water utilizing MPR. Thus, various parameters such as initial pH, ZnO-Kaolin dosage and initial concentration will be investigated in this work [4].

2. Material and Methods

River water samples were collected from a small river behind Kolej Kediaman Perwira, UTHM. Subsequently, ZnO-Kaolin photocatalyst was produced using the precipitation method, and its physicochemical properties were characterized through Fourier Transform Infrared (FTIR), X-ray Diffractometer (XRD). The research then evaluated the MPR performance for treating polluted river water, considering varying conditions such as initial pH (5,7 and 9), ZnO-Kaolin photocatalyst dosing (0.04, 0.05, 0.06 g/L), initial concentration (90, 95 and 100%) and utilizing a hollow fiber membrane figuration. Finally, the treated water underwent analysis for pH, chemical oxygen demand (COD) and biochemical oxygen demand (BOD) to assess the efficiency of the photocatalyst in water treatment.

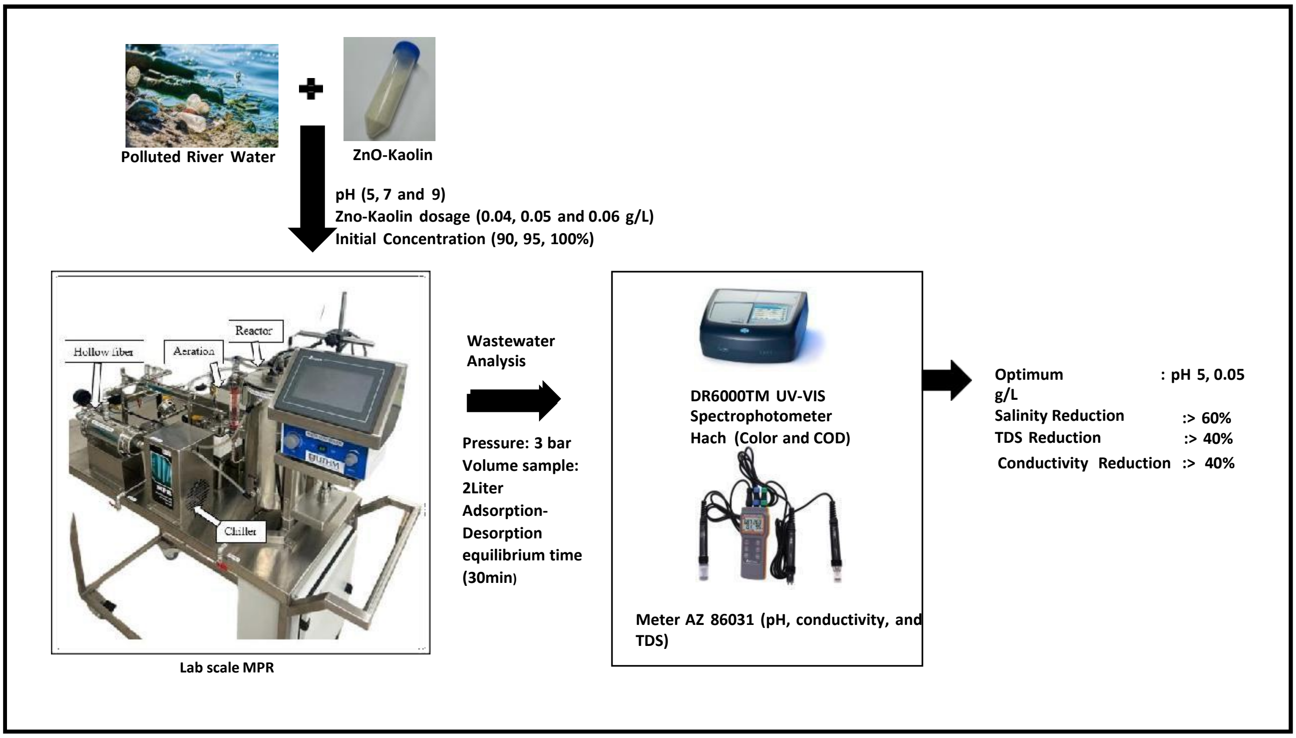

Fig. 1 *Apparatus in analyse the quality river water*

2.1 ZnO-Kaolin Preparation

The ZnO-Kaolin nanocomposite was prepared by using the precipitation method. Weight 4.39g of Zinc acetate dehydrate and dilute in 200m L of de-ionized water and stir for 5 minutes. Weight 3.79g of Oxalic acid dehydrated and diluted in 200m L of de-ionized water and stir for 5 minutes. Mix Zinc acetate solution and oxalic acid solution together and stir for 5 minutes using magnetic stir. Add 13. 33g of kaolin powder to the mixed solution and stir for 24 hours. White precipitate will be formed. Filter the solution to collect the white precipitate. Wash and rinse the collected white with De-ionized water several times. Dry the white precipitate for 1 hour in oven at temperature of 100C. The white powder of Zn0 -kaolin will be formed. The powder will be calcinate using furnace at temperature of 550C for 3 hours.

2.2 Characterization of ZnO-Kaolin

The composition and characterization of the synthesized ZnO -Kaolin will be characterized by using a Cary 600 series Fourier transform infrared (FTIR) spectrometer at room temperature with a spectral resolution of 8cm-1 and 16 scans in open beam air background in the mid IR region (500-4000) cm-1. X-ray Diffraction (XRD) is a strong analytical tool for determining a material's crystallographic structure. The crystallinity of ZnO -Kaolin will be examined using an X-ray diffractometer (Bruker AXSGmbH model), the Cu-K radiation will be set at 1.54, and the 2 angle will range from 10-60.

2.3 Reduction Performance of River Water

In order to prepare the membrane sample for the experiment, it will be wetted out by passing distilled water through the MPR at a pressure of 6 bar for a period of thirty minutes. During the permeation or separation trials, the membrane should not get compacted, hence this phase is there to prevent that from happening. For the purpose of stimulating the photocatalyst, ultraviolet light will be installed within the reactor. Both batch and continuous processing of dirty river water may be done in the 2L reactor that was developed for the job. During the trials, ZnO-Kaolin nanoparticles will be introduced into a reactor that is initially filled with dirty river water. The blower will then be used to create bubbles to increase the dissolved oxygen in the mixture. In addition to this, the temperature will be maintained at roughly 25^{o}C by employing a water chiller to recirculate cold water throughout the system [5]. To begin, solutions of hydrochloric acid (HCl) and sodium hydroxide (NaOH) will be employed in order to alter the original pH of the contaminated river water solution. After that, one liter of the solution will be put straight into the reactor to begin the process. After then, 0.05 g/L of ZnO kaolin will be combined with everything else. After the photocatalysis process has been completed, the treated water will be pumped via a masterflex peristaltic pump at a pressure of 6 bar and supplied into the membrane module. The previous procedure will be repeated, but this time with alternative values for the starting pH (5, 7, or 9), photocatalyst dosage (0.04, 0.05, or 0.06 g/L), initial concentration of solution (90, 95, or 100%), and membrane configuration (hollow fiber). The analysis of water quality were salinity, conductivity, TDS and final pH. Moreover, an electronic balance will be used to determine the weight of the permeated volume [3].

3. Results and Discussion

3.1 Characterization of ZnO-Kaolin

The composition of ZnO, kaolin and as-synthesis ZnO-Kaolin prepared using precipitation method were analysed using Fourier Transform Infrared (FTIR). The FTIR spectra of ZnO-Kaolin nanocomposites were calcined at 550°C for three hours after being synthesized as presented in Figure 3.1. The nanocomposites' spectra displayed the distinctive absorption bands of kaolin at around 3,626–3, 696 cm−1 (OH vibration), 796 and 750 cm-1 (Si-O), 560 and 533 cm-1 (Si-O-Al). ZnO was confirmed to be present in the nanocomposites by the absorption peak located at 1633.96 cm 1[6]. It is evident that the FTIR spectra of the ZnO -Kaolin nanocomposites show identical values for clear bands and no peak shift was observed. This was explained by the substantial interaction that existed between ZnO and kaolin within the Ph range that was investigated. This suggests much more of the synergistic effect of ZnO and kaolin sample bonding features [7].

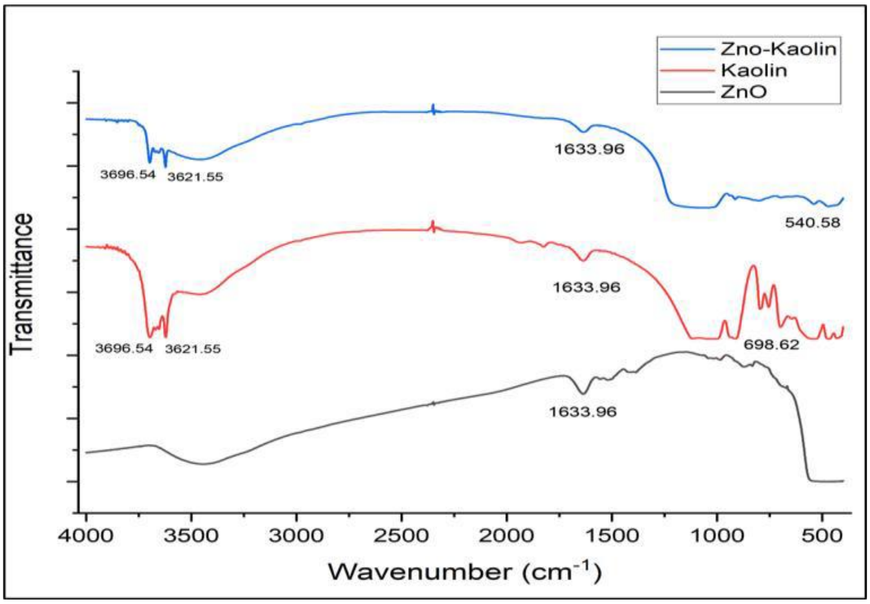

Fig. 2 *FTIR spectra of ZnO, Kaolin and ZnO-Kaolin*

The crystallinity of the ZnO-Kaolin composite refers to how much the crystal structure of the individual parts, zinc oxide (ZnO) and kaolin, remains intact or changes when incorporated. Figure 3.2 depicted the X - ray diffraction (XRD) pattern of the ZnO, kaolin and the as-synthesis ZnO -Kaolin nanocomposites synthesized. It was observed that ZnO possesses high crystallinity peaks at 31. 8°, 34.46°, 36.24°, 47.6° and 56.64°. Those peaks are the identification of ZnO with a hexagonal structure, as observed in FESEM images Fig 3.2 (a). The kaolin significant peaks appeared at 12.34° and 24.88°, both are kaolinite mineral phase [8]. The incorporation of ZnO- kaolin showed peaks corresponding to both ZnO and kaolin. The as-synthesized ZnO -kaolin reduced greatly the crystallinity of naked ZnO, Indicating the successful of the synthesis with the absence of any impurities. The XRD pattern confirmed the effective formation of mixed-phase of kaolin/ZnO nanocomposites [9] also reportedmixed phases of ZnO-Kaolin composites prepared via co-precipitation method [7].

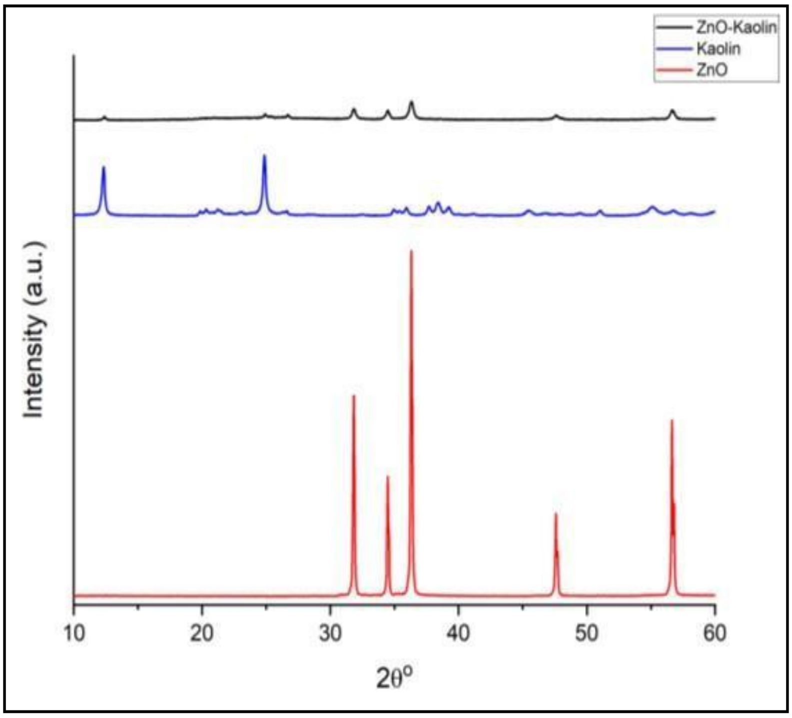

Fig. 3 *XRD spectrum of ZnO, Kaolin, ZnO-Kaolin*

3.2 Effect of Initial pH On the Reduction Performance

Figure 3.3 shown percentage reduction for salinity, total dissolved solids (TDS), conductivity, and final pH at 0.05 g/L dosage. Ph 5 has a higher reduction for salinity followed by pH 9 and pH 7. TDS for pH 5 is also the highest which is 76% followed by pH 9 which is 54% and the lowest is pH 7 which is 46%. Moreover, the conductivity reduction for pH 5 is the highest followed by pH 9 and pH 7. Ph 5 possesses the highest % reduction due to the isoelectric point (pzc) of the ZnO-Kaolin itself. The surrounding pH (pH5) is lower than the pH pzc of the ZnO-Kaolin, creating a positively charged surface. Thus, generating a strong electrostatic force towards negative charge of the water surface molecules [10], resulting in higher percentage reduction compared to other pH. Meanwhile for pH 9, the surrounding pH is higher than the pzc pH, thus surface, causing repulsion forces between them. pH 7 is neutral which equilibrated between slightly negative to neutrally charged molecules. Hence, it neither created weak repulsion forces nor strong electric forces between the molecules and photocatalyst surfaces. Based on figure 3.3 also, pH 5 has a final pH at 6. 4. This is due to the reason of the highestproduction of hydroxyl radical tend to more alkaline pH [10].

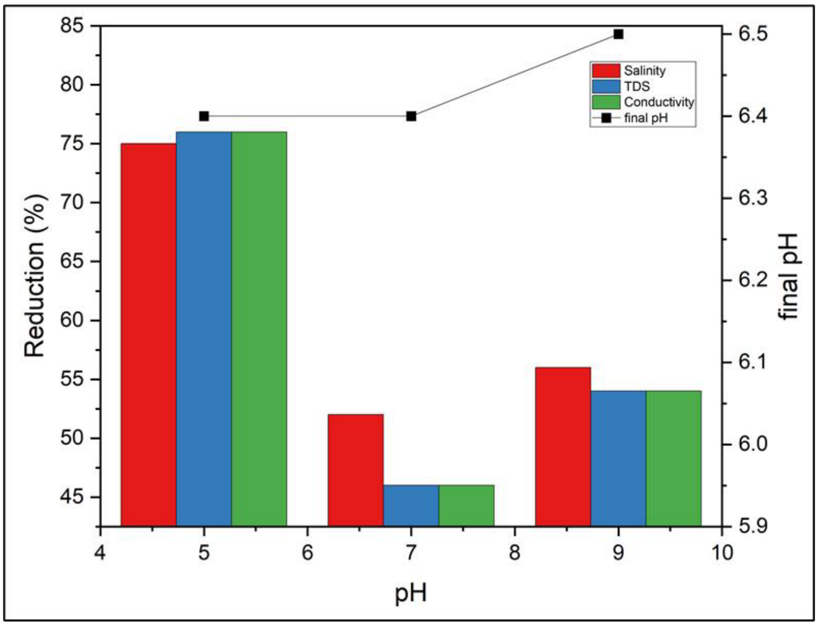

Fig. 4 *Effect of initial pH on the salinity, total dissolve solid (TDS) and conductivity reduction percentage (%) at dosage 0.05 (g/L)*

3.3 Effect of ZnO-Kaolin Dosage On the Reduction Performance

Figure 3.4 shows the effect of ZnO-Kaolin dosing (0.04, 0.05, 0.06 g/L) on the salinity, total dissolved solid (TDS) and final pH. A 0.04 g/L ZnO-Kaolin dosing has the lowest reduction meanwhile dosing 0. 05 g/L has the highest reduction in terms of salinity, TDS and conductivity. ZnO-Kaolin dosing 0.05 g/L was found to be the optimum value in this. The dosage is optimized to ensure that there is sufficient adsorbent present to effectively remove the targeted contaminants. By doing this, the impurities in the water may be eliminated, improving the quality of the water. Dosing 0.06 g/L has lower reduction than dosing 0.05 g/L because the dosage is excessive. It will become less sufficient as the light has limited access to penetrate the photocatalyst. Meanwhile for dosing 0.04 g/L,it is not effective as the reduction is the lowest. The dosage is not sufficient to remove impurities [11].

3.4 Effect of Initial Concentration On the Reduction Performance

Figure 3.5 shows the effect of river water concentration on the salinity, total dissolved solid (TDS) and conductivity reduction percentage (%) at dosage 0.05 (g/L), pH 5. Concentration 100 % has the highest value of reduction compared to concentrations 90% and 95%. The lowest reduction value is concentration 90%. The higher the concentration, the more pollutants to target and remove. Different pollutants behave differently from one another and react differently to different forms of treatment. The particular characteristics of the contaminants determine how concentration relates to one another.

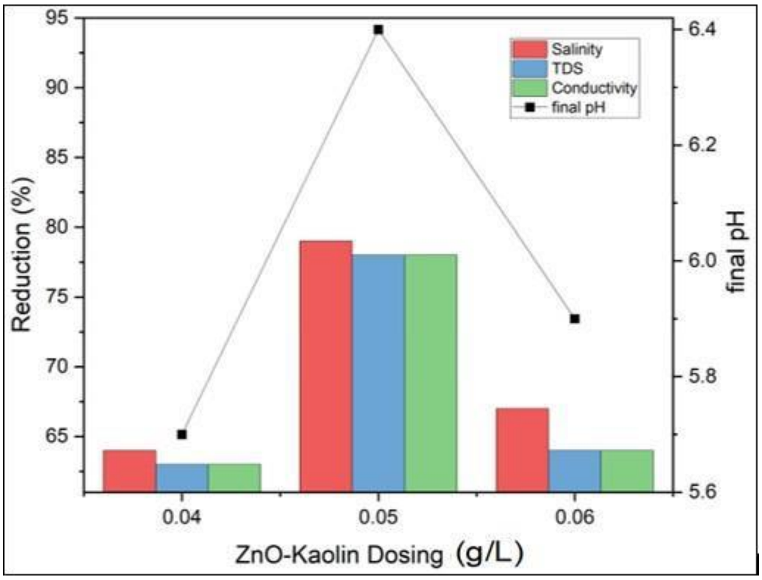

Fig. 5 *Effect of ZnO-Kaolin dosing on the salinity, total dissolve solid (TDS) and conductivity reduction percentage (%) at dosage 0.05 (g/L)*

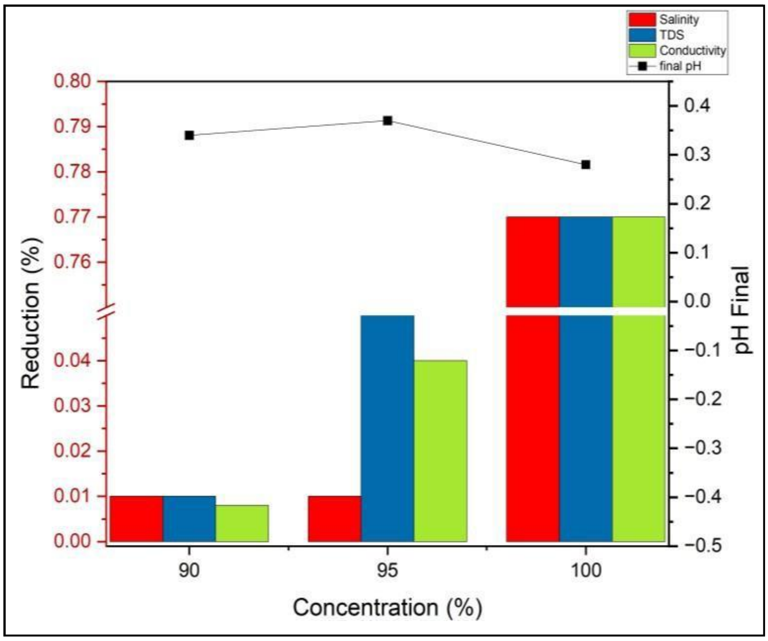

Fig. 6 *Effect of polluted river water concentration on the salinity, Total Dissolve Solid (TDS) and conductivity reduction percentage (%) at dosage 0.05 (g/L)*

4. Conclusion

In conclusion, a membrane photocatalytic reactor (MPR) using ZnO-Kaolin has showed promise in treating contaminated river water as the new approach uses membrane filtration and photocatalysis to clean water. The effective ZnO-Kaolin photocatalyst synthesis laid the groundwork for the study's next steps. MPR has shown that synthesized ZnO-Kaolin degrades polluted river water; the photocatalyst is effective. Comprehensive characterization and measurement of treated contaminated river water revealed the best water quality analysis: pH 5, ZnO-Kaolin 0. 05 g/mL, and 100% river water concentration. This proves that the ZnO-Kaolin photocatalyst improves treated water. In summary, treated river water is safe for daily consumption.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: study conception and design: Wan Haikal Fitri Wan Ahmad Rizalle, Rais Hanizam Madon; data collection Wan Haikal Fitri Wan Ahmad Rizalle; analysis and interpretation of results: Siti Nurfatin Nadhirah Mohd Makhtar, Mohamad Alif Hakimi Hamdan, Nur Hanis Hayati Hairom; draft manuscript preparation: Nor Afzanizam Samiran, MZahar Abd. Jalal. All authors reviewed the results and approved the final version of the manuscript.

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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