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Immobilized/P25/DSAT and Immobilized/Kronos/DSAT on Photocatalytic Degradation of Reactive Red 4 Under Fluorescent Light

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Abstract. In this work, photocatalytic degradation of Reactive Red 4 (RR4) using immobilized P25 and kronos were performed under fluorescent light sources. The photocatalysis activity for both catalysts was investigated under fluorescent lamp source which consist UV and Visible light. The effect of various parameters such as initial concentration, initial pH and strenght of immobilized plate were studied. The result showed that 90% of RR4 dye was degrade in 1 hr using immobilized/kronos/DSAT at 100 mg L^{-1} of RR4 dye while 81% degradation was achieved by immobilized/P25/DSAT at the same condition. The lowest pH showed the higher photocatalytic activity. Hence, the effect of dye concentration and pH on the photocatalysis study can be related with the behavior of environmental pollution. The low strength showed by immobilized/P25/DSAT where it remain 37 % as compared with strength of immobilized/kronos/DSAT (52 wt.%). For the future work, the polymer binder like Polyvinyl alcohol (PVA), Polyethylene glycol (PEG), and others polymers can be apply in immobilized study to overcome the strength problem.

1 Introduction

The development of rapid industrialization in this world will contribute toward the major pollutant. Furthermore, organic dyes are one of the main industrial wastewater pollution. Despite the industrial are already schemes the various treatment to combat the pollutant unfortunately, the decrease in levels for specific pollutants has not been achieved. This environment problem of wastewater is significant focus by researcher to study toward effective removal and degradation processes [1-3]. The common biological processes of degradation and discoloration on modern dyes are ineffective because of high degree of aromatic groups in dye molecules [4]. The traditional physical methods such as using filtration, reverse osmosis, active carbon and coagulation are costly. Recently, Heterogenous photocatalysis have gained much attention toward the degradation of water pollution through complete mineralization. heterogenous photocatalysis is the process basically based on generates the hydroxyl radical which is highly oxidizing agents. This hydroxyl radical will oxidize the organic pollutants into harmless product. The combination between semiconductor photocatalyst and light sources is the key process of photodegradation. Among of the semiconductor, titanium dioxide (TiO_2) is the most popular and widely used by researchers due to the chemically stable, low cost, non-toxic,

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reusable and its high photocatalytic activity [5, 6]. This material consist a wide band gaps between 3.0 eV to 3.2 eV which require the UV light irradiation. In this work, photocatalytic degradation of RR4 was studied using immobilized P25 and kronos VLP 7000 under fluorescent light illumination. Herein, RR4 was selected as model pollutant for degradation study. Subsequent experiments were conducted to investigate the effect of parameter of P25 and kronos on the photodegradation of RR4. The effect of initial dye concentration, initial pH on degradation of RR4 was investigated. Otherwise, strength of P25 and kronos on glass plate was investigated.

2 Experimental

2.1 Materials

P 25 TiO_2 (particle size: 20 nm, BET surface: 60 m^2 g^{-1}). P 25 was supplied by Evonic-Aeroxide. Kronos VLP 7000 TiO_2 (BET surface: 250 m^2 g^{-1}) was provided by Kronos International Inc, Hydrochloric acid (HCl) and sodium hydroxide (NaOH) from R&M chemical were used in this study. Reactive red (RR4) dye or commonly known as Cibacron Brilliant Red (Colour Index Number: 18105, chemical formula: $C_{32}H_{23}ClN_8Na_4O_{14}S_4$, molecular weight: 995.23 g mol^{-1}, λ max: 517 nm). Ultra-pure water was used to prepare all solutions in this work.

2.2 Methods

2.2.1 Preparation of immobilized P25/DSAT and kronos/DSAT and photodegradation study

Typically, TiO2-P25 solution was prepared by mixing 13 g of N doped TiO2 with 100 ml of distilled water in 250 ml reagent bottle. The solution was undergoing shaking process for 30 minutes using orbital shaker model PSU-20i, Grant-bio to make it homogenize. P25 solution was then coated (immobilized) by using brush technique and DSAT was stacked onto glass plate with a dimension of 13 x 4.8 cm (L x H) prior coated with N-TiO2. The glass cell with immobilized/P25/DSAT was then dried in the oven at 100 °C for 20 minutes. A dried immobilized/PS25/DSAT sample was cleaned by using distilled water under irradiated of 55-W fluorescent lamp model Qusun E27, 6400K in aerated condition for 1 hour prior to photocatalytic degradation.

The experimental was repeated by using kronos VLP 7000. Photocatalytic degradation study for immobilized was carried out by 25 ml of 100 mg L-1 of anionic RR4 dye was poured into a glass cell with a dimension of 150 cm × 10 mm × 80 mm (L×B×H). Immobilized TiO2 was then transfer into glass cell containing RR4 dye and irradiated with a 55 Watt fluorescent lamp at specific time interval until it turns colourless. An aquarium pump model NS 7200 was used as an aeration source to supply oxygen.

2.2.2 Effect of initial dye concentration, initial pH, on the immobilized kronos

Four sets of RR4 dye with different concentrations (100, 200, 300 and 400 mg L^{-1}) were used as the model pollutant in order to study the effect of concentration of the RR4 dye on the photocatalytic efficiency of the photocatalyst. For pH study, a series of 100 mg L-1 RR4 dye solutions at different initial pH values were used. The pH of each solution was adjusted to values of about 1, 3, 8 and 10 using 1 M NaOH and 1 M HCl solutions. The respective immobilized of the catalyst within the dye solutions was then irradiated with 55 Watt fluorescent lamp for 1 hour. Aliquots were taken at every 15 minutes time interval. The concentration of the remaining RR4 dye was measured spectrophotometrically using HACH DR1900 spectrophotometer.

2.2.3 Effect of strength immobilized P25 and kronos

The strength study was carried out by measuring the remaining weight in immobilized/P25/DSAT and immobilized/kronos/DSAT sample after sonication process with ultrasonic bath Cress Ultrasonic, Model 4HT-1014-6.

3 Results and Discussion

3.1 Photocatalytic activity of immobilized/P25/DSAT and immobilized/kronos/DSAT

Figure 1 shows plot of ln (C/C_0) vs. time of immobilized/P25/DSAT and immobilized/kronos/DSAT. This investigation was carried out by using immobilized P25 and kronos under fluorescent lamp. Based on result, it was observed that 90% of degradation of the RR4 was achieved by kronos/DSAT in 1 hr. Meanwhile, about 81% degradation of RR4 was contributed by P25/DSAT in 1 hr. Kronos VLP 7000 contain C-doped TiO_2 and it also known as visible light photocatalyst. Previous study claimed that the band gap of kronos VLP 7000 is around 2.32 eV meanwhile band gap for TiO_2 P25 is around 3.0-3.2 eV [7, 8].

Thus, it can be claimed that the immobilized kronos was degrade the RR4 dye under visible light region and UV light region resulting in more photogenerated electrons and holes thereby will increase the photocatalytic activity. The surface area also play an important role toward the decolorized the RR4 dye since kronos consist high surface area 250 m^2 g^{-1} resulting more absorption of energy enhancing the photocatalytic activity .

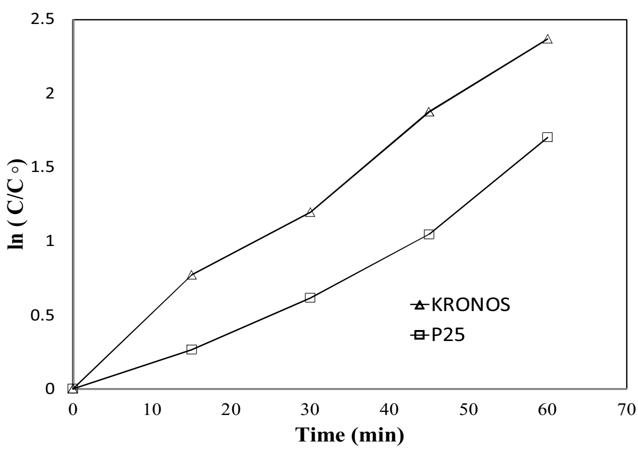

Figure 1. ln (C/C_0) vs. time of immobilized/P25/DSAT and immobilized/kronos/DSAT.

3.2 The effect of initial dye concentration and initial pH on the photocatalytic efficiency of immobilized/kronos/DSAT.

The effect of initial dye concentration on the photocatalytic efficiency of immobilized sample is shown in Figure 2(a). As expected, the photocatalytic activity of RR4 dye decreased with increasing RR4 dye concentration where the highest photocatalytic activity occurred for 100 mg L^{-1} concentration of RR4 dye solution. This phenomenon caused by the color of solution becomes more intense while increasing the concentration of solution. The light of fluorescent lamp was retarded to penetrate into the surface of TiO_2 resulting in reducing the formation of OH• and O_2• radicals thereby decreasing the photogenerated of electrons and holes. Figure 2(b) shows the rate of the photodegradation of RR4 under immobilized/kronos/DSAT at different pH conditions as a function of the irradiation time. As a result showed that the photocatalytic degradation increase with decreasing the pH value. At pH 1-3, a significantly high electrostatic attraction exists between negatively charged anionic dyes which is RR4 and positively charged surface of the TiO_2 kronos . This phenomenon is due to the amphoteric behavior of the TiO_2 semiconductor. The potential at zero charge of TiO_2 surface is at pH_{pzc}= 6.80 [9, 10]. The surface charged of TiO_2 is positively charged in acidic PH (PH<6.8) and negatively charged in alkaline pH (pH>6.80). As a consequence of TiO_2 surface above pH ~ 6.8 is negatively charged hence repulsive force dominates between negative TiO_2 surface and RR4 anions. So the basic pH (pH 8-10) will cause poor degradation of RR4 molecules.

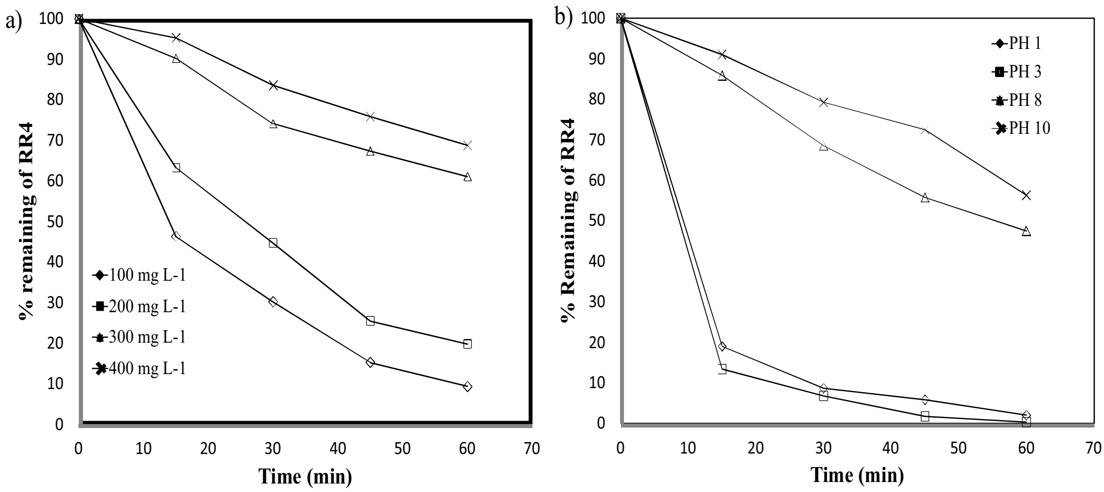

Figure 2. Photocatalytic degradation at different initial concentration: (a) and initial pH, (b) of RR4 using immobilized/kronos/DSAT sample irradiated with 55 Watt fluorescent lamp.

3.3 Effect of strength of immobilized/P25/DSAT and immobilized/kronos/DSAT

TiO_2 layer in immobilized/P25/DSAT is only remain 52 wt.% meanwhile, the result showed by immobilized/kronos/DSAT is only remain almost 37 wt.% after sonication process at strength test as can be seen in Figure 3. It is well expected because no binder was applied on entire immobilization system. But, the immobilized TiO_2 by using DSAT as a thin layer binder significantly improved the photocatalytic degradation rate of RR4.

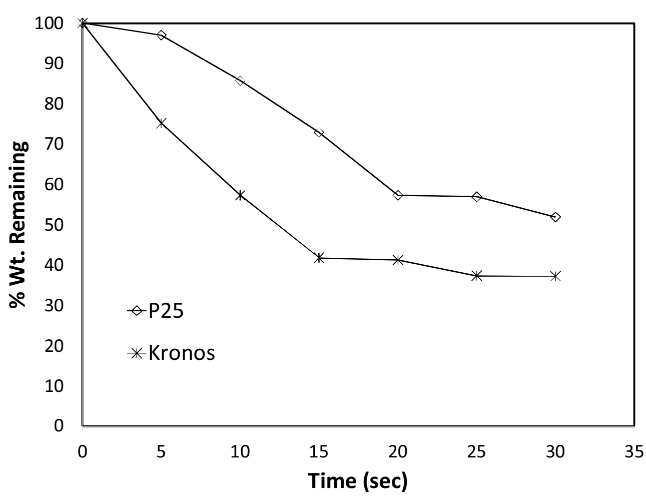

Figure 3. Effect of strength on immobilized/P25/DSAT and immobilized/kronos/DSAT under sonication process.

4 Conclusions

In this work,the comparative study was done for photocatalytic degradation of RR4 using TiO_2kronos VLP 7000 and TiO_2 P25. The immobilized technique was successfully applied this work. The initial pH has significant effect on photocatalytic degradation. The result showed that the photodegradation anionic RR4 is more active toward the acidic pH due to the amphoteric behavior of TiO_2. The ability of kronos VLP 7000 to enhanced photocatalytic degradation under visible light that related with high surface area was showed higher photocatalytic activity than P25. It was observed that 90% and 81 % of degradation was achieved by kronos VLP 7000 and P25 in 1 hr respectively under fluorescent lamp. Less strength showed by immobilized/kronos/DSAT when test on sonication process compared to the layer of coated P25. This research studies will contributed toward the eco-environmental that can be great potential to becoming preliminary treatment of wastewater especially for dyes industries. This strength study of immobilized can be proved that its can be purify contaminated water continuosly since the P25 and kronos can intact even not strong enough intact on the glass plate. Hence, the polymer binder like Polyvinyl alcohol (PVA), Polyethylene glycol (PEG), and others polymers can be apply for future work of immobilized study to overcome the strength problem.

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