

An Effective and Low-Cost TiO₂/Polystyrene Floating Photocatalyst for Environmental Remediation

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ABSTRACT: A floating polymer-supported photocatalyst based on polystyrene impregnated with titanium dioxide particles was developed using a facile solvent-cast method at ambient temperature. The prepared photocatalysts were characterized by X-ray diffraction, scanning electron microscopy and fourier transform infrared spectroscopy. The photocatalytic activity of the developed photocatalysts was investigated using methylene blue dye. The prepared polystyrene-supported titanium dioxide photocatalysts successfully removed color from the aqueous solution without any additional pH adjustment under ultraviolet (254 nm) irradiation and non-stirred, non-anchored conditions. The maximum color removal achieved by the optimized photocatalyst (10 weight percent loading of Degussa P25 with respect to amount of polystyrene) was around 93% after 7.5 h of ultraviolet light exposure. Further, the photocatalyst sheets were also tested for recovery and reuse. The efficiency of color removal achieved by the optimized photocatalyst on reuse was in the range of 99–100%. The developed photocatalyst seems to be a promising candidate that can be further investigated for large scale commercial applications.

Key words: TiO₂ photocatalyst, Polystyrene, Impregnated, Methylene blue, Buoyant

INTRODUCTION

Heterogeneous photocatalysis using semiconductor titanium dioxide (TiO₂) has emerged as one of the most efficient techniques in advanced oxidation processes (AOPs) that is being used for removal of recalcitrant contaminants present in wastewater. This is attributed to the well-known unique properties of TiO₂ (Singh *et al.*, 2013). TiO₂, also known as titania, is one of the most investigated and efficient photocatalysts finding use in a wide range of applications such as air purification, photo-induced hydrophilic coating and self-cleaning devices, self-sterilization, wastewater treatment and production of hydrogen fuel (Singh *et al.*, 2013). In spite of the significant progress made in the development of TiO₂ photocatalysts, their commercialization in environmental remediation is still hindered due to the costly and time consuming post-treatment recovery of the very fine TiO₂ particles (Yang *et al.*, 2006; Zeng, 2011; Pelaez *et al.*, 2012). To overcome this limitation, extensive research is being carried out to immobilize TiO₂ on various substrates such as hollow glass spheres, reactor walls (Fabiya & Skelton, 2000), inorganic carbon fabrics (Yuranova *et al.*, 2004), glass mats (Dhananjeyan *et al.*, 2001), synthetic fabrics (Bozzi

et al., 2005), natural fabrics (Yuranova *et al.*, 2006) and polymers (Yang *et al.*, 2006). The methods for fixing titania particles on the chosen substrate may vary from as simple as dip-coating, or sol-gel techniques (Singh *et al.*, 2013) to more complex, specialized and expensive methods like electrophoretic deposition (Djoic *et al.*, 2006) chemical vapor deposition (Kuo *et al.*, 2007), thermal treatment method (Tennakone *et al.*, 1995; Fabiya & Skelton, 2000), hydrothermal methods (Liu & Chen, 2007) and flame-synthesis (Kammler *et al.*, 2001). In this work, a simple method has been used to develop an effective floating photocatalyst by impregnating polystyrene (PS) substrate with TiO₂ particles without the need for any thermal treatment. The objective was to develop a photocatalyst, which being buoyant can be used directly at the water surface under UV light and/or solar irradiation. Buoyant polymer-supported TiO₂ photocatalysts offer several advantages such as: (i) they can utilize light radiation directly and to a fuller extent without any light attenuation; (ii) they can be applied directly to various applications and thereby, eliminate the need of any special equipment or installation; (iii) being buoyant they have greater discoloration efficiencies in destroying suspended

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insoluble organic contaminants; (iv) their proximity with the air/water interface would enhance oxygenation of the photocatalyst—a prerequisite for an efficient photocatalytic process and (v) their post-treatment recovery is simpler (Magalhaes & Lago, 2009; Han & Bai, 2010; Magalhaes *et al.*, 2011).

PS is a readily available, cheap, inert, non-toxic and low density thermoplastic polymer that is widely used in food service and retail industry (Fa *et al.*, 2013). Furthermore, being a hydrophobic material, PS has an added advantage to pre-concentrate the organic pollutants on its surface thereby, increasing the efficiency of adsorption and subsequent oxidation of the contaminants (Magalhaes *et al.*, 2011). Little work on floating photocatalysts and still fewer research works on PS-supported floating TiO₂ photocatalysts have been reported. There are some published works that are based on PS as a support for anchoring titania particles (Dutschke *et al.*, 2003a; Dutschke *et al.*, 2003b; Shang *et al.*, 2003a; Shang *et al.*, 2003b; Doong *et al.*, 2007; Fa *et al.*, 2008; Altın & Sokmen, 2014). Dutschke *et al.* (2003a, 2003b) in their studies have used pre-treated PS substrate for depositing partially crystalline TiO₂ using liquid phase deposition technique. In another work, Doong *et al.* (2007) have used PS both as a filler and as a template for developing an ordered TiO₂ porous film. Some researchers have used PS to immobilize titania particles so as to bring about degradation of the polymer itself (Shang *et al.*, 2003a; Shang *et al.*, 2003b, Fa *et al.*, 2008; Fa *et al.*, 2013). On the other hand, other researchers have also used TiO₂/PS photocatalysts in order to bring about photodiscoloration of organic contaminants such as methylene blue (MB) (Fabiya & Skelton, 2000; Magalhaes & Lago, 2009; Altın & Sokmen, 2014). For instance, Shang *et al.* (2003a) prepared TiO₂ photocatalyst by sol-gel method and subsequently immobilized it on waste PS substrate in order to degrade the polymer itself. Shang *et al.* (2003b) also investigated the solid-phase photocatalytic oxidation of PS over copper phthalocyanine sensitized TiO₂ photocatalyst under fluorescent light. Recently, Fa *et al.* (2013) prepared nanocomposites by embedding TiO₂ and ferric stearate into commercial PS while in another study, Fa *et al.* (2008) prepared the photodegradable nanocomposites by embedding TiO₂ and iron (II) phthalocyanine into commercial PS. The solid-phase photocatalytic degradation of the polymer was investigated under UV light in the former work and under both UV as well as natural sunlight in the latter study. Fabiya & Skelton (2000) developed a thermal treatment procedure for immobilizing titania nanoparticles on PS beads and investigated its photocatalytic activity (PCA) by studying the decolorization of MB dye. The photodecolorization

rates were found to increase (0.15 - 0.25 mmol/min) with an increase in the concentration of the catalyst (0.6-7.2 g/L of MB solution) at a pulsing frequency of 60 rpm and air flow rate of 200 cm³/min. Magalhaes & Lago (2009) grafted TiO₂ P25 particles on expanded polystyrene (EPS) beads. The percentage discolorization of the three dyes, namely, drimaren red (DR), indigo carmine (IC) and MB, undertaken for investigating the PCA was found to be about 30%, 60% and 50% respectively after 240 min of UV irradiation (254 nm). Adopting the thermal treatment method as developed by Fabiya & Skelton (2000), anatase TiO₂ particles were immobilized on waste PS beads by Altın & Sokmen (2014). While investigating the PCA, it was found that almost total removal of MB dye (3 mg/L, 15 mL) was achieved at pH = 6 under 2.5 h of UV illumination (365 nm, Spectroline ENF-260). There are a few published works that have employed solvent-cast method to anchor titania particles into the polymer matrix (Sriwong *et al.*, 2008; Sivlim *et al.*, 2012). For instance, Sriwong *et al.* (2008) impregnated natural rubber latex with TiO₂ particles and evaluated the PCA of the prepared photocatalysts by studying the photocatalytic degradation of MB dye (2.5 x 10⁻⁵ M, 60 mL). It was found that 99.67% degradation of the dye was achieved in 5 h under UV irradiation (100 W) employing stirred conditions. Sivlim *et al.* (2012) employed solvent-cast process to immobilize anatase TiO₂ particles into a biodegradable polymer, polycaprolactone. The produced TiO₂ immobilized polymer could achieve around 60% total removal of organic contaminant, 4-chlorophenol (7.78 x 10⁻⁴ M, 5 mL) in 150 min of UV (365 nm) irradiation. In both the above mentioned works (Sriwong *et al.*, 2008; Sivlim *et al.*, 2012), the developed photocatalysts were non-buoyant unlike as presented in the current research paper.

The solvent-cast method employed in this study does not require thermal treatment unlike that suggested in some of the previously published works (Fabiya & Skelton, 2000; Altın & Sokmen, 2014). The location of the titania particles inside the PS matrix precludes the leaching of fine titania particles from the photocatalyst and thus eliminates the need of employing cumbersome post-treatment techniques for their separation. The stability and robustness of the developed photocatalyst when compared with the research works in which TiO₂ particles are attached thermally onto the surface of PS or EPS beads (Fabiya & Skelton, 2000; Altın & Sokmen, 2014) makes it a promising candidate to be explored. The current method also leads to uniform distribution of TiO₂ particles in the PS matrix and thus scores over the method as adopted by Altın & Sokmen (2014) where they have reported that the addition of TiO₂ on PS

beads resulted in an uneven surface that contained aggregated TiO_2 particles. The PCA of the prepared photocatalysts was investigated by studying the photocatalytic discoloration of MB dye, a model contaminant in aqueous solution under UV irradiation without any additional pH adjustment employing non-stirred and non-anchored conditions. MB (C.I. 52015), is a heterocyclic aromatic chemical compound and a potent cationic dye which is commonly used in printing and dyeing industries. Although MB does not pose a severe hazard yet acute exposure to it can cause skin irritation, vomiting, cyanosis, quadriplegia, heinz body formation, permanent eye injury to both human and aquatic animals. It can also lead to irritation of gastrointestinal tract (Sahoo *et al.*, 2012). The PCA of MB has been extensively studied in several research articles and thus, its selection for our work would assist researchers in making a convenient correlation as well as comparison with those works. The reusability of the developed photocatalysts was also investigated as it a vital parameter to be considered for large scale industrial applications.

The focus of the present study was to develop an effective PS-supported photocatalyst with a vision to utilize the same method in near future for fabrication of TiO_2 photocatalyst supported on abundantly available PS waste. This waste PS plastic which leads to “white pollution” due to its non-biodegradability in natural environment is a major concern to the environmentalists all over the world. Therefore, by adopting a similar method as suggested in this paper, the waste PS which cannot be recycled can be used as a substrate for developing TiO_2 photocatalysts. In this manner, the ever increasing PS contaminant can be utilized judiciously to degrade or completely remove other pollutants present in the environment.

MATERIALS & METHODS

The chemicals used in this study were: TiO_2 (Degussa P25) from Evonik Degussa AG, Germany; PS beads from Sigma-Aldrich; Xylene (GR) from Merck India Limited; MB obtained from Merck India Limited and used without further purification; HCl and NaOH, obtained from Merck India Limited. Double distilled water was used throughout the study. The instruments used in the study were: ELICO SL159 UV-Vis spectrophotometer, PANalytical X’pert PRO X-ray diffractometer, Mirero Inc. AIS-2100 scanning electron microscope (SEM), Thermo Nicolet-Avatar 370 fourier transform infrared (FTIR) spectrometer, Philips UVC lamp (5 x 20 W), Remi magnetic stirrer, Remi R-8C laboratory centrifuge, Systronics digital pH meter and Sartorius BSA423S-CW electronic precision balance. The buoyant PS-supported TiO_2 photocatalysts were prepared at room temperature ($25\text{ }^\circ\text{C} \pm 2\text{ }^\circ\text{C}$) by using

solvent-cast method as subsequently described. PS beads (5.0 g) were completely dissolved in 20 mL of xylene. To the required amount of TiO_2 Degussa P25 (as calculated with respect to a particular weight percent (wt%) based on the amount of the polymer used), another 20 mL of xylene was added and stirred vigorously for 20 min using a magnetic stirrer. Thereafter, the PS solution was carefully and slowly added to TiO_2 suspension and further stirred at high speed for 30 minutes. Aliquots (10 mL) of TiO_2 -PS-xylene suspension were casted in glass petri dishes (85 mm diameter) and these dishes were placed in a fume hood at room temperature in the dark to allow slow evaporation of the solvent. The dried polymer films were carefully removed from the petri dishes, flipped and further dried at room temperature for 24 h. Thereafter, the polymer sheets were washed with double-distilled water, dried and stored in dark until use. The obtained PS sheets impregnated with TiO_2 powder corresponding to 1 wt% were designated as PSPC (I-1). Adopting a similar method as described above, PSPC (I-5), PSPC (I-10), PSPC (I-15) and PSPC (I-20) sheets were also prepared by varying the amount of TiO_2 Degussa P25 from 5 to 20 wt% relative to the weight of PS used. An illustration of the impregnated photocatalyst (PSPC (I-10)) is provided in Fig. 1.

To identify and confirm the crystalline phases of TiO_2 Degussa P25 and PSPC (I) sheets, XRD analyses with X-ray diffractometer using Cu K α radiation ($\lambda = 0.154056\text{ nm}$) were performed. For analysis, the (1 0 1) diffraction peak with $2\theta = 25.334^\circ$ of anatase and (1 1 0) peak with $2\theta = 27.967^\circ$ of rutile were used. The average crystallite size of the particles was calculated using Scherrer’s equation (Behnajady & Eskandarloo, 2013).

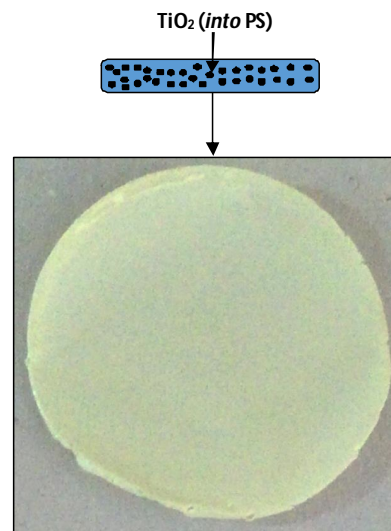


Fig. 1. Illustration of impregnated photocatalyst [PSPC (I-10)]

Density measurements for all the prepared PSPC (I) sheets were also done so as to establish their buoyancy.

The surface morphologies of the TiO₂ Degussa P25 powder, pristine PS sheet, and PSPC (I-10) sheet (before and after UV exposure) were observed by using SEM. To investigate whether or not the PS surface was attacked by the radicals, i.e. surface deformation during UV light exposure, FTIR analyses of the pure PS sheet before UV exposure and PS sheet placed in distilled water after 8 h of UV exposure (100 W, 254 nm) were carried out. Further, to establish the stability of the prepared photocatalysts in UV light, FTIR of the buoyant PSPC (I-10) sheet before UV exposure and PSPC (I-10) sheet placed in MB solution after 8 h of UV exposure was also carried out.

The PCA of the prepared PSPC (I) sheets was investigated by the discoloration of MB dye in its aqueous solution under UV light (254 nm) at the dye's natural pH of 7.68 (concentration = 1.56×10^{-5} M). For studying the PCA, complete PSPC (I) sheets namely PSPC (I-1), PSPC (I-5), PSPC (I-10), PSPC (I-15) and PSPC (I-20) were placed in separate petri dishes (100 mm diameter) and 50 mL of MB solution having a concentration of 5 mg/L was poured into each of them. The solutions were neither stirred nor were the photocatalysts anchored. This was done in order to facilitate the use of floating photocatalysts. Prior to irradiation, the solutions were kept in dark for 2 h to reach adsorption-desorption equilibrium. Thereafter, the solutions were irradiated with UV light for 7.5 h. For this purpose, a laboratory constructed irradiation system (Fig. 2) consisting of a wooden box fitted with five UVC tube lights (20 W) at fixed positions on top so as to provide only surface illumination was used. During this study, the highest intensity of UV light (100 W) was used. The approximate distance from the liquid surface in the petri dish to the UV tube lights was 14 cm. During the experimental runs, 5 mL of dye solutions were collected at regular time intervals and

analyzed with the help of UV-Vis spectrophotometer at λ_{\max} (wavelength for maximum absorbance) value of 664 nm. The solutions were returned to the petri dish after each analysis so as to maintain the same volume of MB solution. Two controlled experiments were also conducted: one with only MB solution and the other with pristine PS sheet placed in MB solution. For studying the effect of pH on the PCA of impregnated photocatalysts, PSPC (I) sheets were subjected to test under varying pH (from 3 to 11) conditions. For varying the pH of the dye solution, 0.1 M of HCl and NaOH solutions were used.

The absorbance values obtained by UV-Vis spectrophotometer were used to determine the concentration of MB solution quantitatively with the help of a calibration graph ($R^2 = 0.9966$) constructed for MB from its standard solutions prepared at various concentrations.

RESULTS & DISCUSSION

The XRD analyses (Fig. 3) of pure TiO₂ Degussa P25 and the PSPC (I) sheets, namely PSPC (I-1), PSPC (I-5) and PSPC (I-10) showed very similar diffraction patterns. The peaks obtained at 2θ of 25.305°, 48.038°, 53.892°, 55.062° and 62.690° in case of TiO₂ powder and 25.334°, 48.103°, 53.919°, 55.136° and 62.751° in case of PSPC (I-5), PSPC (I-10) illustrates that both TiO₂ Degussa P25 powder and PSPC (I) samples have anatase crystalline structure (JCPDS card no. 84-1285 and 83-2243 respectively). These results clearly suggest that no change in the crystal structure of TiO₂ was produced during the preparation of the photocatalyst. The anatase crystallite size for both TiO₂ powder and PSPC (I) nanoparticles was approximately 14 nm as calculated from their respective XRD patterns.

A large broad peak near $2\theta = 20^\circ$ is observed in the diffraction patterns of all the impregnated TiO₂/PS photocatalyst samples. This can be attributed to the scattering of the X-ray by the polymer. It can also be

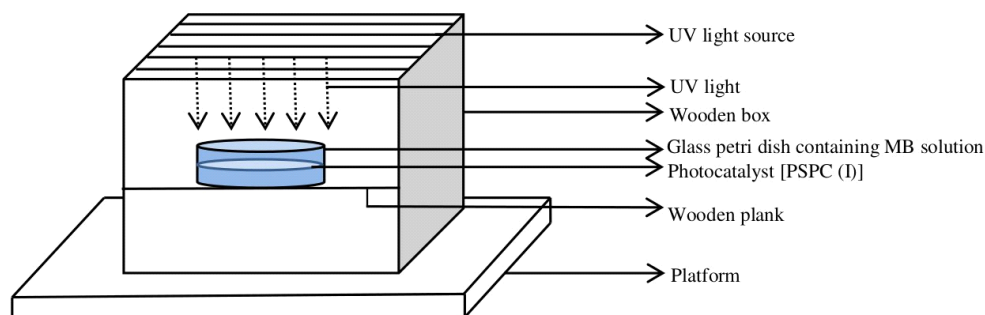


Fig. 2. Schematic diagram of the experimental setup used for investigating the photocatalytic discoloration of MB dye under UV irradiation

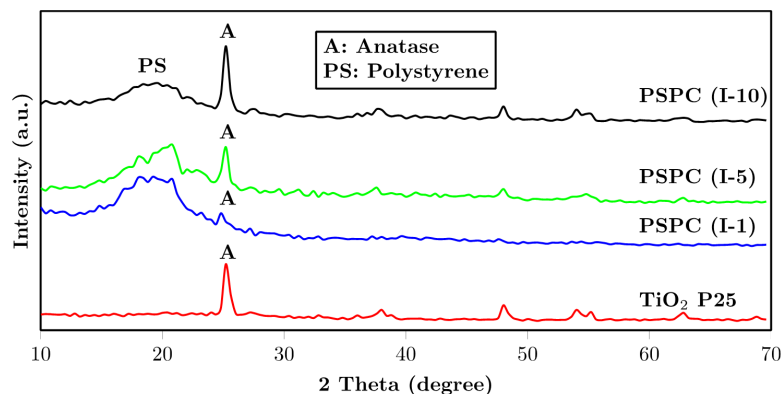


Fig. 3. XRD patterns of TiO₂ P25 and impregnated TiO₂/PS photocatalysts

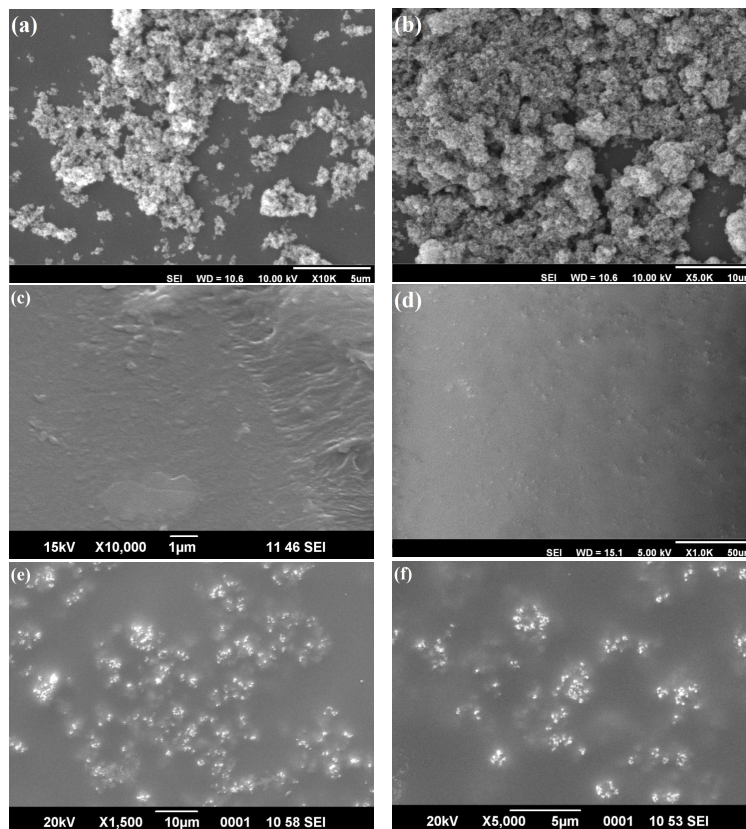


Fig. 4. SEM images of (a-b) TiO₂ P25 nanoparticles, (c) Pristine PS sheet, (d) PSPC (I-10) sheet before UV exposure and (e-f) PSPC (I-10) sheet after UV exposure

seen that as the amount of TiO₂ particles increases, the average matrix of the PS also increases which lead to less scattering of the X-ray. The density of all the prepared TiO₂/PS photocatalysts was found to be in the range of 0.8–1 g/cm³. During the experimental runs, it was observed that some of the PSPC (I) sheets were neutrally buoyant. The SEM images of pure TiO₂ P25 powder [Fig. 4(a-b)] show an aggregated, sponge-like, porous structure having a high degree of roughness. The surface morphology of pristine PS sheet [Fig. 4(c)] is smooth in appearance. The SEM image of PSPC

(I-10) [Fig. 4(d)] suggests dispersion of titania particles into the polymer matrix. Furthermore, it is clear that the TiO₂ particles are embedded in the PS matrix. The SEM images of photoirradiated impregnated photocatalyst are shown in Fig. 4(e-f). These images reflect that the TiO₂ particles remain embedded into the polymer matrix even after being exposed to the UV light. Thus, no significant change in the morphology of the impregnated sheet is observed after the UV irradiation process.

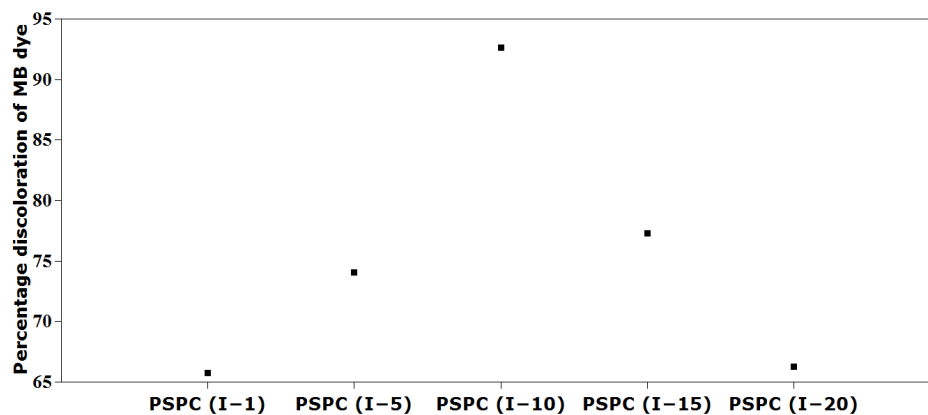


Fig. 5. Photocatalytic discoloration of MB from its aqueous solution by PSPC (I) samples after 7.5 h of UV irradiation

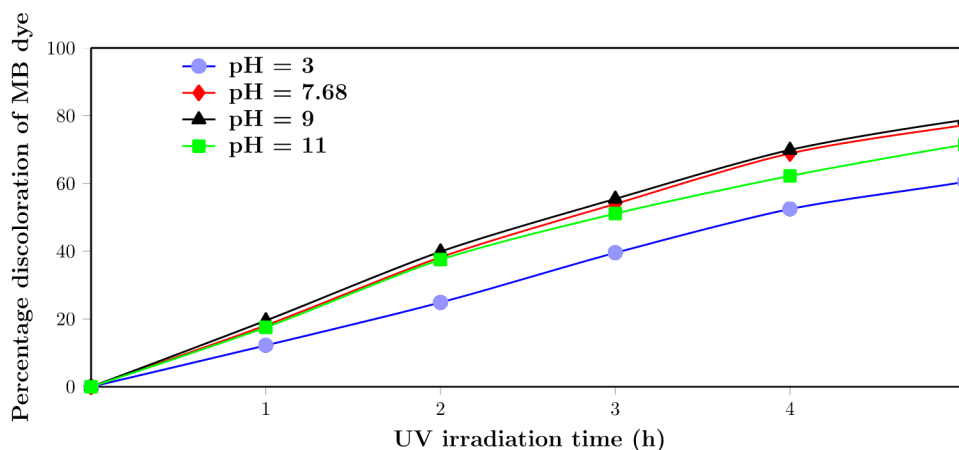


Fig. 6. Investigating the photocatalytic activity of [PSPC (I-10)] sheet under varying pH conditions

The photocatalytic studies were carried out by investigating the discoloration of MB by the impregnated samples under UV light. The percentage color removal of MB from its aqueous solution by the various PSPC (I) samples after 7.5 h of UV irradiation is illustrated in Fig. 5. It must be noted that the percentage color removal of the MB signifies its removal by both, adsorption as well as photocatalytic discoloration. It was observed that all the prepared impregnated samples could remove more than 65% of MB color in the solution, with the maximum discoloration of around 93% achieved by the PSPC (I-10) sample. Hence, the PSPC (I-10) sample was chosen as the representative sample of all prepared impregnated photocatalysts for characterization by SEM, FTIR and for further experimental studies. A slight discoloration of MB was also observed in blank experiments which could be attributed to the high intensity of light irradiation employed and the adsorption of the dye molecules by the pure PS sheet. For comparison, the photocatalytic discoloration by 0.05 g (loading amount = 1g/L) of pure

TiO₂ P25 in slurry form was also investigated and it was observed that the slurry form completely decolorized the MB in solution within 1 h of UVC illumination. This could be attributed to the greater surface area offered by the photocatalyst in powder form as compared with the supported forms. The effect of varying the pH on the PCA of the developed photocatalysts is shown in Fig. 6. It can be observed that the discoloration process was greater in alkaline conditions than acidic conditions. This is because in an alkaline solution, the pH > pzc (point of zero charge (= 6.8)) of TiO₂ (Kasanen *et al.*, 2011). Therefore, the surface of TiO₂ is negatively charged and hence, the adsorption of cationic MB dye parent fragment is favored. In case of an acidic medium, the pH < pzc of TiO₂ and so due to electrostatic repulsion between positively charged TiO₂ surface and the dye parent fragment, the adsorption of the latter and hence the PCA is retarded. The removal percentages of MB were found to be almost similar for the dye at its slightly alkaline natural pH and higher pH value (= 9). Therefore,

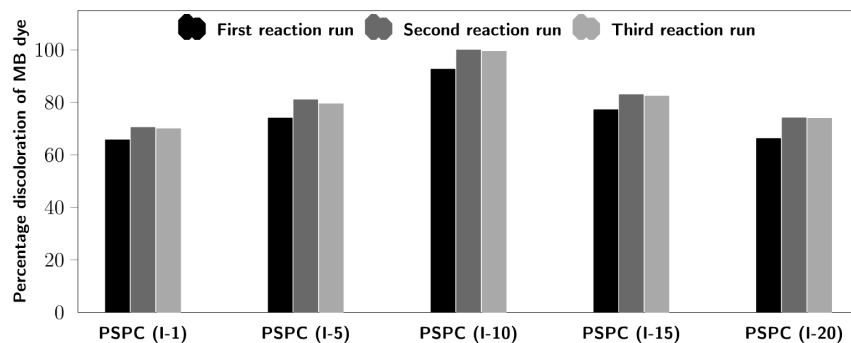


Fig. 7. The efficiency of MB dye discoloration by PSPC (I) samples during three consecutive reaction runs after 7.5 h of UV irradiation

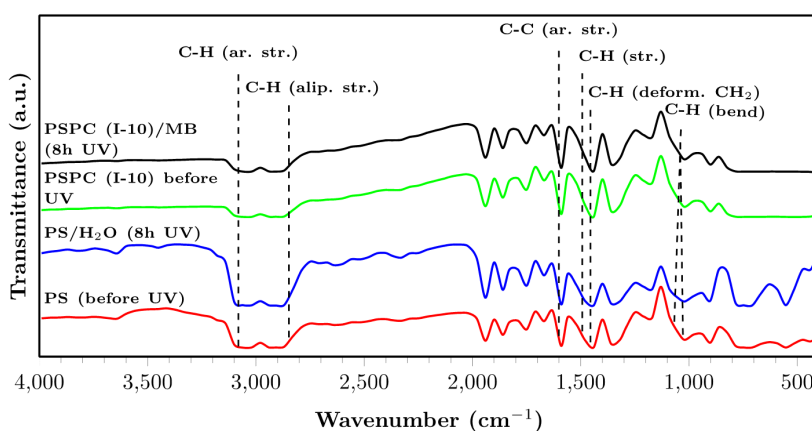


Fig. 8. FTIR spectra of pure PS sheet and PSPC (I-10) sheet before and after 8 h of UV irradiation

Table 1. IR Absorption Peak Assignments for PS

Assignments	Wave numbers (cm ⁻¹)
C-H aromatic stretching vibration	3001-3082
C-H aliphatic stretching vibration	2910-2928
C-C (in plane) stretching vibration of ring	1601
C-H (in plane) stretching vibration of the ring	1493
C-H deformation of CH ₂	1455
C-H (in plane) bending vibration of the ring	1068
C-H (in plane) bending vibration of the ring	1028

the natural pH of the dye solution was chosen for investigating the PCA of the developed PSPC (I) samples as it eliminates any need for additional pH adjustment. The recovery and reusability of the developed PSPC (I) sheets were also investigated. For this, the PSPC (I) samples were recovered easily by sieving and then without any intermittent cleaning, were used for discoloration of fresh MB solutions in two more consecutive reaction runs. The results are shown in Fig. 7. One noticeable observation is that the PCA of the impregnated sheets is lower in the first reaction run as compared to the subsequent runs. This

observation may be attributed to the following two reasons: First, the surfaces of the freshly prepared impregnated photocatalysts might be covered with some trace impurities that got removed in the first reaction run and therefore, in the subsequent runs, the photocatalysts showed a higher PCA. Second, the impregnated sheets, being buoyant and used in non-stirred conditions, became wetter in subsequent uses as compared to their first use. This leads to more number of MB molecules coming into contact with the top surface of the photocatalyst and therefore, a higher PCA was observed.

Furthermore, it was found that under UV irradiation, the percentage discoloration of MB from its aqueous solution was 70% and above for all the prepared PSPC (I) samples in both second and third runs with an insignificant decline in PCA in the third run. After three runs, it was noticed that the surfaces of some of the photocatalyst samples developed a slight blue tinge. This could be ascribed to the MB molecules that remained adhered to the photocatalyst samples. These results suggest that the developed PSPC (I) samples could be re-used for several reaction runs without any significant decline in their PCA.

To study any surface deformation on the support surface and in order to investigate whether or not the photocatalyst surface is attacked by reactive radicals, FTIR analyses of the pure PS sheet and PSPC (I-10) sample before UV exposure as well as pure PS sheet and PSPC (I-10) placed in the distilled water and MB solution respectively after 8 of UVC (100 W) exposure were carried out (Fig. 8). FTIR serves as an important tool for determining and analyzing the various functional groups present in an organic compound (Banwell & McCash, 1994; Silverstein & Webster, 2004). The assignment of the major absorption bands for pure PS is tabulated in Table 1, which serves to identify any conformational changes that occur in the pristine PS and the photocatalyst on UV exposure.

From the FTIR analyses, it can be observed that the spectrum of pure PS sheet placed in distilled water and exposed to UV light for 8 h shows slight changes in the intensity of the absorption peaks. This indicates the possibility of the polymer undergoing structural changes on being exposed to highly intense and prolong UVC irradiation (=100 W). These changes could be attributed to either photolysis (degradation and crosslinking) and/or photooxidation (photoinduced oxidation) of the PS (Rabek & Ranby, 1974; Weir, 1978; Lawrence & Weir, 1973; Ranby & Lucki, 1980; Geuskens *et al.*, 1978a; Geuskens *et al.*, 1978b). On the other hand, an almost similar spectra (absorption peaks) have been obtained for the developed photocatalyst before and after exposure to the UV light. This suggests the stability of the impregnated photocatalyst under the UV light irradiation.

CONCLUSIONS

A simple and economical solvent-cast method has been used to develop buoyant, effective and robust PS-supported TiO₂ photocatalysts. The method for developing these floating impregnated photocatalysts leads to a significant reduction in the cost of catalyst preparation. This is because it neither requires any expensive titanium precursors nor high temperatures. Also, it utilizes a readily available & an inexpensive

polymer. The successful photodiscoloration of MB under UV light without the need of any additional pH arrangements and the ease of recovery after use further adds to the usefulness of the developed photocatalysts. The maximum PCA was achieved by the optimized TiO₂/PS [PSPC (I-10)] sheet, which was able to remove around 93% of the MB color from its aqueous solution.

The efficiency of the developed impregnated photocatalyst could be ascribed to its floating nature which imparts better positioning of the photocatalyst on the water surface which in turn, provide it a better illumination and more efficient oxygenation. Thus, it can be directly used in removing recalcitrant organic contaminants from natural lakes and contaminated wastewater reservoirs without the need of any special equipment or installation. Further, the stability of the photocatalyst as suggested by the FTIR results make the utilization of abundantly available PS waste an attractive and suitable substrate to be explored for fabricating low-cost TiO₂ photocatalyst for environmental remediation. Overall, TiO₂ impregnated PS photocatalyst seems to be a promising candidate that needs further investigation for large scale commercial applications, such as, complete mineralization of persistent and toxic contaminants from wastewater.

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