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USE OF BI_2S_3 AS A PHOTOCATALYST FOR PHOTOCATALYTIC DEGRADATION OF TEXTILE AZO DYE REACTIVE BLUE 160 (RB160)

DIMPLE SHARMA[1] AND K.S. MEENA[2]

Department of Chemistry, M.L.V. Government College Bhilwara 311 001, Rajasthan, India

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ABSTARCT

In apparel industries removal of the color of dye is one of the main problem. In the current work semiconductor photo-catalyst Bi_2S_3 utilized in photo catalytic decolorizing of textile azo dye Reactive Blue 160 under UV light. Spectrophotometric measurements of the reaction rate were made. It has been investigated how many variables, including dye concentration, photocatalyst quantity, and pH, affect reaction efficiency.

KEY WORDS: Reactive blue, Bi_2S_3, Photo-catalytic degradation

INTRODUCTION

Water is the most valuable material on the earth, without it life will not exit. It is crucial to avoid polluting these priceless resources due to the lack and pollution of water supplies. Textile industries produce enormous quantities of wastewater containing colourful dyes that are both poisonous and non-biodegradable (Reife, 1996). Synthetic dyes are often used nowadays in several products, such as textiles, wood, leather, and plastic. However, roughly 12 percent of these colours are lost in the process of dyeing, and about 20 percent of this waste ends up in the environment. (Rafi *et al.*, 2021). Dyes which are bright in color Water-soluble colours, such as reactive and acid dyes, are the most difficult to remove.

As a result of the accidental release of toxic wastewater a pollution problem arises in worldwide textile industries which have a big impact on the quality of water supplies. According to the World Bank report 17 to 20 percent of industrial water contamination rises from textile dyeing and treatment. Therefore, this is a significant environmental concern for the textile industry. There is a demand for ecologically acceptable technology to remove colours from industrial and municipal effluent, as environmental consciousness increases.

Classical ways to clean up dirty water that are still used today are adsorption, (Nasuha, 2010; Nagawe, 2018), coagulation (Riera, 2010), biodegradation (Xu *et al.*, 2011) chlorination (Ge, 2008), ion flotation (Shakir, 2010), sedimentation (Zodi, 2010), membrane process (Jirankova, 2010) and solvent extraction (Juang, 2008). However, physical and biological treatments do not eliminate contaminants; they merely change their phase. The disadvantage of chemical approaches is that they utilise strong oxidants such as chlorine and ozone, which are themselves pollutants (Algarni *et al.,* 2022) Complete purification of these processes' final products requires further processing. Dye photodecolorization is a potential technique for treating of industrial effluent.

Due to the cheap cost of the procedure, the absence of secondary pollution, and the approach's environmental friendliness, it is a viable option. In recent years, the advanced oxidation method of photo-catalysis has attracted a significant amount of focus on the process of water purification. To make sure the environment is safe and clean, it is important to separate and break down these organic wastes. Photo-catalysis, the removal of colours from water using an advanced oxidation process (AOP) is now being done without the creation of any dangerous by-products (Iqbal *et al.*, 2018). AOPs are based on the production of extremely reactive species like hydroxyl radicals ($^{\bullet}OH$), which are second only to fluorine in terms of their substantial oxidation potential [E0 = + 2.80 V]. Numerous organic contaminants are quickly and non-selectively oxidised by hydroxyl radicals. (Daneshwar *et al.*, 2003). And it can be improved further with the use of UV-visible radiation that produces extra hydroxyl radicals.

Photocatalytic degradation of direct black155 and Reactive Blue 160 dye were examined by using UV light in photochemical reactor with photocatalyst SnO_2 (Meena and Meena, 2021). Under UV light, zinc oxide also takes part in the photo-catalytic degradation of Reactive Red 152. (Meena and Dadheech, 2019). In the presence of the heterogeneous photocatalyst $CeFeO_3$, the azo dye Reactive Blue 160 underwent photocatalytic degradation. (Pamecha *et al,* 2016). $SnO_2/Bi_2S_3/BiOCl/Bi_{24}O_{31}Cl_{10}$ Composites' Easy Synthesis Significantly Increases Photocatalytic Degradation of Rhodamine B under Visible Light (Fenelon *et al.*, 2020).

The usage of a paint-coated substrate for wastewater remediation through the photocatalysis experiment using visible light irradiation was both economical as well as free from separation and filtration processes to recover the catalyst. The $BiVO_4^-$ paint composite coated on an aluminium substrate was used for photocatalytic MB dye degradation (Kumar and Vaish, 2022).

Using chalcogens as photocatalysts for degradation has grabbed the interest of the scientific community in recent years. Due to its cost in comparison to TiO_2 and ZnO and its low band gap energy, which ranges from 1.3 to 1.7 eV, bismuth sulphide is an attractive material. (Zhu, 2017).

MATERIALS AND METHODS

Reactive Blue 160 was chosen for the current photocatalytic degradation investigations. This is a diazo dye with sulphonate groups. It was acquired from Bhilwara Textile Industries (Raj). The Structural formula of the dye is $C_{38}H_{23}C_{12}N_{14}Na_5O_{18}S_5$ and Molecular mass is 1309.86gm. The photocatalyst Bismuth sulphide (Bi_2S_3) was used as a photocatalyst. Bi_2S_3 is a semiconductor that has a band gap that is on the narrower side. It has been shown to be an exceptional light absorption material, which finds widespread use in photonic devices. The laboratory's reagents were all of analytical quality.

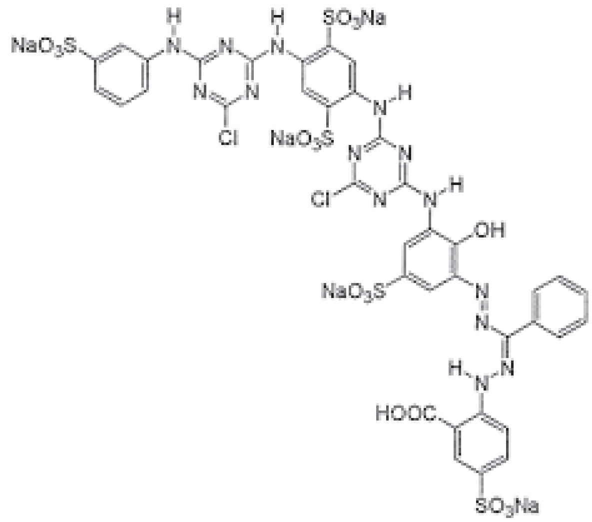


Fig. 1. Reactive Blue 160.

Bi_2S_3 was used as a photocatalyst while RB 160 degradation was examined at various pH levels, catalyst loadings, and dye concentrations. To make a dye solution that has a concentration of $1X10^{-3}$M, 1.309 grammes of dye were dissolved in a volume of 1000 millilitres of distilled water. In order to determine the initial absorbance of the dye solution, a UV-VIS spectrophotometer was used. At 560nm (max), the highest absorption value was noted. The reaction mixture was made up of three millilitres of Reactive Blue 160 solution ($1x10^{-3}$ M) and 0.3 grammes of bismuth sulphide. The amount of the reaction mixture was brought up to 100 ml by the addition of double-distilled water. The reaction mixture included $3x10^{-5}$M dye molecules. (Dadheech, 2021) The reaction mixture was exposed to UV radiation using a photochemical reactor to do the photobleaching. Using a pH metre, the solution's pH was determined (Systronics 106). At certain time intervals, a spectrophotometer set at 560 nm (max) was used to measure absorbance in order to track the reaction's progress. The rate at which the colour faded over time was also continuously examined.

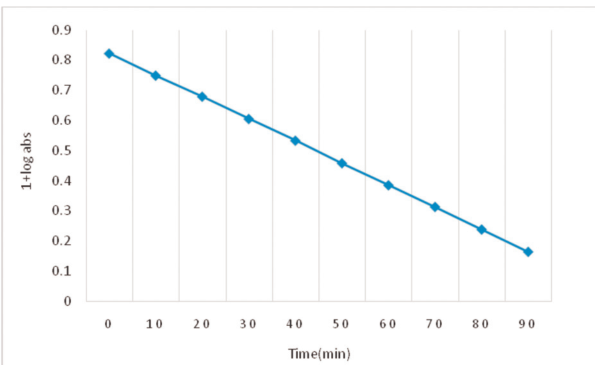
RESULTS AND DISCUSSION

At 554 nanometers, the photocatalytic degradation of RB160 was observed. The best conditions for dye photooxidation were dye concentration = 3 x $10^{-5,}$ pH = 8, and catalyst quantity = 0.3g/100 ml. Fig. 2 displays visually the effect of RB160's photodegradation.

Table 1. Depicts a common run of photocatalytic degradation of Reactive Blue 160.

Time (min)	abs	1+log abs
0	0.664	0.822
10	0.561	0.749
20	0.478	0.679
30	0.402	0.605
40	0.341	0.533
50	0.287	0.458
60	0.242	0.385
70	0.205	0.313
80	0.172	0.238
90	0.145	0.164

Based on the theory of first order reaction, the straight line graph of 1+logA vs time. This phrase k=2.303xSlop was used to figure out the rate constant.



$k = 2.8 \times 10^{-4}$ sec^{-1}

Fig. 2. Photocatalytic degradation of Reactive Blue 160

Effect of parameters

Variations in pH have the following effects

Variations in pH have an effect on the photocatalytic degradation of RB160. The pH has a significant impact in the formation of hydroxyl radicals.

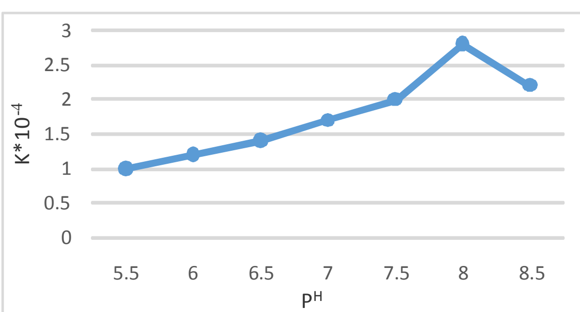


Fig. 3. A curve demonstrating the impact of changing hydrogen ion concentration on the speed at which the dye degrades.

Photocatalytic degradation was carried out at pH levels ranging from 3 to 9, while all other parameters remained constant. It was discovered that when pH increases, so does the rate of reaction. The rate of degradation was greatest at pH 8.0.

Variation in dye concentration has the following effects

The impact of dye concentration variation on photodegradation was studied for Bi_2S_3 with varying concentration of RB160 from 1.0×10^{-5} to 5×10^{-5}M, while all other variables were held constant. Up to a concentration of 3×10^{-5} M for Bi_2S_3, it was shown that the degradation rate increases with increasing dye concentration. The surface of the dye catalyst becomes saturated as the dye concentration rises. As a consequence, the rate of decolorization slows.

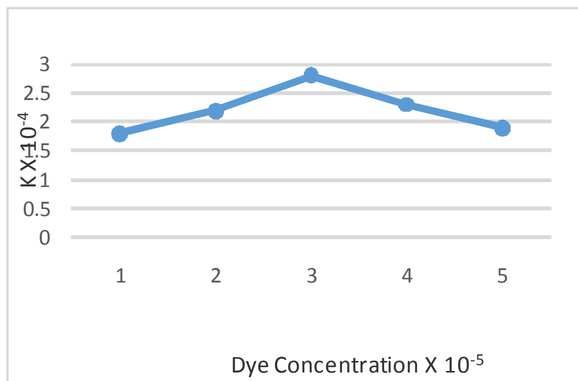


Fig. 4. A plot illustrating the impact of variations in dye concentration on the rate of dye decolorization.

Changing the Catalyst Concentration and Its Effects

By changing the quantity of Bi_2S_3 while keeping all other components constant, the influence of photocatalyst amount on the photo-decolorization of Reactive Blue 160 was studied. It was found that when catalyst amount is increased, the rate of degradation for Bi_2S_3 rises to 0.3g/100ml. The findings are shown in Fig. 5. Following an increase in catalyst concentration, the rate of reaction either decreases or remains almost constant. A possible explanation for this behaviour is that when the quantity of catalyst is increased, the surface area of the catalyst will expand and include more active sites. Because there are no longer any substrate dye molecules accessible for adsorption on semiconductor active sites beyond a certain quantity of catalyst, the rate of reaction decreases.

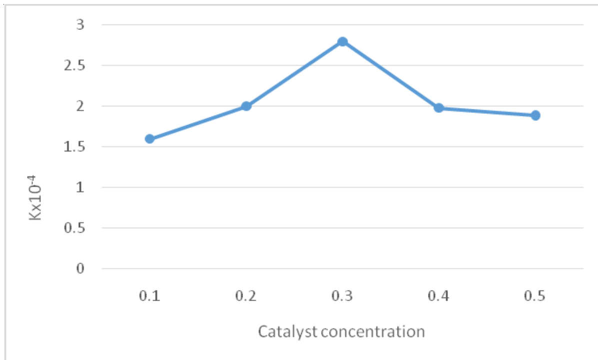


Fig. 5. A curve indicating how changes in catalyst dosage affect the dye decolorization pace.

Mechanism

The first step in the process of photocatalysis is the absorption of photons with an energy that is equal to or higher thanhe semiconductor Bi_2S_3 band gap. The conduction band is reached by the electrons after they pass through the valence band. As a direct result of this, a hole, denoted by the symbol h+, is produced in the valence band. The photogenerated hole acts as a potent oxidising agent, while the conduction band electron performs the function of a reducing agent in a semiconductor.

$Bi_2S_3 + hv \rightarrow Bi_2S_3^*$
$h^+ (vb) + e^- (cb)$

These pairs of electrons and holes move to the surface of the catalyst, which is the location where radicals are formed.

Hole (h^+)+ $OH^- \rightarrow {}^{\bullet}OH$
Hole(h^+)+ $H_2O \rightarrow OH^{\bullet} + H^+$
$e^- + O_2 \text{ (ads)} \rightarrow O_2^{-\bullet}$
$O_2^{-\bullet} + H^+ \rightarrow HO_2^{\bullet}\ OH^{\bullet}$ (hydroxyl radical)

Superoxide radicals and peroxide radicals are powerful oxidising species. These radicals reacts with dye molecules to turn them into oxidised molecules. At the same time, a dye molecule absorbs the right amount of radiation and moves from its initial singlet state to its triplet state through a "intersystem crossing."

$^1Dye_o + hv \rightarrow {}^1Dye_1$ (single state)
ISC $^1Dye_1 \rightarrow {}^3Dye_1$ (triple state)
$^3Dye_o$ + radicals $\rightarrow$ colourless end products

Propane-2-ol was used as a scavenger to verify the participation of the hydroxyl radical $OH^{\bullet}$. The pace of the reaction was significantly slowed down when 2-propanol was included in the mixture. The fact that degraded reaction mixture contains carbon dioxide (CO_2), nitrate ion (NO_3^-), and nitrite ion (NO_2^-) shows that this process is fully mineralized. The final goods are environmentally safe.

CONCLUSION

The photocatalyst Bi_2S_3 is utilised to degrade the dye Reactive Blue 160. According to the experimental findings, pH, dye concentration, and catalyst quantity all had an impact on the photodegradation of RB160. With increasing photocatalyst dose and initial azo dye concentration up to a certain point, the rate of dye photodegradation increased. Degradation is more likely to occur in basic situation. The ideal photodegradation conditions were found to be pH 8, 0.3gBi_2S_3/100ml, and 3 X 10^{-5}M dye concentration. On Bi_2S_3, dyes degrade using first-order kinetics. The predominant reactive species in the degradation, according to experiments on radical scavenging, is the hydroxyl radical. Overall results indicate that this photocatalyst should be used to treat industrial effluent wastewater.

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