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DEGRADATION OF NAPHTOL BLUE BLACK BY PHOTO-FENTON
SYSTEM: EFFECTS OF HYDROGEN PEROXIDE
CONCENTRATION

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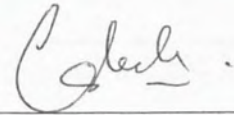
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ABSTRACT

Degradation of reactant azo dye namely Naphtol Blue Black (NBB), using an Advance Oxidation Process (AOPs) base on photo-Fenton system was conducted at different H_2O_2 concentrations (H_2O_2 and Fe^{2+} concentration ratio 500:1, 100:1, 50:1, 10:1, 1:1, 25:1 and 5:1) and different contact time (0,10,30,60,90 and 120 minutes). The methodology was adapted and modified from pass researchers. The compilation of the varying H_2O_2 and Fe^{2+} dosages and the varying UV contact times for the NBB dye make up the experimental matrix. The result from the experiment has shown that ratio of H_2O_2 and Fe^{2+} concentration 5:1 was the ideal operational parameters with 96.96% degradation of 1×10^{-4} mol/L NBB solution in two hours.



ABSTRAK

Penyelidikan keatas perawatan dye 'naphtol blue black' (NBB) oleh sistem 'Advances Oxidation Process' (AOPs) dengan bantuan sinaran ultra ungu telah dijalankan pada kadar kepekatan H_2O_2 yang berlainan (nisbah kepekatan H_2O_2 dan Fe^{2+} 500:1, 100:1, 50:1, 10:1, 1:1, 25:1 dan 5:1) dan dalam selangan masa (0,10,30,60,90 and 120 minit). Ia bertujuan untuk mengenal pasti kebolehrawatan azo dye jenis reaktif dan mengkaji kaedah baru perawatan air melalui penggunaan sinaran ultra ungu. Kaedah methodology kajian ini adalah petikan daripada kajian lepasan yang mana telah diperbaiki dan dikemaskinikan. dengan tujuan untuk mencari suatu parameter tindak balas yang ideal bagi degradasi dye NBB. Hasil keputusan kajian menunjukkan nisbah kepekatan 5:1 adalah parameter yang paling ideal bagi degradasi NBB dengan mencatatkan 96.96% degradasi 1×10^{-4} mol/L dye NBB dalam jangka masa 2 jam.



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CHAPTER 1

INTRODUCTION

1.1 Advanced Oxidation Processes In Wastewater Treatment

According to Federation of Malaysia Manufacture (Young, 1997) the textile industry in Malaysia is one of the largest industries in term of export volume. Textile industries are water intensive using between 50 to 400 l/kg fabric and 30 million gallon of water per year (Ince and Tezcanli, 1997). Over 7×10^5 tons and approximately 10,000 different types of dyes and pigments are produced worldwide annually and it is estimated that 10 to 15% of the dye is lost in the effluent during the dyeing process (Young, 1998). In Turkey 10% of the total dye usage in textile industry was wasted during the process of dye-bath discharge and subsequently produced high chemical oxidation demand (COD) as well as carcinogenic products such as aromatic amines, owing to the large consumption of azo dyes in dyeing processes (Ince and Tezcanli, 1997). Effluents discharged from dyeing industries are highly coloured and they can be toxic to aquatic life in receiving waters (Lee et al., 1999; Kadirvelu et al., 2000 a; Kadirvelu et al. , 2003).



There are nearly 3000 types of dyes in the commercial market and more than half of them are azo compounds (Ince and Tezcanli, 1997). Azo dyes are difficult to be biodegraded due to its azo bond $-N=N-$ in the chromophore (Feng, W., 1999). Further more incomplete decolorization of the industrial dye effluent discharge shifts the burden of treatment to publicly owned water treatment facilities and these dyes often end up as sludges (Malik and Saha, 2002). Consequently many researches on azo type dye wastewater treatment were done.

Advanced oxidation processes (AOPs), involving Fenton's Reagent (FR) and recently research on combination of UV light and FR which known as Photo-Fenton have been proposed in recent years as a potential alternative for colour and substantial COD as well as TOC removal from textile effluents (Ince and Tezcanli, 1997). One of the advantages of AOPs compared to the conventional chemical oxidation processes is the absence of kinetic limitations (Feng, W., 1999). Through AOPs, the amounts of free radicals generated are 10^6 to 10^9 times faster compared to the strongest chemical oxidants such as ozone (Ince and Tezcanli, 1997). Besides that, AOPs are also sludge free processes due to its ability to completely or partially mineralized the recalcitrant organic compounds (Feng, W., 1999).



1.2 Objective of the research

The urgency for conservation and reuse the world's limited water resources has expand the research of wastewater treatment. Textile industry poses a very serious threat in the future compared to other major industry. In that case, more and more specific textile effluent treatments are being formulated to suite the different types of industrial dye. This research focuses mainly on the photo-fenton degradation of textile azo dye. The objectives of this research are:

- (a) to determine the treatability of azo dye using $\text{Fe}^{2+}/\text{H}_2\text{O}_2/\text{UV}$ system,
- (b) to evaluate the effects of different operational parameters in $\text{Fe}^{2+}/\text{H}_2\text{O}_2/\text{UV}$ system towards the degradation of textile azo dye, and
- (c) to obtain an optimal condition of $\text{Fe}^{2+}/\text{H}_2\text{O}_2/\text{UV}$ system in degrading textile azo dye.



1.3 Scope of The Research

Photo-Fenton degradation of textile azo dye is FR method with UV light (UV/Fe²⁺/H₂O₂) as a promoter. All the experiments in this study were conducted at lab scale using a photoreactor made out of pyrex-glass with cylindrical shape (450ml capacity) with Naphthol Blue Black N9002/Sigma solution as simulated textile dyeing effluent. The entire research will concentrate on three main parameters namely dye concentration, Fe²⁺ concentration and H₂O₂ concentration. Sample withdrawal at different time interval have been analysed under the UV-VIS spectrophotometer. Graf of Abs against reaction time and also lnAbs against reaction time were plotted to evaluate its degree of degradation and order of the chemical reactions. A linear graph will be plotted base on its chemical reaction following the first kinetics law.



CHAPTER II

LITERATURE REVIEW

2.1 Colour

Colour plays an important role in the textile industries. Colour can be categorized into three categories using The Munsell Colour System (*hue, value and chroma*). Hue is the quality distinguishes one colour from another, such as red from blue or yellow from green (Collier, 1999). The hue of a dye depends on the wavelength it absorbs. Values represent lightness and darkness of a coloured surface. Chroma is the strength of the colour and is also designated by number. A high chroma colour is often casually referred to as a bright colour, and a low chroma may be described as dull (Collier, 1999).

The colour appearance of an object depends on the source of illumination, the object's interaction with light, and the response of sensors in the observer's eye to the light reflected from the object (Collier, 1999). The human eye contains three different types of color receptor cells, or *cones*. The first ("red") are most responsive to wavelengths around 565 nm, the second ("green") to those around 535 nm, and the third ("blue") to those around 445 nm. The sensitivity curves of the cones are roughly bell-shaped and overlap considerably. The incoming signal spectrum is thus reduced



by the eye to three values, representing the intensity of the response of each of these types of color receptors.

2.1.1 Photon Absorption by Molecules

Electromagnetic radiation is a mixture of radiation of different wavelengths and intensities. When this radiation has a wavelength inside the human visibility range (approximately from 380 nm to 740 nm), that radiation is called light. The light's spectrum records each wavelength's intensity. The full spectrum of the incoming radiation from an object determines the visual appearance of that object, including its perceived color. A surface that diffusely reflects all wavelengths equally is perceived as white, while a dull black surface absorbs all wavelengths and does not reflect. Photon absorption is a form of energy transfer to move either molecules or electrons from their ground state into some excited state.

However, only one of these effectively applies to dye molecules, since dye molecules are almost without exception organic conjugated systems. The absorbing groups in the molecule are called chromophores. The chromophore is a group of atoms, which control the colour of the dye. Chromophore is usually electron withdrawing, and auxochromes are normally electron donating. An auxochrome does not itself absorb radiation, but, if present in molecule, it can enhance the absorption by a chromophore or shift the wavelength of absorption when attached to the chromophores (Christian 1994).



In contrast the overlapping *p*-orbitals effectively mean that no one electron absorbs more energy than another, since all *p*-electrons in the conjugated system are smeared above and below the molecule. Conjugated organic molecules absorb specific wavelengths of electro-magnetic radiation. If this absorption falls within the visible region, then the light reflected or transmitted is deficient in a particular colour, and the solid (or solution) appears coloured. Base on quantum theory, energy transformations on an atomic or molecular scale occur discontinuously in discrete packets or quanta,

$$\Delta E = E_1 - E_0 = h\nu = \frac{hc}{\lambda}$$

where

E_1 / E_0 = Energy reaction at time of 1 and 0

ν = frequency

c = velocity of light ($3.0 \times 10^8 \text{ ms}^{-1}$)

λ = wavelength of the absorbed radiation

h = Planck's constant ($6.63 \times 10^{-34} \text{ Js}$)

Transition to a σ^* anti-bonding orbital can be ignored where the energy required corresponds to radiation in the far ultraviolet but a π or n electron can be promoted to a π^* anti-bonding orbital by visible light. Three such transitions are important as far as colorants are concerned: $n \rightarrow \pi^*$, $\pi \rightarrow \pi^*$ and charge transfer (Moh, 2002).



2.2 Textile Dye Characteristics

Numerous structures of dyes exist; all are assigned a Colour Index (C.I) classification number. According to Shore (1990), most of the dyes and pigments in the Colour Index are placed in one of the 25 structural classes according to their chemical type. Azo dyes is the largest class and has been subdivided into four sections. Classification of the four sections depends on the number of azo groups within the dye molecule. The depth of colour is related to the molecular structure of the dyes, which is related to the chromophores (-N=N- or >C=O) involved within the structure. In addition, visible and the UV irradiation electron transfer effects at varying wavelengths on the dye structures have been observed, supporting tautomeric capabilities of the dye molecules (Shore 1990).

2.2.1 Dyes Constitution

A typical dye molecule contains at least three unique chemical groups, each responsible for a particular property of the dye (Dianne, 1995). The chromophore is the colour-producing portion of dye, the auxochrome influences the intensity of the dye and provides a site at which the dye can chemically bond to the fabric. Examples of chromophores are:



- NO Nitroso group



- NO² Nitro group

Examples of auxochromes are:

- NH ₂ , - NHR, - NR ₂	Primary, secondary and tertiary amine
- Cl	Chloride
- Br	Bromide
- OH	Hydroxyl
- OR	Alkoxy

2.2.2 Azo Dyes

The azo compound class accounts for 60-70% of all dyes. They all contain an azo group, -N=N-, which links two sp² hybridised carbon atoms. Often, these carbons are part of aromatic systems, but this is not always the case. Most azo dyes contain only one azo group, but some contain two (*disazo*), three (*trisazo*) or more (www.chm.bris.ac.uk). In theory, azo dyes can supply a complete rainbow of colours. However, commercially they tend to supply more yellows, oranges and reds than any other colours. Azo dyes give bright, high intensity colours, much more so than the next most common dye class (anthraquinones). They have fair to good



fastness properties, but not so good as the carbonyl (C = O) and phthalocyanine classes.

2.2.3 Reactive Azo Dyes

According to Moh (2000), approximately 80% of all reactive dye is based on azo chromogen. Reactive dyes are coloured compounds with covalent bonds from between carbon or phosphorus atom of the dye ion or molecule with oxygen, nitrogen or sulphur atom of hydroxyl, an amino or a mercapto group. Reactive dyes are very soluble in water and therefore, are poorly adsorbed by UV visible light (Churchley and Upton, 1997).

2.2.4 Treatability of Reactive Azo Dye

There are three aims associated with reactive dye technology: (a) reduce the reaction of electrophilic group of reactive dye with water (hydrolysis), (b) optimise the affinity of reactive dyes to the textile substrate, and (c) increase the dye-fiber linkage. Unfortunately these industries created a lot of water pollution problem (Moh, 2000). In general, the wastewater from a typical textile industry is characterised by high values of BOD, COD, colour, and pH, because of the high BOD, the untreated textile wastewater can cause rapid depletion of dissolved oxygen if it is directly discharged into the surface water sources (Danis et al., 1998). The common method of textile wastewater treatment is the combination of biological oxidation and physical-



chemical processes (Moh, 2000). However this method is ineffective in the degradation of textile effluent while its also generate sludge. The highly constituted molecular structure and high solubility in water of textile dye harder the process of wastewater treatment (Moh, 2000). Moreover, under anaerobic conditions, biological process of azo dyes can be reduced to potentially carcinogenic aromatic amine (Danis et al., 1998).

2.3 Advances Oxidation Processes

Advanced oxidation processes (AOPs) include UV/H₂O₂, UV/O₃, O₃/H₂O₂, Fenton's reagent, and the wet-air oxidation process. The concept behind the AOP is that exposure of a strong oxidizing agent exposed to UV light generates hydroxyl free radicals (Ince and Gonenc, 1997), which are even stronger oxidants. Table 2.1 shows the relative strength of several oxidants.



Table 2.1: Electrical potential of selected oxidants (Moh, 2000)

Oxidant	Electrical Potential (Volts)
Fluorine	3.03
Hydroxyl radical	2.80
Atomic oxygen	2.42
Ozone	2.07
Hydrogen peroxide	1.78
Perhydroxyl radical	1.70
Chlorine	1.36

AOPs, which involve the generation of highly potent chemical oxidant such as the hydroxyl radicals ($\text{OH}\cdot$), have recently emerged as an important class of technologies for accelerating the oxidation and destruction of a wide range of organic contaminations in polluted water and air (Anna and Marina, 2000). Figure 2.1 illustrate an overview about the classification of AOPs.

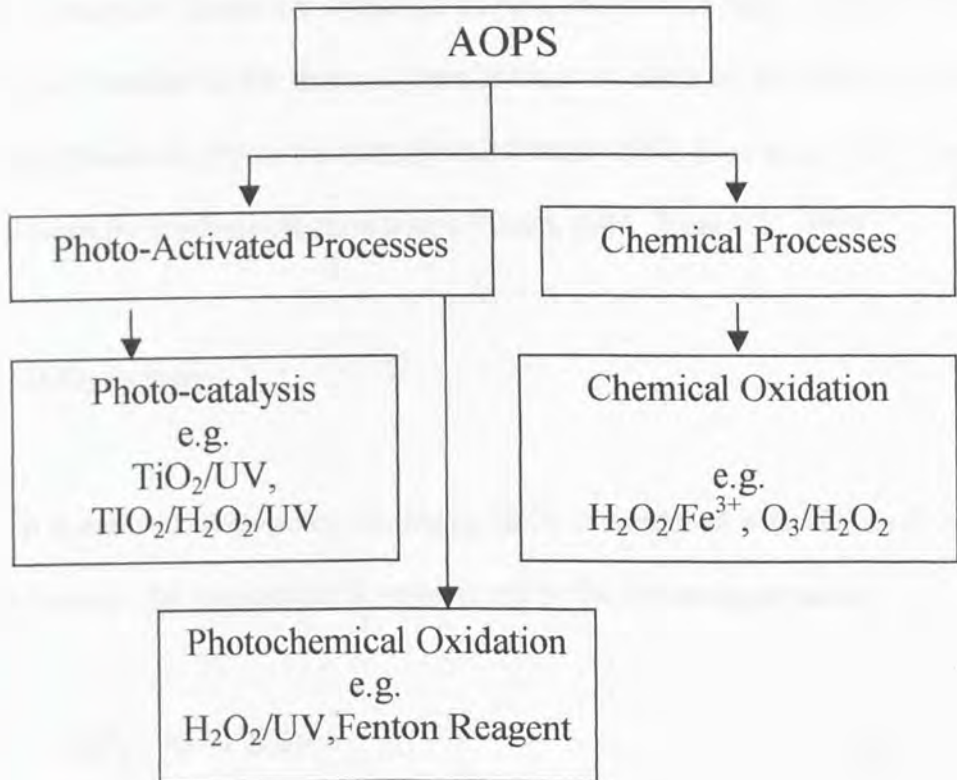


Figure 2.1: Classification of AOPs

2.3.1 Ultraviolet Light

Ultraviolet light is an electromagnetic radiation spread between the wavelengths 100 nm and 400 nm. Most UV lamps used in wastewater treatments perform at a wavelength of 354 nm. A mercury vapour lamp is the most common UV light source (Hanzon and Vigilia, 1999). The lamp is filled with mercury vapour at different pressures and excitation of the mercury atoms causes the emission of UV light. Typically, UV lamps are installed inside quartz sleeves and when implemented at a plant is usually placed in banks with the lamps evenly spaced either vertically or

References

Anna GOI and Marina TRAPIDO., 2001. *Comparison of advanced oxidation processes for the destruction of 2,4-Dinitrophenol.*

Azmi Aris, Razman Salim and Marsin Sanagi., 1998. *Treatment of Textile Finishing Wastewater Using Fenton's Reagent.* Jurnal Kejuruteraan Awam (Journal Of Civil Engineering) vol. 11 (No. 2).

Churchley, John and Upton, John., 1997. *Latest Developments in Textile Colour Removal Case Studies.* Severn Trent Water Limited. Coventry, United Kingdom.

Daniş, Ü.; Gürses, A.; Canpolat, N., 1998. *Removal of some azo dyes from wastewater for using PAC as adsorbent,* 1 International Workshop on Environmental Quality and Environmental Engineering in the Middle East Region, Konya, Turkey.

Dianne N. Epp. *A world of colour: Investigating the chemistry of vat dyes.* Journal of chemical education, vol 72, No.8, August 1995.

E. Neyens*, J. Baeyens. *Review of classic fenton's peroxidation as an advanced oxidation technique.* Journal of Hazardous Materials 3973 (2002) 1-19.



Glaze, William., 1993. *An Overview of Advanced Oxidation Processes: Current Status and Kinetic Models*. Eckenfelder, W., Bowers A.R., Roth, J.A., Editors. Proceedings of the Third International Symposium Chemical Oxidation: Technology for the Nineties. Technomic. Lancaster.

Gregor, Karl H., 1992. *Oxidative Decolorization of Textile Waste Water with Advanced Oxidative Processes*. Peroxid-Chemie GmbH, D-8023 Hollriegelskreuth, FRG.

Ince, N.H. and Gonenc, D.T., 1997. *Treatability of a Textile Azo Dye by UV/H₂O₂*. *Environmental Technology*. 18:179-185.

Ince, N.H. and G. Tezcanli., 1999. *Treatability of Textile Dye-Bath Effluents by Advanced Oxidation: Preparation for Reuse*. *Wat. Sci. Tech.* Vol. 40. No. 1. pp, 183-190.

Kadirvelu, K.; Brasquet, C. , Cloirec, P., 2000. *Removal of Cu (II), Pb (II) and Ni (II) by adsorption onto activated carbon cloths*. *Langmuir* 16, 8404- 8409.



- Kadirvelu, K.; Kavipriya, M.; Karthika, C.; Radhika M.; Vennilamani, N.; Pattabhi, S. 2003 *Utilization of various agricultural wastes for activated carbon preparation and application for the aqueous solutions*, *Bioresource Technology* 87 (2003) 129-132.
- Lee, C.K.; Low, K.S.; Gan, P.Y., 1999 *Removal of some organic dyes by acid treated spent bleaching earth*. *Environ. Technol.* 20, 99-104.
- Liao, C., Lu, M., Yang, Y., Lu, I., 2000. *UV-Catalyzed Hydrogen Peroxide Treatment of Textile Wastewater*. *Environmental Engineering Science*. 17:9-18.
- Montaser Y. Ghaly, Georg Hartel*, Roland Mayer, Roland Haseneder. *Photochemical oxidation of p-chlorophenol by UV/H₂O₂ and photo-fenton process. A comparative study*. *Waste Management* 21 (2000) 47-47.
- Namboodri, C.G. and Walsh, W.K., 1996. *Ultraviolet Light/Hydrogen Peroxide System for Decolorizing Spent Reactive Dyebath Waste Water*. *American Dyestuff Reporter*.
- P.K. Malik and S.K. Saha., 2002. *Oxidation of Direct Dyes with Hydrogen Peroxide using Ferrous Ion as Catalyst*. *Separation Purification Technology* (2002), 1-10.



Shu, H., Huang, C., Chang, M., 1994. *Decolorization of Mono-Azo Dyes in Wastewater by Advanced Oxidation Processes: A Case Study of Acid Red 1 and Acid Yellow 23*. Chemosphere. 29:2597-2607.

Society of Dyers and Colourists., 1990. *Colorants and Auxiliaries*. Volume 1- Colorants. John Shore, editor. BTTG. Manchester, England.

Sundstrom, D.W., Weir, B.A., Klei, H.E., 1989. *Destruction of Aromatic Pollutants by UV light Catalyzed Oxidation with Hydrogen Peroxide*. Environmental Progress. 8:6 11.

Wailling C. *Fenton's reagent revisited*. Acc Chem Res., 1975; 8: 125-31.

Wu Feng, Deng Nansheng and Hua Helin., 1999. *Degradation of Azo Dye C. I. Reactive Red 2 by Iron Powder Reduction and Photo oxidation in Aqueous Solutions*. Chemosphere 41 (2000), 1233-1238.

Yang, Y., Wyatt, D.T.II., Bahorshky, M., 1998. *Decolourization of Dyes Using UV/H₂O₂ Photochemical Oxidation*. Textile Chemist and Colorist. 30:27-35.



Young, L. and Jian Yu., 1997. *Ligninase-catalyzed decolorization*, Wat. Res. Vol. 31,
No.5 pp. 1187-1193.

