



## Degradation of yellow-GCN by photolysis with UV-light and solar irradiation using C-N-codoped TiO<sub>2</sub> catalyst

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### ABSTRACT

The degradation of textile dye (Yellow-GCN; C<sub>28</sub>H<sub>14</sub>N<sub>2</sub>O<sub>2</sub>S<sub>2</sub>) has been done by UV-light and solar irradiation photolysis using C-N-codoped TiO<sub>2</sub> catalyst. Degradation of yellow-GCN by UV-Light photolysis is conducted using 10 watt UV lamp (λ365 nm). The intensity of solar during the degradation of yellow-GCN is 27300 lux. Both of photolysis method has been done without and with C-N-codoped catalyst on varied degradation times. 120 mg/L of yellow-GCN could be degraded by 5,40% after 120 minutes UV-light irradiation without catalyst, and the degradation percentage increase to 23,6% by using 10 mg C-N-codoped TiO<sub>2</sub> catalyst. While yellow-GCN could be degraded 18,7% after 120 minutes solar irradiation and the degradation percentage increase to 38,0% by using 10 mg C-N-codoped TiO<sub>2</sub> catalyst.

**Keywords:** Photolysis, Yellow-GCN, C-N-codoped TiO<sub>2</sub>, UV-Light, Solar irradiation

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### INTRODUCTION

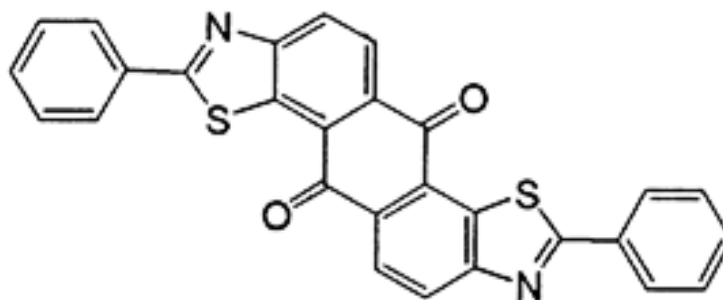
Textile industry has become the most polluting sector when the dye waste discharged into water. The synthetic organic dyes are very commonly used in textile industries. In processing, yellow-GCN dye was used to produce yellow color of textile products. Yellow-GCN is a synthetic organic dye which has stable heterocyclic-aromatic chain. This stable structure of yellow-GCN will produce a durable fabric. However, excessive consumption will be a serious impact on aquatic ecosystems. Color of yellow-GCN will affects the nature of water by inhibiting sunlight penetration hence reducing photosynthetic action[1]. Thus, it takes the right way to resolve the problem of dye removal.

Various chemical and physical processes can be used for color removal from textile effluents such as precipitation, adsorption, air stripping, flocculation, reverse osmosis and ultrafiltration[2,3]. However these techniques are non-destructive, because they only transfer the non-biodegradable dyes into sludge, giving rise to new danger pollution, which needs further treatment[4]. Recently, there has been considerable interest in the utilization of advanced oxidation processes (AOP's) which appears an effective and promising method for degradation of organic chemical pollutants in water and/or wastewater such as aromatic compound[5,6]. UV-light photolysis or solar irradiation photolysis is one of this method[7].

The semiconductor  $\text{TiO}_2$  has been widely utilized as a photocatalyst for inducing a series of reductive and oxidative reaction on its surface. When photon energy ( $h\nu$ ) of less than to the band gap energy of  $\text{TiO}_2$  is illuminated onto its surface, the lone electron will be photo-excited to the empty conduction band in fem to second and leaves a hole ( $h^+$ ) in the valence band[8]. These species ( $h^+$  and  $e^-$ ) can further react with other species and produce highly reactive hydroxyl radicals[9]. Photocatalytic treatments are based on production of highly reactive hydroxyl radicals in reaction[5]. These radicals are high oxidant species that attack the most organic molecules in wastewater treatment[10]. Doping  $\text{TiO}_2$  with nonmetal atoms such as nitrogen and carbon has received increasing attention in recent years. It has been reported to exhibit superior photocatalytic activity under visible light irradiation as both carbon or nitrogen can effectively narrow the band gap of  $\text{TiO}_2$ [11-14]. Zhang et al. prepared C-N-codoped  $\text{TiO}_2$  by a hydrolysis-polymerization-calcination method and showed that photocatalytic activity of C-N codoped  $\text{TiO}_2$  was greatly improved[15]. Another work from Chen et al. in preparing C-N codoped  $\text{TiO}_2$  showed that the photocatalytic activity under visible light irradiation of the samples were the highest compared to C-doped and N-doped  $\text{TiO}_2$ [16].

In this work, photodegradation with UV-light and solar irradiation will be introduced to degrade the yellow-GCN dye compounds. In an effort to find an effective way for enhancing the efficiency of the photodegradation of organic pollutants, we will apply phodegradation with addition of C-N-codoped  $\text{TiO}_2$  catalyst.

Figure 1. Structure of yellow-GCN



## EXPERIMENTAL SECTION

### 2.1 Equipments and materials

Equipments which were used are Spectrophotometer UV-Vis (S.1000 Secomam Sarcelles, French), UV-lamp (Germicidal CE G 13 Base BFC11004,  $\lambda=365$  nm), irradiation box, magnetic stirrer, analytical balance, centrifuge with 10.000 rpm, petridish, and other glasses equipment's. Materials are yellow GCN dyes ( $\text{C}_{28}\text{H}_{14}\text{N}_2\text{O}_2\text{S}_2$ , Mr = 474.56 g/mol) get from Silungkang industry, double distilled water, and C-N-codoped  $\text{TiO}_2$  catalyst.

### 1.2 Degradation of dye in catalyst loading

A varied mass series of C-N-codoped  $\text{TiO}_2$  catalyst was added into 20 mL solution of 120 mg/L yellow GCN in petridish. The mixture solution was degraded with UV-Light and solar irradiation for 120 minutes. Result of degradation was centrifuged at a speed of 10.000 rpm to separate the catalyst. The absorbance of solution that has been degraded measured by UV-Vis spectrophotometer.

### 1.3 Degradation of dye invaried of irradiation times

Each 20 mL solution of 120 mg/L yellow GCN was loaded into four petridishes. The solution in petridish was placed into irradiation box and illuminated by 10 watt UV-light for varied time degradation (30, 60, 90, and 120 minutes). While solar photodegradation was done with the same preparation procedure at 10:00 to 12:00 pm and is accompanied by measurement of the intensity of the sun. Degradation products are kept in dark bottles and measured absorbance with UV-Vis spectrophotometer.

## RESULT AND DISCUSSION

### 3.1 Absorbance of yellow GCN

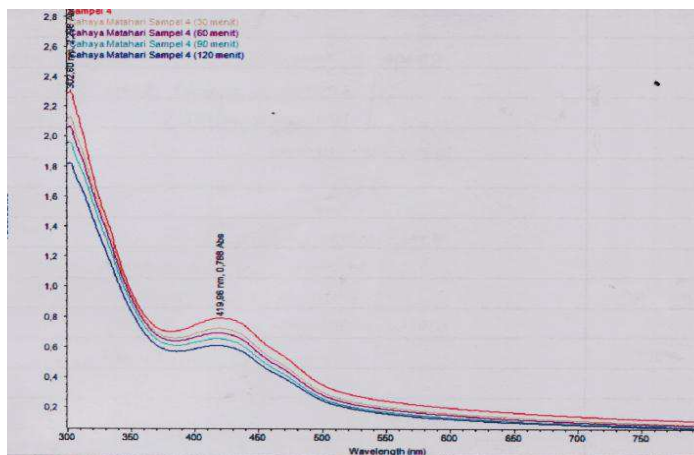


Figure 2. Spectrum of yellow-GCN absorbance

The measurement of maximum wavelength of 120 mg/L solution of yellow-GCN was performed at range 300 – 800 nm. **Figure 2** shows spectrum of yellow-GCN maximum absorbance at 419 nm.

### 3.2 Effect of catalyst loading

The optimum concentration of C-N-codoped TiO<sub>2</sub> catalyst required for the degradation of 120mg/L of yellow-GCN solution was examined by varying the catalyst amount from 0 – 15mg. The photocatalyst plays important role in photodegradation process, due to producing the hydroxyl radical. **Figure 3** shows the effect of catalyst loading in degradation of yellow-GCN for 120 minutes irradiation by UV-Light. It was observed that as C-N-codoped TiO<sub>2</sub> amount increased from 5-10 mg will increase percentage degradation of yellow-GCN and the percentage degradation decrease after added 15 mg catalyst. By increasing the amount of catalyst will produce lots of active site to produce hydroxyl radical, so that most of dye molecules will be degraded.

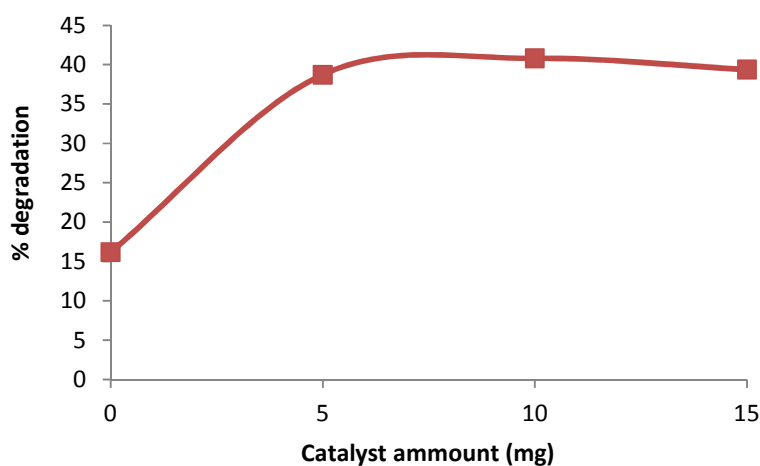
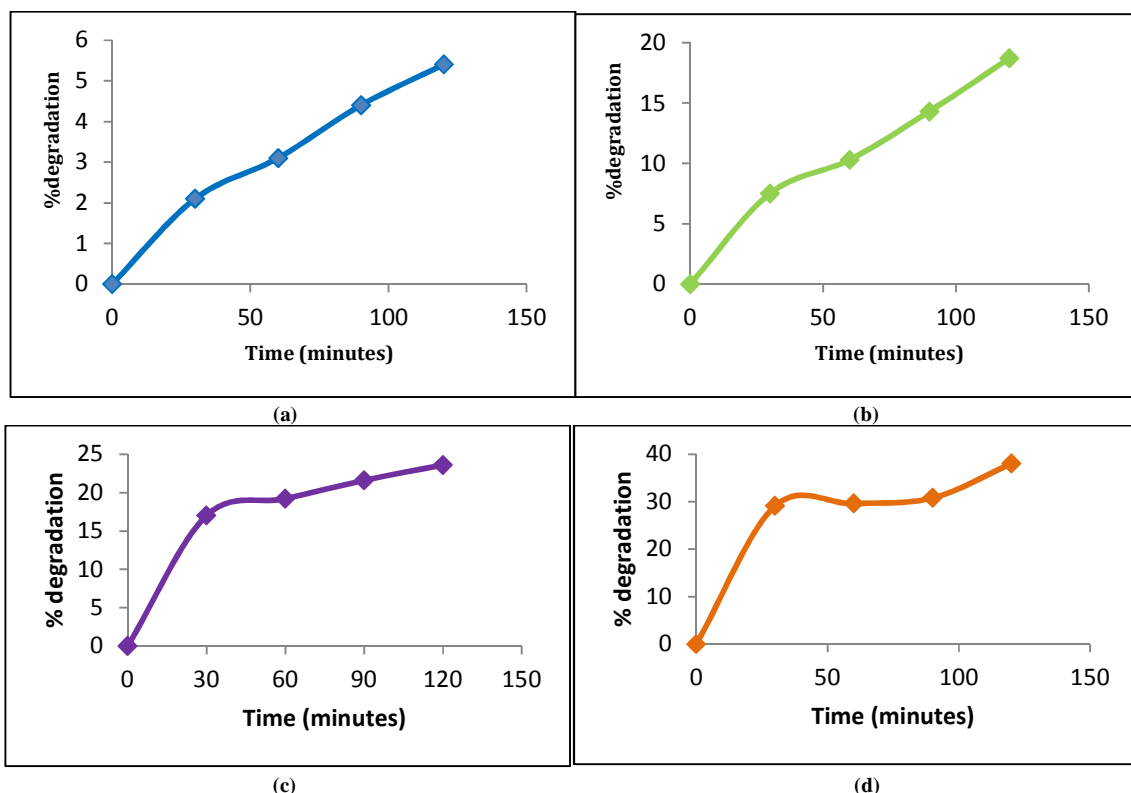


Figure 3. Effect of catalyst loading in photodegradation of yellow-GCN

### 3.3 Effect of irradiation time

The absorbance of yellow-GCN degradation in varied times is measured by UV-Vis spectrophotometer and showed at **Figure 4**.



**Figure 4.** Effect of irradiation time (a) Solar photolysis (b) UV-Light photolysis (c) Solar photolysis using catalyst (d) UV-Light photolysis using catalyst

It is shown that with increasing of irradiation time, both UV-Light and Solar irradiation, the degraded yellow-GCN will increase as well. The degradation of yellow-GCN for 30 minutes of UV-light irradiation is only 2.1%, by increasing the irradiation time until 120 minutes, the degradation become 5.4%. Similar to solar irradiation, for 30 minutes degradation of yellow-GCN could be degraded 7.5% and increasing the degradation time until 120 minutes, the degradation become 18.7%. By increasing the irradiation time will longer the contact that occurs between OH radicals with dye molecules.

Compared to degradation of yellow-GCN without and with C-N-codoped  $\text{TiO}_2$  catalyst, **Figure 4** shows the real effect of catalyst loading. In the presence of 10 mg C-N-codoped  $\text{TiO}_2$ , the degradation percentage increase to 23.6% for 120 minutes UV-Light irradiated, while the degradation become 38.0% by solar irradiation. The more effective way in degradation of yellow-GCN is by using C-N-codoped  $\text{TiO}_2$  catalyst.

### 3.4 Effect of light sources

Photodegradation of yellow-GCN (120mg/L) was carried out under UV-light and solar radiation without catalyst to assess the effect of irradiation sources. As clearly seen at **Figure 5**, UV-Light photodegradation occurs appreciably slower than solar photodegradation under similar experimental conditions. After 120 minutes of treatment with UV-Light and solar radiation 5.4% and 18.7% degradation, respectively, was achieved.

### 3.5 Analysis by High Performance Liquid Chromatography (HPLC)

Solution of yellow-GCN was analyzed by HPLC by UV detector 419 nm wavelength. The chromatography column  $\text{C}_{18}$  (250 x 4.6 mm) with mobile phases are acetonitrile and aquabidest (60 : 40, v/v), 100  $\mu\text{m}$  of volume injection and 1.0 mL/minutes of flow rate. The result of UV-light photolysis is shown in **Figure 6**. And the result of solar photolysis is shown in **Figure 7**. The chromatogram of yellow-GCN clearly shows the decreasing of chromatogram peak after degradation by UV-light and solar irradiation, and very low-peak in the presence of C-N-codoped  $\text{TiO}_2$  catalyst. It is showed that the yellow-GCN molecule has been degraded.

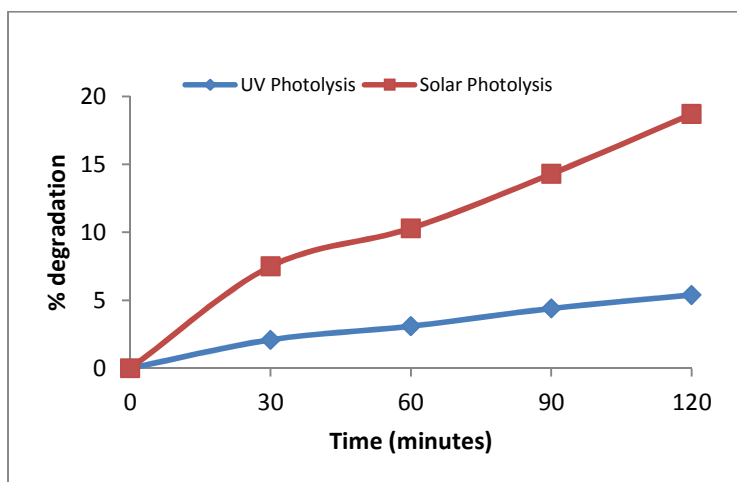
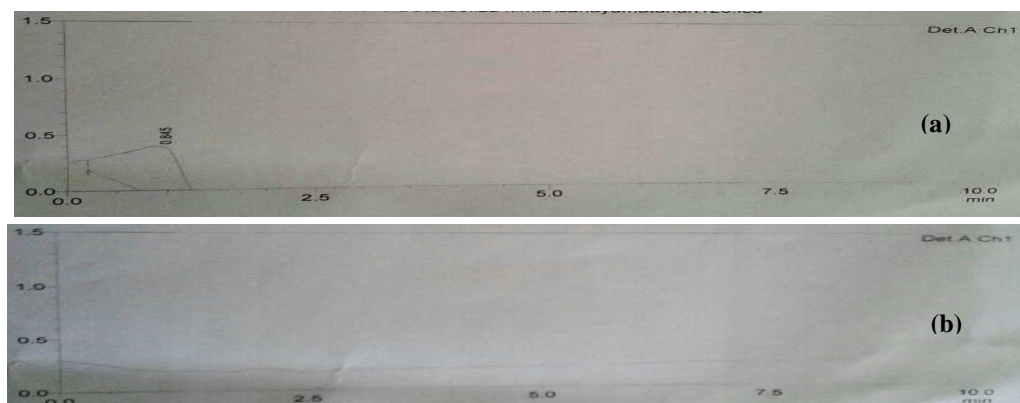


Figure 5. Effect of irradiation sources

Figure 6. HPLC Chromatogram of yellow-GCN (a) standard solution (b) UV-Light photolysis (c) UV-light photocatalytic C-N-codoped TiO<sub>2</sub>Figure 7. HPLC Chromatogram of yellow-GCN (a) Solar irradiation photolysis (b) Solar irradiation photocatalytic C-N-codoped TiO<sub>2</sub>

### CONCLUSION

The degradation of yellow-GCN was obviously affected by the addition of catalyst and light source of radiation. The degradation of yellow-GCN by UV-light photolysis for 120 minutes was obtained 5,4% degradation and adding 10 mg of C-N-codoped TiO<sub>2</sub> highly increase the degradation become 23,6%. While the degradation of yellow-GCN by solar irradiation photolysis under the same condition obtained 18,7% and adding 10 mg of C-N-codoped TiO<sub>2</sub> increase the degradation become 38%. The result confirm that using solar photocatalytic C-N-codoped TiO<sub>2</sub> is more efficient in degradation of yellow-GCN.

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