Photocatalytic degradation of methylene blue using glass fibers catalytic layer covered with red mud

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Abstract: The aim of this paper is to evaluate the degradation of methylene blue using progressive oxidation method. We have examined the effect of the intensity of the UV radiation and the influence of used catalytic layer on the methylene blue degradation efficiency. We have applied red mud catalyst on glass fibers Saertex layer in order to higher the degradation rate. We have found out that higher intensity of UV light of positively affects the efficiency of the degradation. Use of the catalyst layer formed by deposition of alternative catalyst (red mud) on glass fibers has increased the degradation efficiency of methylene blue.
Keywords: UV degradation, methylene blue, photochemical methods, catalyst, red mud

1. Introduction

Development of technologies to remove substances harmful to health, which can be removed using sunlight and natural substances is one of the greatest scientific efforts nowadays. The most important natural material used as the photocatalyst is a titanium dioxide having photocatalytic properties[1].

The biggest problem of wastewater treatment at present is to eliminate persistent and toxic substances in the waters occur at very low concentrations. The effective degradation processes increasing the mineralization of these compounds is required. One of the methods thus developed, which is one of the so-called advanced oxidation method is photocatalytic degradation and UV degradation of organic pollutants in water using colloidal semiconductor photocatalyst TiO_2 type using UV. The progressive method removes contaminants and the risk reduces to the available level[2,3].

Methylene blue (MB) is a cationic dye which is widely used mainly for dyeing cotton, wool and silk. The risk of this dye in wastewater can cause various negative effects on the body. Due to use of chemicals industry, this substance is increasingly getting into surface water[4].

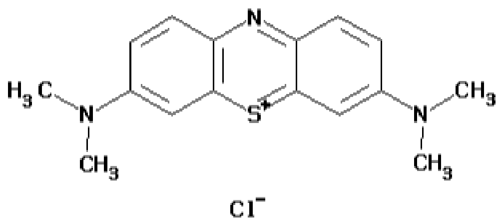

Fig. 1: Methylene blue

MB disposal considerable advantage when released into the environment is the use of knowledge that the substance is able to capture the surface. In the case of evaporation of the aqueous solution can be easily removed from the contaminated components of different remediation methods, by contaminated environmental media[5,6].

Red mud (RM) is a solid waste residue formed after the caustic digestion of bauxite ores during the production of alumina. Each year, about 90 million tonnes of red mud are produced globally. Red mud is a highly alkaline waste material with pH 10–12.5 mainly composed of fine particles containing aluminium, iron, silicon, titanium oxides and hydroxides. Due to the alkaline nature and the chemical and mineralogical species present in red mud, this solid waste causes a significant impact on the environment and proper disposal of waste red mud presents a huge challenge where alumina industries are installed[7].

RM is produced during the Bayer process for alumina production. Bauxite ores are usually a mixture of minerals rich in hydrated aluminium oxides. However, they also contain iron, silicon and titanium minerals. After the digestion of bauxite ores with sodium hydroxide at elevated temperature and pressure, aluminium oxide is dissolved in the solution and the solid residue is red mud. The amount of the residue generated, per tonne of alumina produced, varies greatly depending on the type of bauxite used, from 0.3 tonnes for high grade bauxite to 2.5 tonnes for very low grade. Yearly production of red mud in Slovakia was about 70 000 kg and supplies are estimated at 8 million tons[8-10].

As red mud has a strong alkalinity, which will cause some potential risks to its reuse, pre-treatment to change the alkalinity will produce beneficial effects. In the past years, several methods have been proposed such as acid neutralization, seawater wash treatment, heat treatment and the combination of above three treatments. Acid neutralization is widely used for red mud treatment and this method can remove alkali metals and other inorganic impurities as well as some organics. It is generally found that acid neutralization can increase the surface area and pore volume, favouring adsorption. Heat treatment can decompose unstable compounds and organic substances; however, it can also cause particle aggregation or sintering[11].

Utilization of red mud will produce significant benefits in terms of environment and economics by reducing landfill volume, contamination of soil and ground water, and release of land for alternative uses. Moreover, it can be used to produce valued materials for other applications and thus saving natural resources[12].

2. Experimental

To study the degradation of methylene blue using photochemical method photochemical reactor with a UV lamp with an output of 125 W or 400 W was used. The initial concentration of methylene blue was 5 mg l^{-1}. Glass UVVis spectrophotometer cells with optical paths of 10 mm were used. The efficiency of methylene blue degradation was determined at a wavelength of 660 nm when the absorption of the radiation reaching the maximum value:

$$U = \frac{A_{660\ t0} - A_{660\ t1}}{A_{660\ t0}} \times 100 \qquad [\%] \tag{1}$$

10 g of red mud were suspended in 20ml of distilled water. Prepared mixture was applied to the surface of the glass fiber Saertex (1.7 cm x 15 cm) with a brush, and was placed in a muffle furnace for 2 hours at 700 °C.

3. Results and discussion

3.1 Photodegradation of methylene blue with 125 W UV lamp without catalyst

As it could be seen from table 1 and figure 2 the degradation of MB using 125 W UV lamp is quite rapid. The efficiency after 60 min. of irradiation is 85.73%.

3.2 Photodegradation of methylene blue with 400 W UV lamp without catalyst

In this experiment we have investigated the influence of intensity of UV lamp to the degradation rate. We have observed that the use of 400 W UV lamp instead of 125 W caused a slight increase in degradation rate (table 2, figure 3). The efficiency of MB degradation after 60 min. was 88.78 %.

3.3 Photodegradation of methylene blue with 125 W UV lamp with the use of red mud catalytic layer

We have used red mud catalytic layer to speed up the degradation rate of methylene blue. We have found out that the increase of degradation efficiency after 60 min. of irradiation is approximately 8 % (93.45 %) . The use of prepared layer may reduce the cost for UV irradiation in shortening the time of complete degradation of methylene blue solution.

Table 1: Values of MB absorbance at 660 nm vs. time of degradation with 125 W UV lamp without catalyst

Time of degradation [min.]	0	1	2	3	5	7	10	20	30	60
$A_{660\ nm}$	1.072	0.960	0.978	0.703	0.716	0.569	0.468	0.354	0.229	0.153

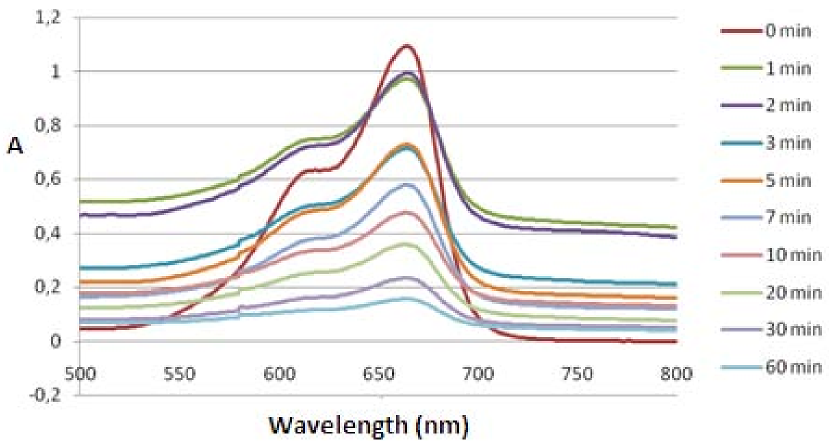

Fig. 2: Absorbance of methylene blue solution vs. wavelength in different time of UV irradiation (125 W) without the use of red mud as a catalyst

Table 2: Values of MB absorbance at 660 nm vs. time of degradation with 400 W UV lamp without catalyst

Time of degradation [min.]	0	1	2	3	5	7	10	20	30	60
$A_{660\ nm}$	1.127	0.882	0.862	0.736	0.586	0.510	0.390	0.196	0.111	0.068

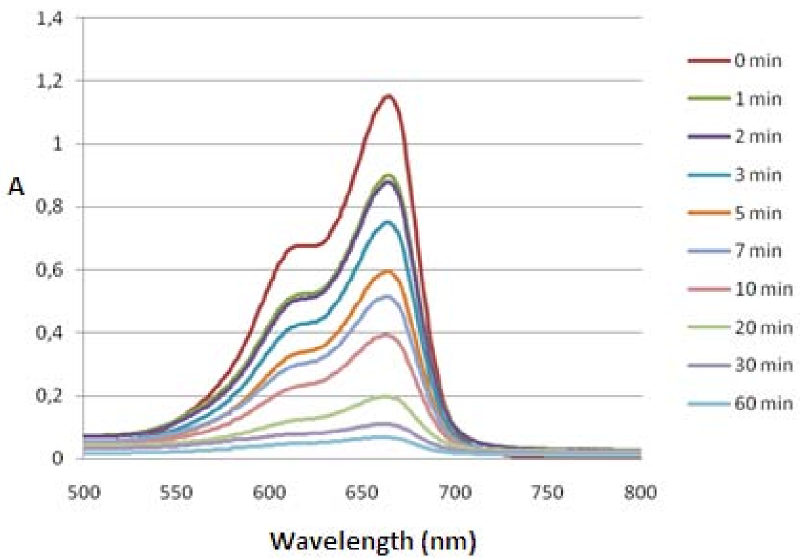

Fig. 3: Absorbance of methylene blue solution vs. wavelength in different time of UV irradiation (400 W) without the use of red mud as a catalyst

Table 3: Values of MB absorbance at 660 nm vs. time of degradation with 125 W UV lamp with red mud catalytic layer

Time of degradation [min.]	0	1	2	3	5	7	10	20	30	60
$A_{660\ nm}$	0.929	0.789	0.692	0.614	0.512	0.376	0.27	0.118	0.039	0.019

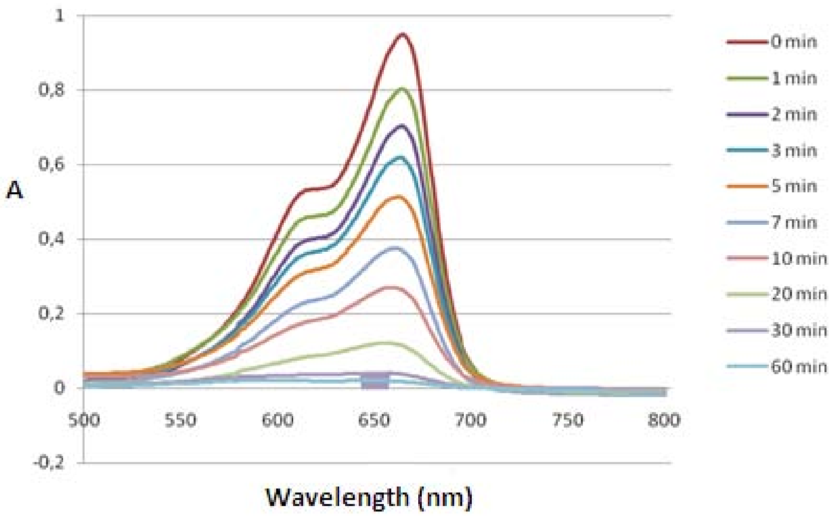

Fig. 4: Absorbance of methylene blue solution vs. wavelength in different time of UV irradiation (125 W) with red mud catalytic layer

3.4 Photodegradation of methylene blue with 400 W UV lamp with the use of red mud catalytic layer

We have found out that the increase of degradation efficiency after 60 min. of irradiation is approximately 10% (98.45 %). The use of prepared layer has led to completely full degradation of methylene blue after 60 min. of irradiation.

Table 4: Values of MB absorbance at 660 nm vs. time of degradation with 400 W UV lamp with red mud catalytic layer

Time of degradation [min.]	0	1	2	3	5	7	10	20	30	60
$A_{660\ nm}$	1.127	0.710	0.599	0.513	0.397	0.303	0.204	0.088	0.040	0.017

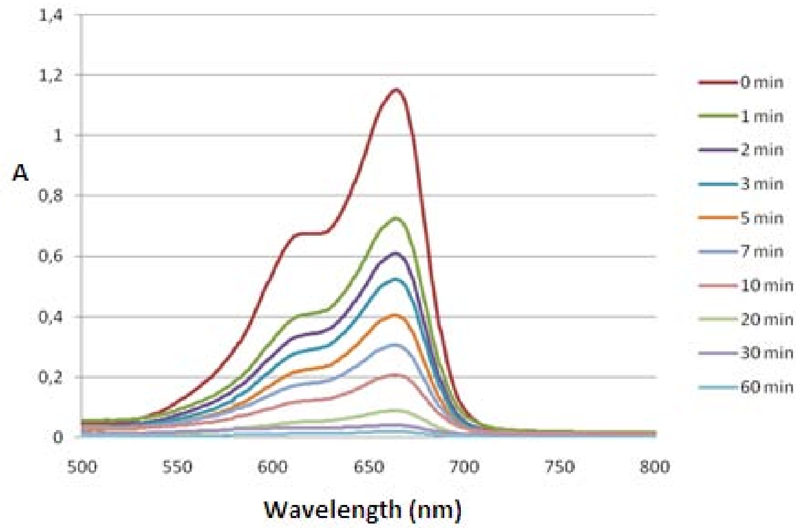

Fig. 5: Absorbance of methylene blue solution vs. wavelength in different time of UV irradiation (400 W) with red mud catalytic layer

4. Conclusion

Comparing the results of different experiments, we came to the following conclusions:

1) The intensity of the UV radiation affects the degradation efficiency of MB solution

2) Use of the catalyst layers formed by deposition of red mud on glass fibers has increased the degradation efficiency of MB.

3) 60 min. time of UV irradiation is sufficient for complete degradation of MB with the use of 400 W UV lamp and red mud catalytic layer.

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6. References

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