Studying the effect of monochrome light on the photocatalytic activity of tungsten oxide

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Abstract. The paper presents studies of the photocatalytic activity of tungsten oxide nanopowder agglomerates under the action of monochrome light in the decomposition reactions of an organic pollutant (methylene blue). It is determined that the radiation of 470 nm (blue) provides the highest values of the rate constant of phototransformation of methylene blue.

1. Introduction
The production and use of synthetic chemical products have increased dramatically over the last century. These products do not decompose and are harmful to the environment. New water treatment technologies are needed to remove or decompose dangerous pollutants in wastewater. This will purify water resources and make them suitable for human consumption.

In recent years, the authors have proposed ways to treat this kind of wastewater such as: flocculation, electrodialysis, filtration, reverse osmosis, chemical coagulation, adsorption and sedimentation [1–3].

In comparison with the existing technologies the methods of photocatalytic water purification have advantages, e.g., the end products of running reactions are neutral for the environment. In addition, they do not require additional engineering costs, and water purification units can be created on the basis of already existing technical solutions [4].

Studies of the authors [5] have shown the effectiveness of tungsten oxide as a photocatalyst for the decomposition of methylene blue in concentrations from 5 mg/l. At the same time, tungsten oxide is included in complex compounds with various metals. In addition, WO3 is applicable in various fields such as photodegradation, bacterial disinfection, and water splitting [6–8].

2. Research methodology
To study the photocatalytic activity of tungsten oxide nanoparticles under the action of monochrome light, samples obtained in SRC “Perspective Technologies and Materials” [2, 3] were used.

A sample of nanopowder weighing 0.2 g was placed in a round flat-bottomed flask and 200 ml of methylene blue solution with a concentration of 15 mg/l was added.

Aqueous solutions of methylene blue were irradiated in chambers, equipped with diode tapes with wavelengths of 620, 520, and 470 nm for 10 h, and stirred constantly on a magnetic stirrer “Rhythm-01” with a speed of 500 rpm. The decomposition process of methylene blue was studied using spectrophotometry. Sampling was performed every 2 hours to control the course of photochemical reaction and to observe changes in the concentration of pollutant in the solution; 10 ml of the sample was centrifuged for 15 min at 3000 rpm, separating the sediment. After that the solution
was decanted and on photometer “Expert 003” manufactured by “ECONIKS-EXPERT” Ltd. The concentration of dye was estimated by the degree of discoloration of solution. After the analysis, the sample was returned to the initial solution.

3. Results and discussion
During the process, the methylene blue solution was discolored, and the formation of “flakes” representing crystalline insoluble oxidation products was observed. As can be seen from the presented data (Fig. 1–3), the main absorption maximum of methylene blue occurred in the region of 655 nm.

![Figure 1. UV-vis spectrum of photocatalysis reaction for red spectrum (620 nm).](image1)

![Figure 2. UV-vis spectrum of the photocatalysis reaction for the green spectrum (520 nm).](image2)
Analysis of the diagrams has shown that the photocatalytic activity of tungsten oxide in the blue spectrum is higher than in the red and green spectra.

To estimate the degree of photocatalytic activity of tungsten oxide, we used the formula:

$$E = \left[ \frac{(C_0 - C_k)}{C_0} \right] \cdot 100\%,$$

where $E$ is the photocatalytic activity of the sample, %; $C_0$ is the initial optical density of dye in solution; and $C_k$ is the final optical density of dye in the solution.

The results of the calculations are shown in Diagram 4-6. After 10 hours of continuous process, the value of the dye spectrum decreased by 34, 50, and 64 %.

From the given data, we can see that after 10 hours of continuous process, the dye spectrum value has decreased by 34%. The process is effective for the first 6 hours, and then there is a decrease in the degree of removal.
Figure 5. Photocatalytic activity data in the photodegradation reaction of the dye methylene blue in the green spectrum.

Analysis of the results of photocatalytic activity of tungsten oxide in the green spectrum has shown that after 10 hours of a continuous process, the dye spectrum value decreases by 50%. The decomposition process of methylene blue has a uniform character.

Figure 6. Photocatalytic activity data in the photodegradation reaction of the dye methylene blue in the blue spectrum.

The photocatalytic activity data in the photodegradation reaction of the dye methylene blue in the blue spectrum has revealed that after 10 hours of continuous process, the dye spectrum value decreased by 64%. Additional studies to find the optimal wavelength will be carried out in the future.

Conclusions

It was shown that tungsten oxide has photocatalytic activity under the action of visible light in the photodegradation of the dye methylene blue. It has been determined that 470 nm (blue) radiation provides the highest values of the rate constant of phototransformation of methylene blue.

The obtained data on the photocatalytic activity of tungsten oxide nanopowder agglomerates indicate that it can effectively find application in the technology of wastewater treatment from organic substances.

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