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Effect of surface morphology of macro-scale perlite particles on adsorption process of Malachite Green dye

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ABSTRACT

Perlite is a mineral compound. It is a mixture of SiO_2, Al_2O_3, Na_2O, K_2O, Fe_2O_3 and so on. Its high porosity and low density cause that it is being used as an adsorbent to remove organic and inorganic pollutants from wastewater in many researches. But its capacity depends on its structure as an adsorbent. In this research, the effect of macro-scale size of perlite particles has been investigated on adsorption capacity and procedure. The results show that the difference is in perlite macro-scale size of surface morphology and there is no significant difference in micro-scale size.

Keywords: Adsorption; Perlite; Wastewater treatment; Malachite Green (MG) dye; Macro-scale size

1. Introduction

Various colorants (dyes and pigments) are being applied in many industries for different coating applications. It is the inevitable reason for existence these materials in industrial wastewater. Colored wastewaters, especially organic ones, are wastes of different industries, such as paper, textile, leather, food, polymers, minerals and plastics [1]. These cause that treatment of water and wastewater, contaminated with colorants, are one of the main concerns of researchers in recent decades.

In a real wastewater, there is a complex of different materials, such as colorants, polyacrylates, phosphonates, anti-coagulation factors, and so on. Most of these compounds are poisoning and it is necessary for ecological balances that these dangerous contaminants are being removed from treated wastewater completely. Therefore, the governments and different UN organizations have recently established many rules to prevent and standardize these materials in environment [2,3].

Different physicochemical decolorization processes have been developed to remove contaminants from industrial wastewater in recent years, such as membrane separation, coagulation, flotation, biological, electrochemical, photo-catalysis, and ozonation treatment methods. But most of these methods are expensive and certain economical foundation is necessary. Among physicochemical processes, adsorption technology has found many application in water and wastewater treatment, as one of the most efficient and effective technologies [2,4]. Therefore, natural adsorbents have been used to reduce costs and the environmental side effects, such as diatomite [2], red mud [5], chitosan [6], orange skin [7], soy meal hull [8], almond skin [9], sawdust [10], zeolite [11] and clay [12]. These adsorbents have natural base and they are environmental friendly. It is possible to be regenerated most of them or be applied in different products.

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In this research, removal of Malachite Green (MG) has been investigated from simulated textile wastewaters by perlite. Perlite is a natural and cheap adsorbent. Two different macro-scale size of this adsorbent was prepared by sieve and their macro and micro-scale structures have been compared by scan electron microscope instrument (SEM). The material distributions are uniform in perlite.

2. Materials and equipments

Perlite was supplied from internal sources. It can be prepared in any material construction store. Malachite Green (MG) dye was supplied from Ciba Company. Its molecular structure has been shown in Fig. 1.

A laboratory balance (Sartorius-d = 0.1 mg, max 120 g model) was used to weight samples. Some simple laboratory heater–stirrer systems were used to mix samples; UV/Visible spectrometer (One beam, Cecil-CE2021-2000 series) was applied to measure the change on concentration of dye. In addition, various sieves with different meshes were used to categorize the adsorbent. A centrifuge (Hettich EBA20, max. 6000 rpm) was applied to sediment and remove colloidal particles, and pH meter (Metrohm 713) was used to measure and adjust the pH of simulated wastewaters. SEM (scan electron microscope, LEO 1455VP) was used to increase the knowledge about perlite microscopic structure and its real nature. Other chemicals, such as sodium hydroxide and chloridric acid, were supplied from Merck Company, especially to adjust the pH of wastewater.

2.1. Perlite categorizing

Supplied perlite was categorized with size of its particles in 5 macro-scale sizes by various sieves. These categories were 60–120, 120–170, 170–200, 200–325, and <325 meshes. The removal of MG dye was examined for all of these categories in concentration of 6 ppm and pH equal to 6. 0.05 g of adsorbent was added to 25 ml of simulated wastewater. Rotational speed of stirrer was

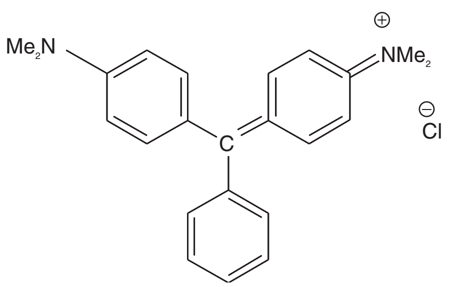

Fig. 1. Molecular structure of Malachite Green colorant [13].

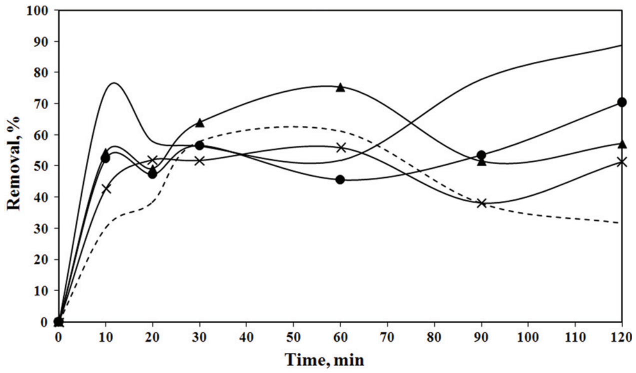

Fig. 2. Removal trend of MG dye from 6 ppm simulated wastewater in pH = 6 by different perlite categories with (—) 60–120 mesh, (--) 120–170 mesh, (····) 170–200 mesh, (==) 200–325 mesh and (=) >325 mesh (0.05 g per 25 ml of solution).

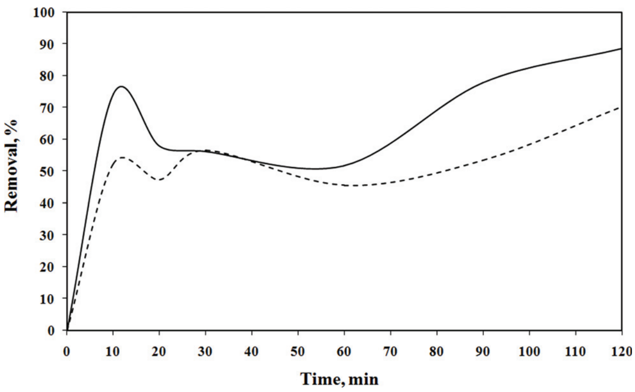

Fig. 3. Removal trend of MG dye from 6 ppm simulated wastewater in pH = 6 by the (—) first and (– –) second perlite samples (0.05 g per 25 ml of solution).

in meddle (less than 1000 rpm). It means that the mass transfer resistant could not be neglected in wastewater bulk. The results are shown in Fig. 2.

The first (60–120 meshes) and the forth (200–325 meshes) categories show the best results and they were chosen to be investigated. These two categories are recognized as first and second samples, respectively. Fig. 3 is only repetition of Fig. 2 with these two categories.

3. Results and discussions

Fig. 3 compares adsorption of MG dye on chosen categories of perlite after 120 min. It shows that the adsorption capacity of the first sample is more than the second one. It is 88.7% and 70.4%, respectively. In addition, its trend shows higher performance.

Figs. 4 and 5 show this comparison for 0.1 g and 0.2 g adsorbent per 25 ml of solution. Fig. 5 shows same

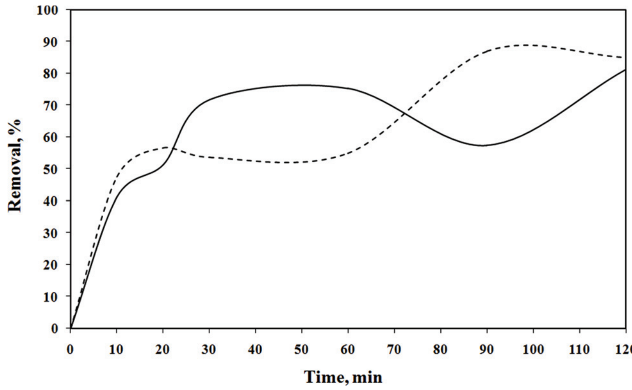

Fig. 4. Removal trend of MG dye from 6 ppm simulated wastewater in pH = 6 by the (—) first and (– –) second perlite samples (0.1 g per 25 ml of solution).

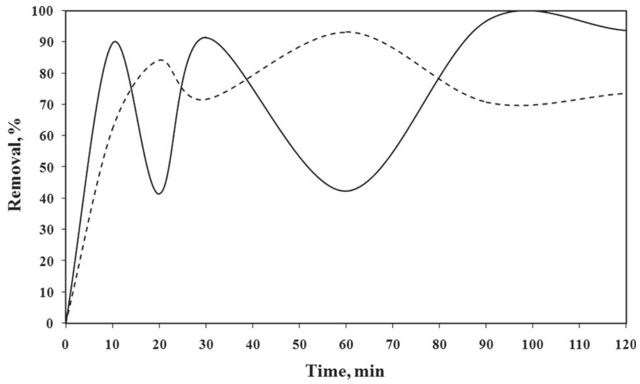

Fig. 5. Removal trend of MG dye from 6 ppm simulated wastewater in pH = 6 by the (—) first and (– –) second perlite samples (0.2 g per 25 ml of solution).

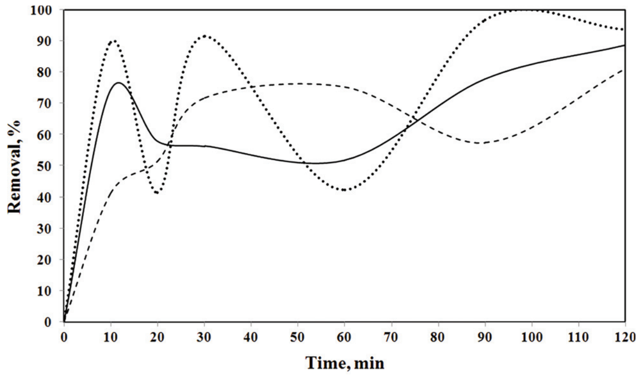

Fig. 6. Removal trend of MG dye from 6 ppm simulated wastewater in pH = 6 by (—) 0.05 g, (– –) 0.1 g and (=) 0.2 g of the first sample per 25 ml of solution.

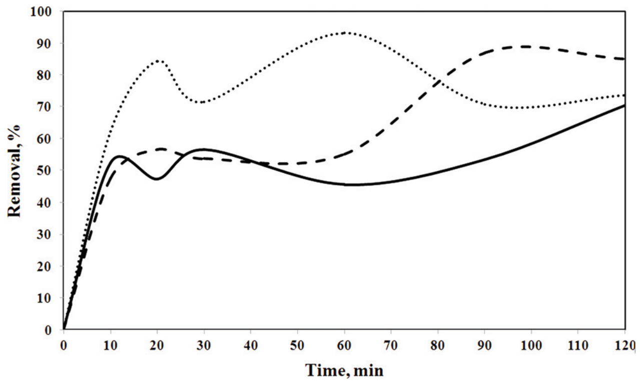

Fig. 7. Removal trend of MG dye from 6 ppm simulated wastewater in pH = 6 by (—) 0.05 gr, (– –) 0.1 g and (=) 0.2 g of the second sample per 25 ml of solution.

trends as Fig. 3. The maximum removal percentages are 93.7 for the first sample and 73.7 for the second sample. But there is not a big difference in Fig. 4. The second sample has only removed 4.8% more.

Figs. 6 and 7 present removal trend of perlite in different adsorbent quantities (0.05, 0.1 and 0.2 g per 25 ml of solution) for the first and second samples, respectively.

These figures show that the variation around equilibrium adsorption capacity would increase with increasing quantity of perlite and it is less in lower quantities. Therefore, quantity of solid (adsorbent) has a big rule on the duration of process, achieving final removal quantity (equilibrium quantity) and damping variations around equilibrium point.

Surface morphology and particle size are the main reasons for these features. Different SEM pictures of these two perlite categories have been presented in Figs. 8–17 for different magnitudes. Figs. 8, 10, 12, 14 and 16 are belonged to the first sample with 500x, 3000x, 10,000x, 30,000x, and 100,000x magnitudes, respectively,

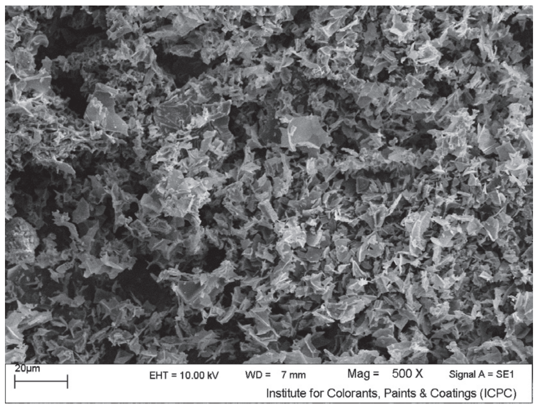

Fig. 8. SEM picture of the first sample (500x).

and Figs. 9, 11, 13, 15 and 17 are belonged to the second sample with 500x, 3000x, 10,000x, 20,000x, and 100,000x magnitudes, respectively.

Comparison of Figs. 8, 10, 12, 14 and 16 with 9, 11, 13, 15 and 17 illustrate that there are many differences

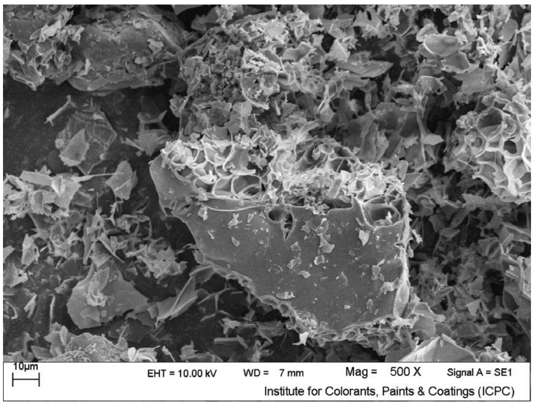

Fig. 9. SEM picture of the second sample (500x).

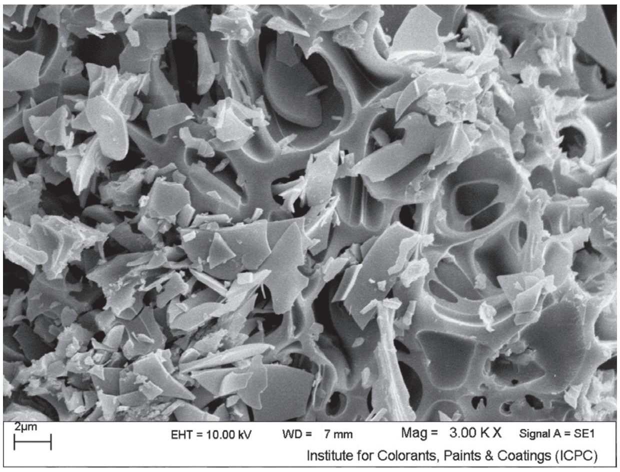

Fig. 10. SEM picture of the first sample (3000x).

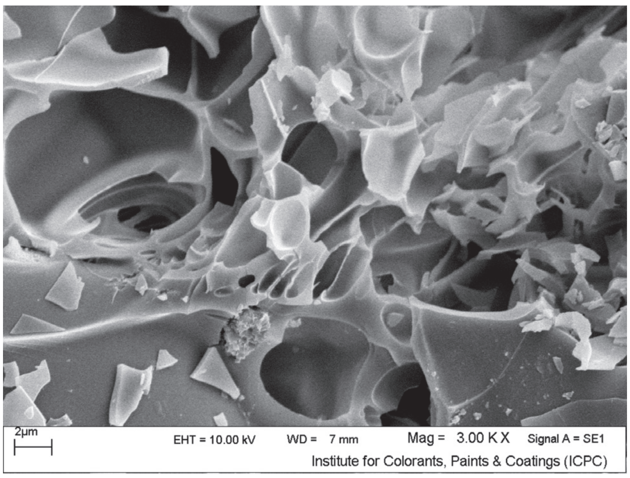

Fig. 11. SEM picture of the second sample (3000x).

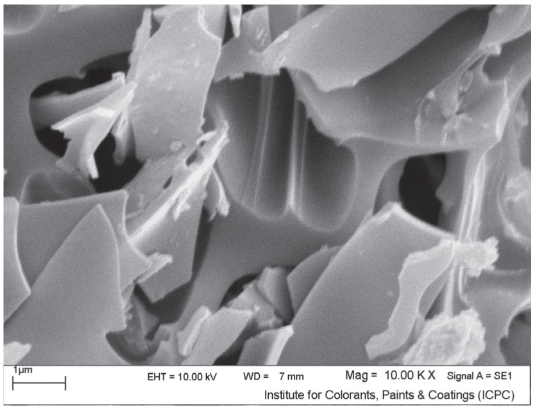

Fig. 12. SEM picture of the first sample (10,000x).

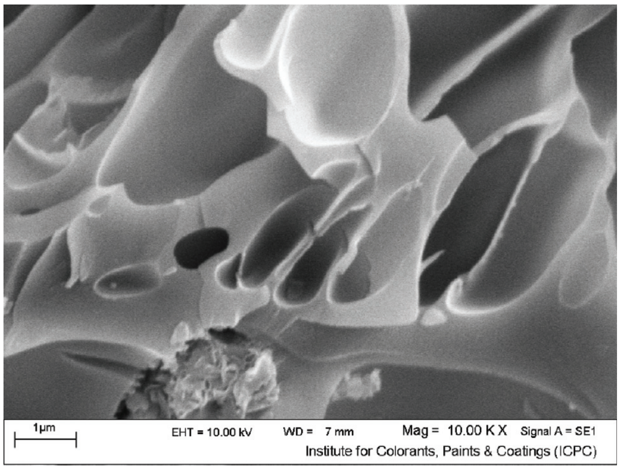

Fig. 13. SEM picture of the second sample (10,000x).

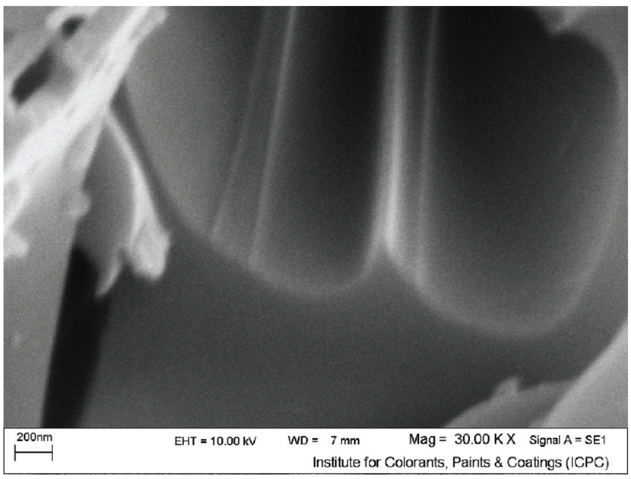

Fig. 14. SEM picture of the first sample (30,000x).

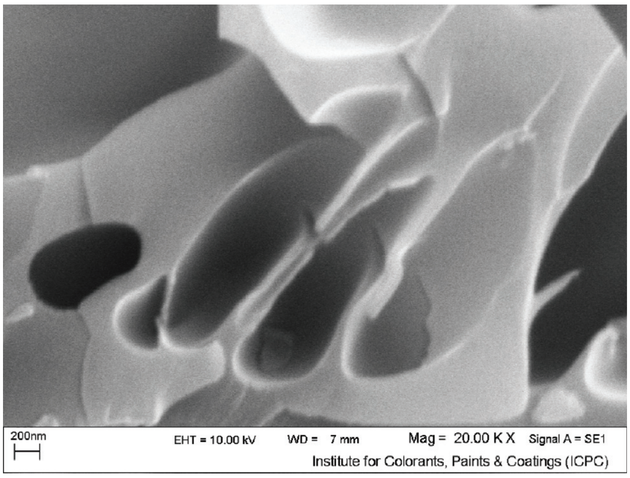

Fig. 15. SEM picture of the second sample (20,000x).

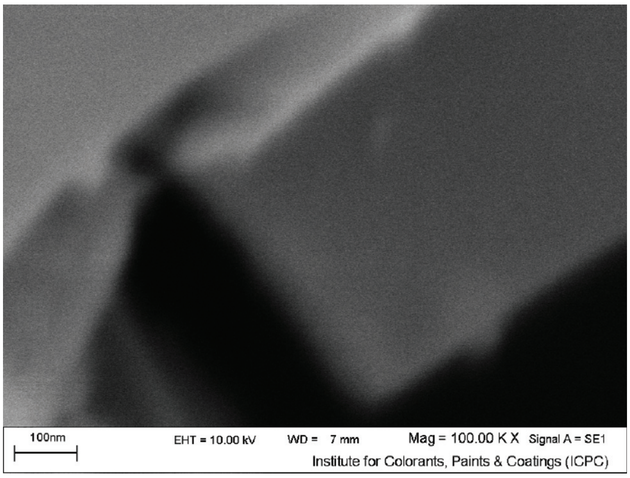

Fig. 16. SEM picture of the first sample (100,000x).

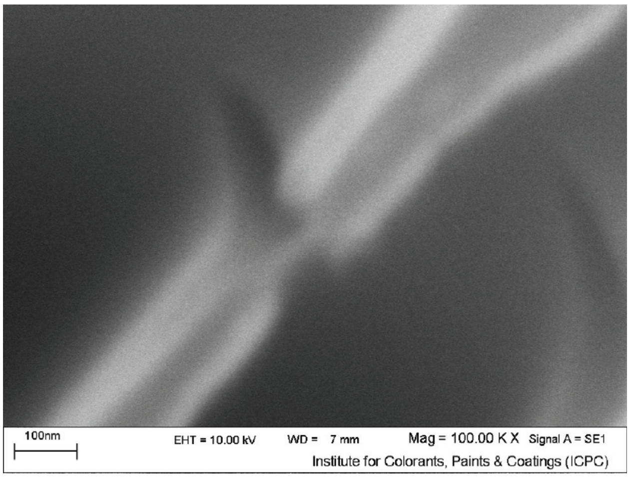

Fig. 17. SEM picture of the second sample (100,000x).

between surface morphology of these categories in low magnitudes (macro-scale sizes), respectively. There are different sized particles over surface of the first sample (Figs. 8–11), but the morphologies of both categories are the same in higher magnitudes (micro-scale sizes). It means that the first sample, with bigger particles, has been structured from smaller particles and it can be the main reason for higher capacity and bigger unstable response to pollution exposure of the first sample with respect to second one.

4. Conclusion

The results of this research show that the surface morphology of perlite has very important role on adsorption process in low bulk mass transfer velocity (rotational speed of stirrer). It is an important point, especially in scale up of adsorption processes. The stirred speed of mixed tank is normally low in industrial scales and it is really significant to attend on effect of particles morphology of perlite in adsorption process.

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