Effect of diatomite with different morphologies on the purity guide performance of formaldehyde in Jilin Changbai area

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Abstract: In this paper, diatomite with different shapes (discoid, cylindric and scaphoid) was purified and characterized by SEM and BET. Then diatomite purification materials were prepared and formaldehyde adsorption test was carried out. The results showed that the pore structure of the purified diatomite was improved and the impurities were eliminated effectively. At 48 hours, the formaldehyde purification rate and the formaldehyde purification persistence rate of the diatomite purification materials with different shapes were different. The purification rate of the discoid diatomite purification materials to formaldehyde was 76.67%, the formaldehyde purification effect lasted 58.18%, the formaldehyde purification rate of the scaphoid diatomite purification materials was 85.45%, and the formaldehyde purification effect lasted 69.83%, the formaldehyde purification rate of cylindric diatom purification material is 88.89%, and the lasting rate of formaldehyde purification effect is 77.10%.

1. Introduction
Diatomaceous earth belongs to a kind of biomass sedimentary rock. The cell wall of unicellular plant diatom is rich in silicon material, which can form a hard outer shell in the outer layer. The remains of a large number of diatom organisms undergo sedimentary mineralization for a certain period of time, and eventually form sedimentary rocks [1]. Its chemical composition is mainly amorphous SiO$_2$, the content is about 75%, and also contains a small amount of other components and organic impurities and other impurities [2]. It has a unique surface area (10-80 m$^2$/g), highly ordered porous structure, thermal stability and very low density (2000-2500 kg/m$^3$) and other unique properties [3]. The common diatoms have the micromorphology of discoid algae, stereocyclic algae, cylindric algae, spherical algae, scaphoid algae and clavate algae, etc. [4]

In the process of new house, furniture, decorate the process often can produce a kind of formaldehyde poisonous gas that affects human body health, compound diatomaceous earth and photocatalytic material is the important means that eliminates indoor formaldehyde gas[5-6]however, there is still no research on the influence of diatomite with different morphologies on formaldehyde purification. Therefore, this paper studies the formaldehyde purification performance of diatomite with different morphologies.

2. Experimental work

2.1. Materials
This experiment uses different morphologies diatomaceous earth and pine powder in Baishan Mountain, Jilin Province. There are also formaldehyde solution, inorganic filler, latex powder, cellulose ether, polypropylene fiber, polyvinyl alcohol and nano TiO$_2$ /white carbon composite photocatalytic material.

2.2. Instrument and equipment
The main instruments used in this experiment are VEGA3 LMH scanning electron microscope, Vc-Sorb2800TP specific surface area and pore size measuring instrument, GDYK-20 automatic double channel atmospheric sampling instrument, GDYJ-201MF automatic multifunction formaldehyde and ammonia measuring instrument.

2.3. Purification of diatomite of different forms
In this paper, the combination of mechanical method, physical method and chemical method is used for purification. The specific process is as follows: mechanical pulverization of diatom soil→ultrasonic pretreatment→water processing→filtration→desiccation→2h 600$^{\circ}\text{C}$ calcination→cooling→the purified diatomite is obtained.

2.4. Preparation of diatom purification material
Different materials are added to the dispersion tank according to a certain ratio for stirring, so that the raw materials are uniformly dispersed, and then water is gradually added thereto, and stirred at a rotation speed of 2000-3000 r/min to obtain a paste-like diatom purification material. According to the provisions of JC/T 1074-2008, the diatom material slurry is evenly spread on a 500 nm × 500 nm × 5 nm glass plate, the thickness is 2 mm, at a temperature (18-22)$^{\circ}\text{C}$, relative humidity (40-60)% dry for 24 h under conditions.

2.5. Adsorption formaldehyde test
The prepared sample is placed in the sample compartment. After sealing, 3 μL of analytical pure formaldehyde solution is injected into the test chamber with a micro-syringe, and the fan is turned on. After the formaldehyde is volatilized uniformly, the concentration at this time is recorded as the initial concentration, every 2 h test the formaldehyde concentration until the end of the test after 48 h, at which time the concentration is the termination concentration. The durability of the sample purification effect is carried out in accordance with the method specified in JC/T1074-2008.

The natural attenuation rate is calculated according to formula (1)

$$R = \frac{\left(n_0-n_1\right)}{n_0}\times100\% \quad (1)$$

Where $R$ represents the natural rate of decay, $n_0$ represents the initial concentration of formaldehyde in the comparison chamber, $n_1$ represents the termination concentration of formaldehyde in the comparison chamber.

The sample net rate is calculated according to formula (2)

$$r = \frac{\left(n_1-n_2\right)}{n_1}\times100\% \quad (2)$$

Where $r$ represents purification efficiency, $n_1$ represents the termination concentration of formaldehyde in the comparison chamber, $n_2$ represents the final concentration of formaldehyde in the sample chamber.

3. Results and discussion

3.1. SEM analysis
The calcination method is a method for removing organic matter and structural water in diatomaceous earth at a suitable temperature [7], and must be calcined at an appropriate temperature. If the temperature is too high, the surface active site of the diatomaceous earth disappears, and the microstructure is destroyed. The temperature is too low, the organic impurities are not effectively
removed, and the permeability is low. The optimum calcination temperature is in the range of 500°C to 800°C, and the time is controlled in the range of 0.5 h to 2 h. This article uses 600°C calcination for two hours.

Figure 1 is a scanning electron micrograph of diatomaceous earth with different morphologies before and after purification. Figures a, b, and c are discoid, cylindric, and scaphoid diatomaceous earth before calcination, respectively. Figures d, e, and f are calcined. Discoid, cylindric, scaphoid diatomaceous earth. It can be seen that no matter which form of diatomaceous earth is purified by high temperature calcination at 600 °C, various metal oxides and organic matter attached to the pores of the diatomaceous earth original are burned out, and the surface of the diatom shell is shaped. The appearance is clear, the surface adhesion impurities are reduced, and only the local position is accompanied by impurities, and most of the holes are exposed and distributed.

![Figure 1. Scanning electron micrograph of different morphology diatomite before and after purification.](image)

### 3.2. BET analysis

From table 1, it can be seen that the specific surface area of diatomite with different shapes after purification has been improved, the specific surface area of discoid diatomite has been increased by 5.02038 m²/g, the specific surface area of cylindric diatomite has been increased by 7.104716 m²/g, and the specific surface area of scaphoid diatomite has been increased by 6.122255 m²/g, which proves that purification can improve the specific surface area of diatomite.

| Sample | Discoid | Cylindric | Scaphoid |
|--------|---------|-----------|----------|
| Specific surface area before purification (m²/g) | 8.002340 | 47.967029 | 10.114451 |
| Specific surface area after purification (m²/g) | 13.022720 | 55.071745 | 16.236706 |

### 3.3. Analysis of formaldehyde purification performance

Figure 2 shows the formaldehyde purification rate curve of diatom purification materials, table 2 shows the test results of formaldehyde purification effect durability, figure 3 shows the process of formaldehyde purification by diatom purification material. As can be seen from figure 2, the diatom purification material adsorbed formaldehyde faster in the first 6 hours, the formaldehyde purification rate of No. 1 diatom purification material (disc diatomaceous earth), No. 2 diatom purification material (cylindrical diatomaceous earth) and No. 3 diatom purification material (saline diatomaceous
earth) for 48 hours were respectively: 76.67%, 88.89%, 85.45%. No. 1 diatom purification material formaldehyde purification rate is lower than the standard 3.33%, the formaldehyde purification rates of No. 2 and No. 3 diatom purification materials were respectively 8.89% and 5.45% higher than the standard. As can be seen from table 2, the formaldehyde purification lasting rates of 1, 2 and 3 diatom purification materials are respectively 58.18%, 77.10% and 69.83%. The No.2 diatom purification material has a good long-term purification effect on formaldehyde, which is 17.10% higher than the standard.

![Figure 2. The curve of the performance of formaldehyde purification with time.](image1)

**Table 2. Test result of lasting performance of formaldehyde purification effect.**

| Serial number | 1     | 2     | 3     |
|---------------|-------|-------|-------|
| Persistent formaldehyde purification effect (%) | 58.18 | 77.10 | 69.83 |

Figure 3 shows the test process of formaldehyde purification performance of diatom material, the main principles of air purification by diatom purification material include degradation adsorption, chemical adsorption and physical adsorption under environmental action. No matter which purification principle is inseparable from the porosity and large specific surface area of the material, when formaldehyde diffuses from the room to the wall surface, it is in contact with the diatomaceous earth in the diatom purification material, based on diatomaceous earth. Strong physical adsorption, chemisorption and natural degradation of formaldehyde in the environment provide a “hotbed” that reduces the total amount of harmful gases in the indoor environment.

![Figure 3. Purification performance test for purifying formaldehyde by diatom purification material.](image2)

**4. Conclusion**

(1) After purification, the surface structure of diatomite becomes clear and most impurities are removed by SEM, BET analysis shows that the specific surface area of diacoid diatomite increased
from 8.002340 m$^2$/g to 13.022720 m$^2$/g, the specific surface area of cylindric diatomite increased from 47.967029 m$^2$/g to 55.071745 m$^2$/g and the specific surface area of scaphoid diatomite increased from 10.114451m$^2$/g to 16.236706 m$^2$/g.

(2) Different morphologies of diatomite 48 h have different adsorption effects on formaldehyde, the purification rate of formaldehyde from discoid diatom purification material was 76.67%, formaldehyde purification effect lasting rate is 58.18%, the purification rate of formaldehyde from scaphoid diatom purification material was 85.45%, formaldehyde purification effect lasting rate is 69.83 %, the purification rate of formaldehyde from cylindrical diatom purification material was 88.89%, formaldehyde purification effect lasting rate is 77.10 %. It is obvious that the cylindrical diatom purification material has the best effect in degrading formaldehyde.

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