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The Concept of Preparation and Swelling of Hydrogel

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Abstract: *Hydrogels can be used as seawater desalination, sewage treatment, and as drug carriers in medical treatment. In this paper, pure water, acrylic acid and acrylamide are used as raw materials, and the hydrogel is made under the irradiation of gamma ray. The hydrogel is placed in a beaker containing pure water for swelling test, placed in an air dryer for drying test, and placed under a xenon lamp light source in the solution of pure water, salt water and sewage for evaporation test. This experiment compress the prepared hydrogel with weights of different weights, and then cut the prepared hydrogel into small strips of the same length with scissors for tensile test. In the high concentration hydrogel, the drying and swelling rate is slower than that of the low concentration hydrogel. The low concentration hydrogel is the fastest, and the slowest is the hydrogel added with graphite. Under the irradiation of xenon lamp light source, different hydrogels have different water loss properties. In the same solution, graphite has the fastest evaporation rate, while the evaporation rate of high concentration hydrogels is slower. In the tensile test, the hydrogel added with graphite stretched longer. In the compression experiment, the high concentration hydrogel is softer and has stronger compression performance. In the photothermal evaporation experiment, this kind of hydrogel also showed an excellent evaporation rate after adding graphite powder. The hydrogel prepared in this paper has good swelling property and seawater desalination performance, which can be used for seawater desalination and sewage treatment. I would devided into 4 parts to summarise the result of the experiment.*

Keywords: *hydrogel, acrylic acid, acrylamide, swelling, seawater desalination, sewage treatment*

1. Introduction

Wastewater is a waste generated by humans in daily life, and it must be treated. Flocculating agent is a common sewage treatment agent, which works by bringing together positively (negatively) charged groups and difficult to separate particles or particles with negative (positive) charges in water, reducing their potential and making them in an unstable state, and utilizing their aggregation properties to concentrate these particles and achieve purification through physical changes. Therefore, sewage treatment is particularly important in daily life. These sewage treatment agents can not only accelerate the efficiency of treatment, but also reduce cost investment[1]. Hydrogel is a kind of classic flocculant, which can absorb waste materials to obtain the purpose of water purification. Hydrogel is a kind of gel material containing a large amount of water, which has soft and elastic characteristics similar to gel [2]. Its main components are water and polymer networks, which form a three-dimensional structure that can absorb and retain large amounts of water[3]. The structure of the hydrogel enables it to maintain a stable shape when expanding, and has good moisture absorption and biocompatibility [4]. Hydrosol has a wide range of applications in the pharmaceutical field, including serving as a carrier for drug delivery and manufacturing biocompatible scaffolds to support cell growth and repair. In the industrial field, it can be used as a thickener and stabilizer to improve product quality and application effectiveness.

For example, the ethanol solution of poly (acrylate stearate co acrylic acid) (P (SA co AAc)) is printed into the fiber in the air, where the evaporation of the solvent causes the sol gel transition of the "ink" [5]. For example, the swelling ratio and mechanical properties of printing gel before swelling in water vary with evaporation time. By evaporating 70-80 wt% of the solvent within 1 hour, a smooth hydrogel fiber with a diameter of about 200 μ m and good mechanical properties can be obtained. Compared with the bottom layer, the upper layer of printed fibers undergoes less evaporation period, exhibiting higher swelling rate but lower modulus. Using this expansion mismatch, a variety of deformable hydrogel structures can be achieved by controlling the printed pattern. After expansion, these hydrogels show controllable deformation with bionic morphology.

The raw material used in this paper is mainly a sol made of water, acrylic acid and acrylamide, which is polymerized into a hydrogel through gamma rays. The structure and water absorption swelling property of the hydrogel are studied. Acrylic acid is an important organic compound with strong strength, toughness, and transparency. It also has good adhesion and can be used for bonding various substrates. Acrylamide is an important organic compound and an excellent flocculant, while also having good water resistance. The swelling principle of this hydrogel is mainly the network structure formed by the cross-linking of polymer chains. This network structure enables hydrosols to accommodate a large number of water molecules [6]. At the crosslinking point, polymer chains are connected together through chemical bonds to form a three-dimensional network structure.

2. Methods and Materials

2.1 Experimental reagents and equipment

Purified water, acrylic acid(AA,CP,≥98.0%), Acrylamide(AM,CP,≥98.0%), Magnesium Chloride(99%), Calcium chloride(96%),sodium chloride(99.8%).Beaker, graduated cylinder, air drying oven, xenon lamp light source, magnetic stirrer, magnet, scale, weight, STA449F3 thermogravimetric analyzer, U-3900 ultraviolet spectrometer.

2.2 Preparation of hydrogel

Accurately weigh pure water and place it in a beaker. Add acrylic acid, then add acrylamide (one group with graphite), and mix thoroughly to dissolve. After mixing evenly, bottle the sample and expose it to gamma rays for 24 hours. After completion, put it into a vacuum bag for storage. The experiment was divided into three groups, with purified water accounting for 90%, 88%, and 80%, acrylic acid accounting for 5%, 5%, and 10%, acrylamide accounting for 5%, 5%, and 10%, respectively. The second group added 2% graphite content. The dried samples are C0-A5-M5, C0-A10-M10 and C2-A5-M5 hydrogels.

2.3 Determination of Swelling Capacity

Cut the three groups of materials prepared above into three small cylinders, and then cut each cylinder into four 90 ° small sectors, for a total of 12 small sectors. After conducting swelling and drying at different time intervals, the following formula for swelling rate has been summarized. As follows:

$$\text{Swelling rate } (\%)=(W2-W1)/W1\times 100\%$$

W1: Weight after swelling W2: Weight before swelling

2.4 Structural characterization

The thermal stability of hydrogel samples was tested by STA449F3 thermogravimetric analyzer in N2 atmosphere at a heating rate of 10 ℃/min.

2.5 Thermal Performance Test

Configure solvents for photothermal experiments separately: purified water group: 500ml purified water saline group: 500ml purified water, 25g anhydrous magnesium chloride, 25g anhydrous calcium chloride, 25g magnesium chloride. Simulated sewage group: 2% methyl blue solution. Preheating of hydrogel: put the cut hydrogel of high concentration group and graphite group into three groups of beakers respectively. The three groups of beakers are pure water (500ml pure water) and salt water (500ml pure water, 25g anhydrous magnesium chloride, 25g anhydrous calcium chloride, 25g magnesium chloride). In simulated sewage, preheat under 1W/M2 light intensity under xenon lamp light source for 15min, observe the solvent loss at five minute intervals, and record the data. Perform UV spectral analysis on the water collected by the sewage group and record the data using a computer.

Evaporation rate according to the formula: $M=\Delta m/A$

M unit (kg/m2/h) is the evaporation rate, Δ m (kg) is the mass loss of the liquid within 1 hour, and A (m2) is the evaporation area.

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2.6 Tensile and compressive performance testing

At room temperature, manually perform tensile testing on the experimental bench. In order to ensure the concentration of polymer in the hydrogel, take out the prepared hydrogel for direct test, cut the prepared hydrogel into strips, measure the width and thickness with a scale, and put it into the test bench for manual tensile test. In the same way, place the gel cylinder on the test bench, place a 500g weight, and observe the morphological changes of the hydrogel.

3. Experimental results and analysis

3.1 Water absorption and loss performance of hydrogel

The influence of polymer concentration type and graphite powder on the water loss performance of hydrogel was investigated. The hydrogel was placed in a 60 ℃ air drying oven for several times to observe the water loss of hydrogel, as shown in Figure 1:

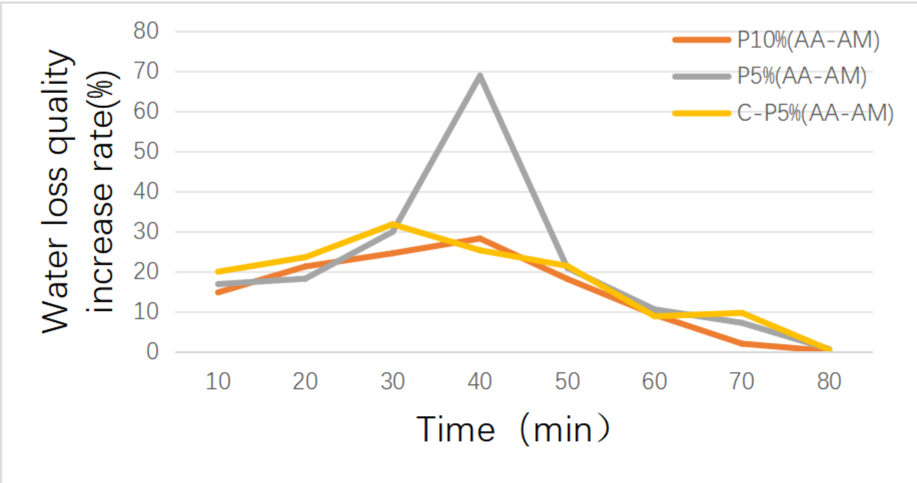

Figure 1: Influence of polymer concentration and graphite powder on the water loss performance of hydrogel

The three groups showed an overall downward trend, with the low concentration group experiencing a relatively greater decrease in water loss, especially between thirty and forty minutes when the decrease was extremely severe. The decrease of hydrogel quality in the high concentration group is relatively small compared with that in the low concentration group, which is not so dramatic, indicating that the water retention of the high concentration polymer is stronger than that of the low concentration polymer. At last, the change of graphite group is smaller than that of the other two groups, indicating that the addition of graphite powder can improve the water retention of this hydrogel. The water loss of the three low concentration groups was the highest, followed by the high concentration group, and finally the graphite group had the lowest water loss. All three groups eventually reached a certain value without losing moisture. It can be seen that the water loss of low concentration hydrogel changes violently, and the water loss rate of hydrogel with graphite powder is relatively low.

The effects of polymer concentration type and graphite powder on the water absorption performance of hydrogel were investigated. As shown in Figure2:

The three groups showed an upward trend. The water absorption of the low concentration group increased the most, especially between 30 minutes and 40 minutes, followed by the water absorption of the high concentration group, which rose relatively steadily throughout the process, indicating that the water absorption of the low concentration polymer was stronger than that of the high concentration polymer. The worst water absorption was the hydrogel added with graphite, which was slightly faster in the second half, indicating that the water absorption of the hydrogel added with graphite was the worst. At the final stage, the water absorption performance of the three groups has reached its limit, and the swelling rate is approaching 0.

The content of PAA-PAM used subsequently is 5%.

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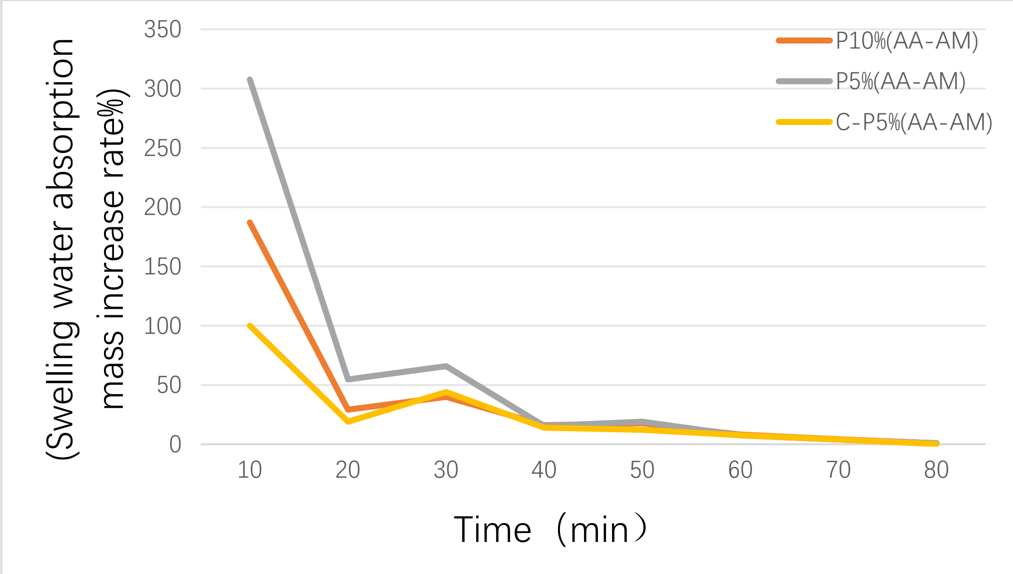

Figure 2: Influence of polymer concentration and graphite powder on swelling property of hydrogel

3.2 Photothermal properties of hydrogel

The influence of high concentration polymer and graphite powder on the water loss performance of hydrogel under xenon lamp light source was investigated. As shown in Figure 3:

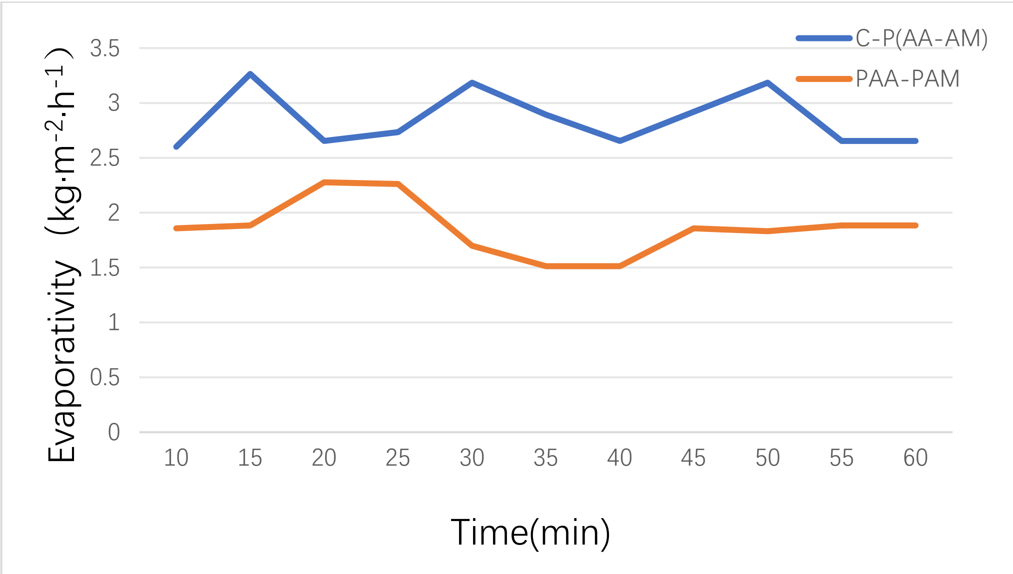

Figure 3: Influence of high concentration polymer and graphite powder in purified water on water loss performance of hydrogel under xenon lamp light source

Both groups showed a steady trend, with the graphite group having the fastest and most intense rate. The reason for this is that the water sol with added graphite powder is black and more endothermic, resulting in a faster rate. The reason why the high concentration group has a slower rate is because it is transparent and not particularly endothermic, resulting in a slower rate. The two groups reached the final stage, with their rates remaining at 2.6kg.m-2.h-1 and 1.9kg.m-2.h-1, respectively.

The influence of graphite powder on the water loss performance of hydrogel under xenon lamp light source was investigated. As shown in Figure 4:

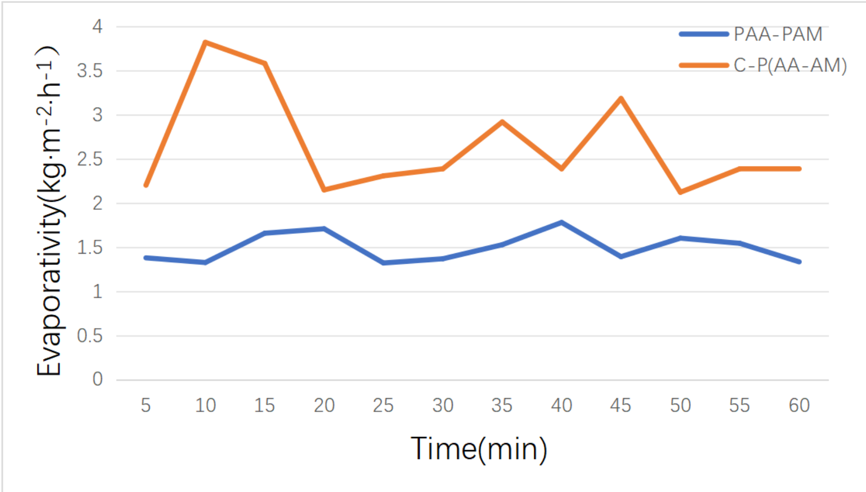

Figure 4: Effect of graphite powder in brine on the water loss performance of hydrogel under xenon lamp light source

The trend of the graphite group tends to stabilize towards the end, and the rate of the graphite group is higher. The reason is that the water sol with added graphite powder is black and more endothermic, so the rate is faster. The rapid change in rate during the first 10 minutes is due to the unstable start of the experiment. When the graphite group reached the final stage, the evaporation rate tended to 2.4kg.m-2.h-1, and the overall evaporation rate was higher than that of pure water gel, indicating that the addition of graphite powder could accelerate the photothermal evaporation rate.

3.3 Preparation of C-P (AA-AM) hydrogel

The synthesis diagram of C-P (AA-AM) hydrogel is shown in the figure 5. Under gamma ray irradiation, primary free radicals are generated, which induce hydroxyl groups in graphite powder to produce macromolecular alkoxy radicals. Alkoxy radicals react with vinyl groups of AA and AM monomers to form three-dimensional cross-linking network structure under the action of gamma ray.

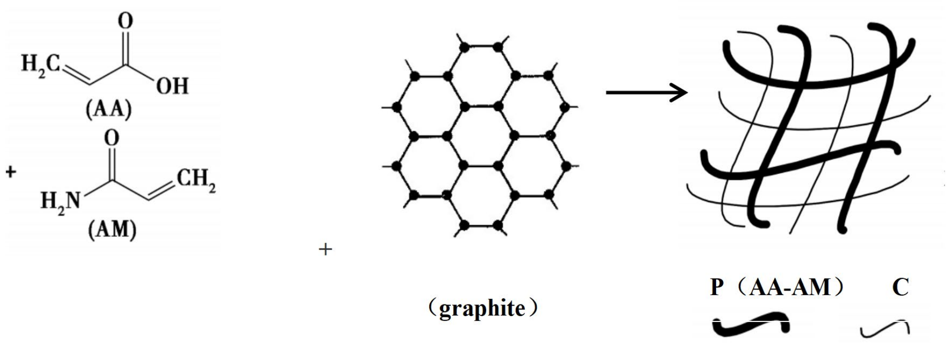

Figure 5: C-P (AA-AM) hydrogel

3.4 Tension and compression of hydrogel

By controlling the single factor variable method, the hydrogels with different monomer ratios and other influencing factors were obtained. The experiment found that the polyacrylamide/polyacrylic acid/graphite powder hydrogels obtained by adding graphite powder were well formed and elastic. Only the influence of graphite powder on the tensile properties and compressive properties of hydrogels was discussed. The results show that the tensile and compressive strength of the hydrogel with graphite powder is better. (see Figure 6)

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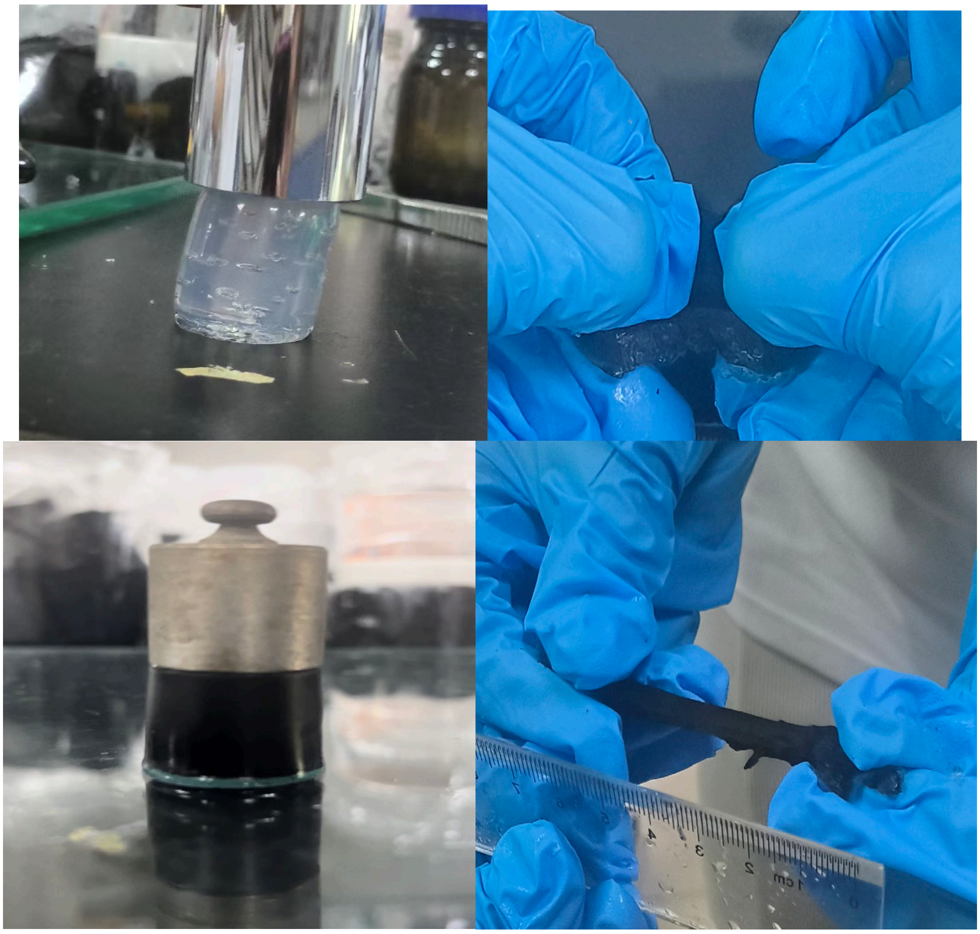

Figure 6: Tension and compression of hydrogel

3.5 Thermogravimetric test of hydrogel

Thermal stability is an important index for practical application of hydrogels. The thermogravimetric spectrum of C-P (AA-AM) hydrogel is shown in Figure 7. From Figure 7, it can be seen that there are mainly two weight loss intervals during the heating process: the first weight loss interval is around 200 ℃. The second weightlessness interval is around 400 degrees Celsius.

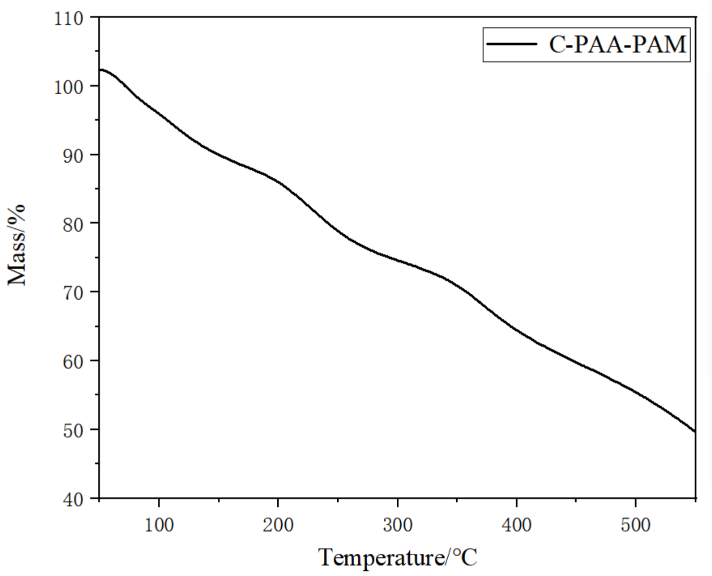

Figure 7: Thermal weight loss spectrum of C-P (AA-AM) hydrogel

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3.6 UV analysis experiment of hydrogel

Use the U-3900 UV spectrometer to conduct UV analysis experiments on the simulated industrial wastewater of the solution after photothermal evaporation and methyl blue solution.

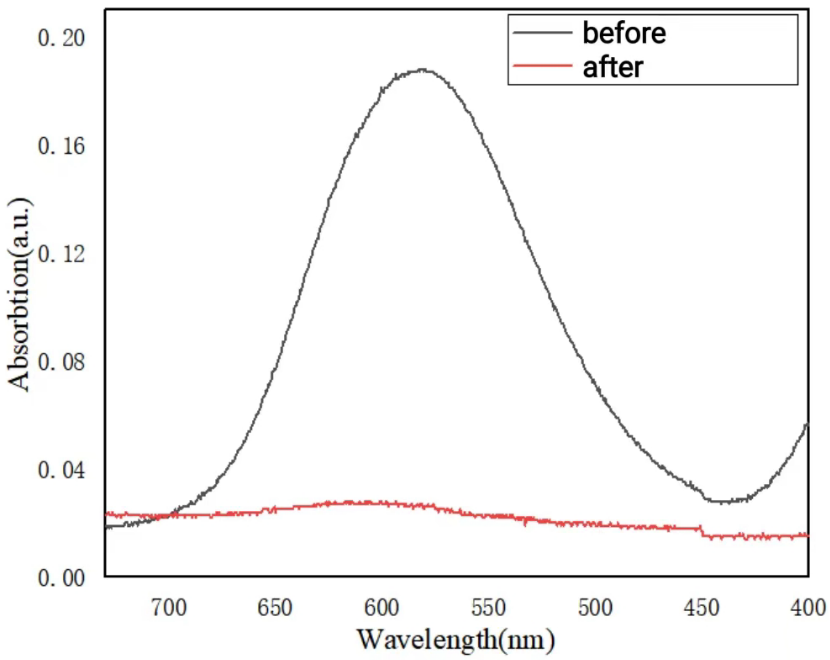

Figure 8: UV analysis experiment of solution and methyl blue solution after photothermal evaporation

From figure 8, it can be seen that there is no characteristic peak of methyl blue with a wavelength of 600nm in the solution after photothermal evaporation, indicating that the content of methyl blue in the solution after photothermal evaporation is almost zero, and the experiment is successful.

4. Summary and Prospect

In this paper, aiming at the preparation and swelling of hydrogel and the water absorption and loss performance of its hydrogel, the hydrogel is made of purified water, acrylic acid, acrylamide, (graphite), and is packed into two groups, which are respectively put into the purified water group and the configured brine group, to test the water loss performance of the hydrogel, and use it in sewage treatment, as summarized below.

This study prepared hydrosols by simply processing inorganic materials. The main focus is on exploring the water loss performance of hydrosols and the variation law of their evaporation rate. In the first part, the hydrogel was prepared by fully mixing and dissolving purified water, acrylic acid and acrylamide, and irradiating them under gamma ray for 24h. In the second part, the cured hydrogel is put into an air dryer for air drying and placed in a beaker for swelling. To explore the differences and changes in the water absorption and water loss properties of hydrogels, as well as the performance differences of different hydrogels. For the hydrogel added with graphite powder, its water absorption and real-time performance are the weakest. The graphite group is dried from about 1.75g to 0.52g, and the swelling rate is from 100% to 336%. However, the high concentration was dried from 2.11g to 0.62g, and the swelling rate was 187% to 609%, which was second only to the hydrogel added with graphite. The hydrogel with low concentration has the strongest water absorption and loss capacity. The mass before drying is 3.31g to 0.52g, and the swelling rate is from 307% to 1337%. In the third part, the prepared hydrogels were placed in purified water and salt water respectively for irradiation evaporation under xenon lamp light source. The hydrogel with graphite has the highest evaporation rate in pure water. The hydrogel with high concentration and graphite is cut into small pieces, placed in a beaker of brine and padded with foam pad under the hydrogel, evaporated and irradiated under the xenon lamp light source, and measured the mass loss at the same interval of time in an hour. The data is made into a broken line chart. It is known that graphite has the fastest evaporation rate and the strongest water loss performance

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in saltwater. The evaporation rate of graphite group is faster than that of pure gel group in the pure water evaporation experiment, reaching 2.6kg.m-2.h-1. Similarly, the evaporation rate of the hydrogel added with graphite powder in brine also reached the expected level. Subsequently, UV spectrum analysis was also used in the methyl blue simulated sewage evaporation experiment to verify that the water evaporated from this hydrogel does not contain sewage components such as methyl blue, which can be applied to sewage treatment.

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