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STUDY ON THE EFFECT OF THREE KINDS OF FILTER AID ON THE DEHYDRATION PERFORMANCE OF MICROCYSTIS AERUGINOSA

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ABSTRACT

In recent years, algae bloom phenomenon outbreaks frequently in large-scale water bodies during summer. At present, mechanical method is used to collect cyanobacteria and reduce volume. However, the characteristics of algae, namely high viscosity, small particle size and high moisture content, lead to poor efficiency of dehydration. In order to improve the dehydration efficiency of algae and achieve the purpose of volume reduction and dehydration, the dehydration performance of Microcystis aeruginosa was studied in this paper. Three filter aid agent, including Poly Aluminium Chloride (PAC), Montmorillonite and Diatomite were added to the algae solution to improve filterability of Microcystis aeruginosa. The results showed that all of three filter aid agent have positive effect on the algae filtration rate, specific resistance, compression index and dehydration efficiency. Compared with the other two filter aid agents, the filtration rate of Diatomite is relatively faster. Meanwhile dehydration performance is better as well. When the dosage of Diatomite was 10.0g/L, the filtration rate increased from 0.108 L/h to 0.504 L/h. In addition, the compression index was reduced from 0.710 to 0.594. The specific resistance was reduced from 7.62×10^{10} s^2/g to 2.35×10^8 s^2 /g while the water content was decreased from 86.5% to 66.4%.

KEYWORDS

Cyanobacteria dehydration, Filter aid agent, Filtration rate, Specific resistance, Compressible index, Water content

INTRODUCTION

In recent years, water eutrophication resulting in abnormal proliferation of algae, formed algae bloom phenomenon, and caused serious pollution of water, which led to internal ecosystem imbalances of water body [1]. The phenomenon is one of the major water environment problems of the world urgent need solving [2]. For the phenomenon of algae blooms, the salvage technology of original location is usually used to collect cyanobacteria in rivers and lakes，which can remove surface algae rapidly and efficiently. However, the salvaged cyanobacteria with high water content and large land area still needs volume reduction and dehydration. Zhang Qiang [3] carried out mechanical removal of water from cyanobacteria in Chao late (89 percent of water content) with sieve mesh filter. Xiong Hongbin et.al [4] adopted biosynthetic Polymerized ferrous sulphate (BPFS) coagulation - chamber filter press integration technology to remove the moisture from the cyanobacteria with water content of 89 percent. Wu Jun et al [5] studied the effect of Polymerized ferrous sulphate on the flocculation dehydration of cyanobacteria with water content around 90

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percent. Even though physical methods and flocculation agents have positive effects on the dehydration, the water content remaining in cyanobacteria could be still relatively high, which may bring difficulties to the subsequent disposal' downstream processes. Therefore, a filter aid agent with lower cost should be chosen to improve the dehydration efficiency without introducing secondary pollution. Nevertheless, there have been few studies on influence of filter aid agent on cyanobacteria dehydration in China. In this paper, the dehydration performance of three filter aid agent, namely: Poly Aluminum Chloride (PAC), Diatomite and Montmorillonite was investigated. Four parameters, including filtration rate, filter cake specific resistance, compression index and moisture content are chosen as the parameters to study the effects of filter aid agent on the dehydration performance and filtration characteristics of cyanobacteria.

MATERIAL AND METHODS

Experimental Materials

Microcystis aeruginosa (FACHB-905) are provided by the Freshwater Algae Culture Collection at the Institute of Hydrobiology (FACHB-collection). Poly Aluminum Chloride (PAC), Diatomite and Montmorillonite are chosen as filter aid agent during the dehydration process of Microcystis aeruginosa.

RIC-250 Artificial climate incubator (Shanghai Bo Xun Industrial Co., Ltd.), UV-2700 ultraviolet visible photometer (Shimadzu Instruments Co., Ltd.), JSM6380LV scanning electron microscope (Hitachi Ltd.), Vacuum suction device (Sinopharm Chemical Reagent Co., Ltd.), High temperature upright microscope DM4000 (Germany Lycra Instruments), Electronic balance ME104E / 02 (METTLER TOLEDO Instrument Co., Ltd.), Blood count plate (Sinopharm Chemical Reagent Co., Ltd.).

Experimental Methods

(1) Cultivation of algae species

The Microcystis aeruginosa is cultured in BG11 medium located in the artificial climate incubator with constant temperature of 28℃ and light/dark time ratio of 12h: 12h. The filtration experiment is started when its absorbance reaches 1.3 Abs. Table 1 presents the physical properties, namely algae solution organic content, particle size, viscosity and quantity of cyanobacteria and its culture medium. .

Tab. 1 - The basic physical properties of cyanobacteria culture medium

Standard	Organics mg/L	Particle series μm	Viscosity m Pa·s	Concentration cell/L
Value	43600	2~5	15	1×1010

(2) Selection of filter aid agent

Two parallel algae solution samples are divided into four groups. One group is the original algal liquid. The other three groups are added different amounts of PAC, Montmorillonite and Diatomite. After well mixed, the filtration experiment is carried out at six different pressure levels (0.03, 0.04, 0.05, 0.06, 0.07 and 0.08 M Pa) in suction filtration device. When the filtrate volume V is increased 5 mL, a time (θ) needs to be recorded. Every θ-V data is respectively recorded. According to the experimental data recorded of different times θ and filtrate volume V, the specific resistance of the filter cake is measured. The specific resistance is calculated theoretically by the Equation 1 under constant pressure [6]:

$$\mathrm{r} = \frac{2PA^2}{\mu}\frac{b}{C} \tag{1}$$

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where *P*(Pa) is the filtration pressure, A(cm^2) is the filtration area; *μ* (g/(cm·s)) is the dynamic viscosity of the filtrate; *C* (g/cm^3) is the dry solid quality of the unit volume filtrate on the filter medium; b (s/cm^6) is the slope of the linear relationship between t / V and V; r (s^2/g) is the specific resistance.

The filtration constant, K, is calculated as:

$$\triangle\theta/\triangle q = 2q/K + 2q_e/K \quad (2)$$

where K is the constant pressure filtration constant; $\triangle\theta$ (s) is the filter time of quantitative filtrate; $\triangle q$ (mL/s) is the amount of filtrate filtering in the unit time of quantitative filtrate; *q* (mL/s) is the amount of filtrate filtering in unit time; q_e (m^3/m^2) is the equivalent filtrate volume of per unit filtration area.

After obtaining K under different pressures, compression indexes are calculated as:

$$\lg K = (1-s)\lg\Delta p + \lg(2K) \quad (3)$$

where s is the compression index; *Δp*(MPa) is the pressure difference.

RESULTS AND DISCUSSION

The filterability of algae liquor

The filtration rate and moisture content of filter cake under different pressure are shown in Figure 1:

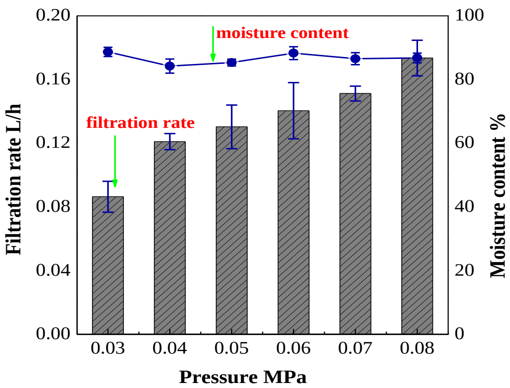

Fig.1 - Relationship between filtration rate and pressure in algae

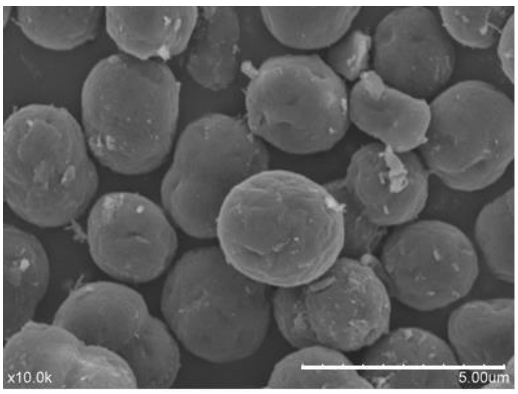

Fig.2 - SEM images of Microcystis aeruginosa

Figure 1 shows the influence of pressure on filtration rate and moisture of the filter cake. The filtration rate of algae solution increase from 0.0864 L / h to 0.174 L / h with the increasing pressure from 0.03 MPa to 0.08 MPa. Meanwhile, moisture content of the filter cate varies between 84.21% and 88.77% with an average value of 86.49%. Microcystis aeruginosa contains a large amount of organic substances, such as chlorophyll, algae proteins, enzymes, algae toxins and so on [7]. The organic matter can increase the viscosity of algae solution [8]thereby reducing the compression performance and permeability of algae solution [9].In addition, elastic deformation caused by the compression of algae mud could reduce the filtration rate of algae solution, eventually leading to the decrease of dehydration efficiency. The scanning electron microscopy (SEM) image of Microcystis aeruginosa are shown in Figure 2. The average diameter of algae is around 2μmthat is larger than microfiltration membrane (0.45μm). Therefore, Microcystis aeruginosa particles deposit on the membrane surface. At the beginning of filtration, the filter cake forms gradually. The inside passage of the filter cake is more smooth, which makes the pass of liquid easier and leads to a faster filtration speed as well. With the increase of the amount of filtrate, the filter cake becomes more compact under the action of pressure. As a result, the permeability of the cake declines gradually. Furthermore, a larger number of ($\times 10^{10}$ cell/L) grained material with a certain level of viscosity may stick on the microfiltration membrane and then slow down the filtering speed.

In order to further study the filterability of algal liquid, the compression performance of the filter cake was calculated according to Equation 2 and 3. The results are shown in Figure 3.

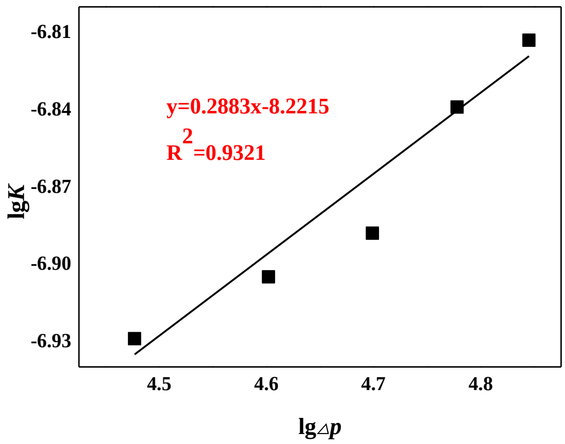

Fig.3 - Determination of Cyanobacteria Compression Index of Algae Water

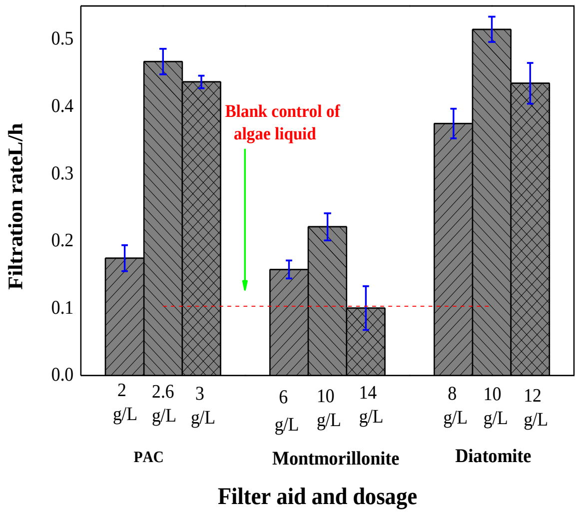

Fig.4 - Effect of Different Dipping Agents on Algae Water Filtration Rate

Figure 3 shows that the trend line of y = 0.4809 x - 9.016, R^2 = 0.9321 has better linear relatedness . According to the slope of the trend line, the filter cake compression index of the algae solution is 0.71>0.3, which is a high compressible material, indicating that the filtration performance of the algae solution is rather poor. The small particle size and viscosity of Microcystis aeruginosa results in slower algal filtration rate. Therefore, the filter aid can be added in the algae solution to speed up its filtration rate and improve its filtration performance.

The Effect of filter aid on filtration rate of algae solution

Three filter aids,including, Montmorillonite and Diatomite were tested to study the effect of filter aids on the filtration performance. The results are shown in Figure 4.

Figure 4 presents that the average filtration rate of algae solution is 0.108 L/h without filter aid agent. With an increasing filter aid dosage, the filtration rates with three filter aids shows similar trend which increase firstly and then decrease. The average filtration rate is 0.467 L / h with PAC dosage of 2.6 g / L. The average filtration rate is 0.221 L / h with Montmorillonite dosage of 10 g / LThe average filtration rate is 0.504 L / h with diatomite dosage of 10 g / L . The dosage of three filter aids had a certain improvement effect on the filtration rate of the algae solution, but the average filtration rate of the algae solution with Diatomite dosage was the highest among the three.

Optical images and cross-sectional SEM images of the filter cakes formed by the original algae solution and the solution with different filter aids are shown in Figure 5 and Figure 6 respectively.

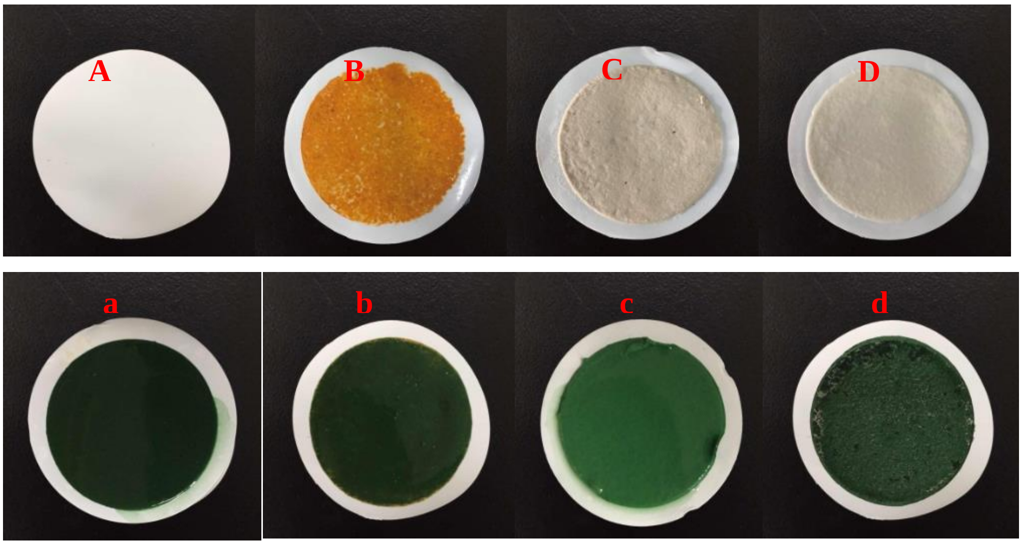

Fig.5 - Blank control（A）、PAC（B）、Montmorillonite（C）、Diatomite（D）Algae (a)、Algae+PAC(b)、Algae+ Montmorillonite（c）、Algae+ Diatomite（d）

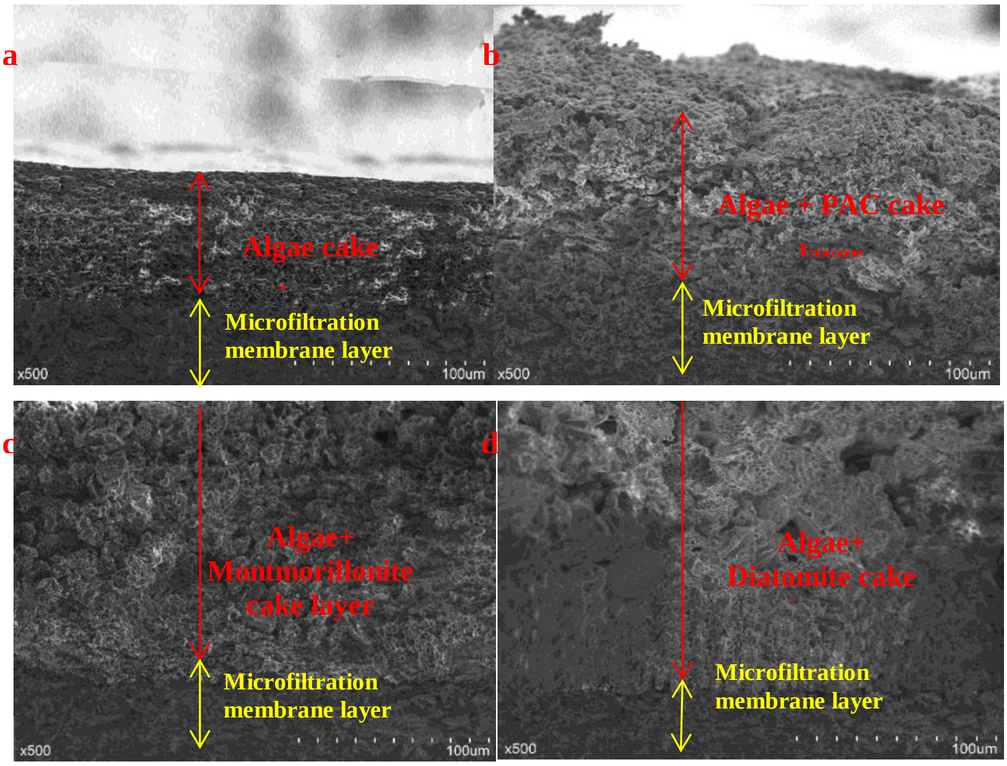

Fig.6 - Algae cake(a)、Algae + PAC cake(b)、Algae + Montmorillonite cake(c)、Algae + Diatomite cake(d)

Compared with the original algae cake, the internal structure of the filter cake formed after adding the three filter aids change. The reasons are as follows:

(1) PAC, as an inorganic polymer flocculant, has flocculation effect on Microcystis aeruginosa. The formed flocculant can gather the algae by the sedimentation trap. As a result, the filtration rate increases frmm 0.13 L / h to 0.467 L / h. Because Microcystis aeruginosa is negatively charged in the water. PAC hydrolyzes positively charged which can rapidly attract negatively charged Microcystis aeruginosa and accumulate to form larger flocculant through sediment mesh (Figure 7)

as well as help to flocculate. However, the positive charges could accumulate on the surface of Microcystis aeruginosa when the dosage of PAC is too high. In this case, electrostatic repulsion between Microcystis aeruginosa will occur, which restrains flocculation and sedimentation. The pores and internal structure of the filter cake formed during the constant pressure filtration are different from the original algal filter cake as shown in Figure 6b and 6a. After passing through the role of sediment mesh, the Microcystis aeruginosa in algae solution will aggregate from the fine-grained material into coarse-grained material. This procedure can increase the porosity of the filter cake thereby speeding up its filtration rate.

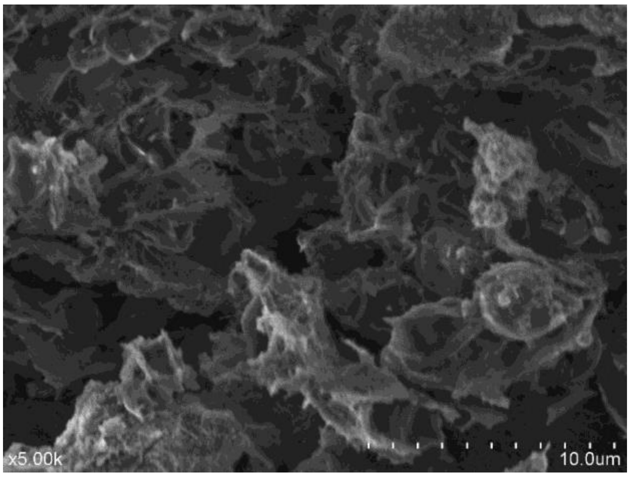

Fig.7 - SEM images of Algae + PAC on cyanobacteria flocculation

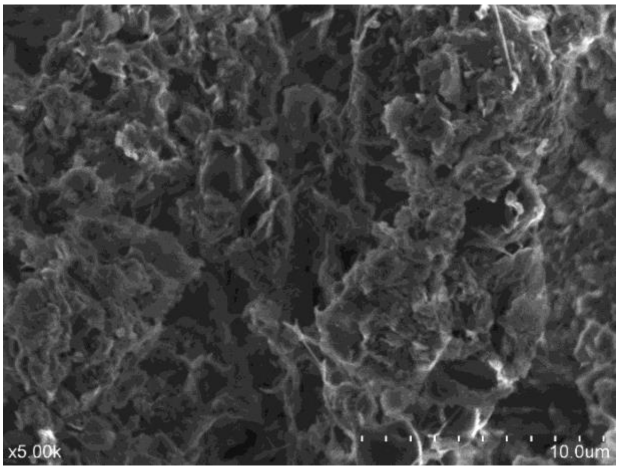

Fig.8 - SEM images of Algae + Montmorillonite

(2) Montmorillonite is a layered mineral silicate consisting of very finely particulate hydrous aluminum silicate. Wang et al [12] showed that the porosity and pore size of the filter cake are directly related to the particle size and composition of the material. The particle size distribution of the filter cake layer is the fundamental factor of the internal structure and filtration of the filter cake. The internal structure of the filter cake after adding Montmorillonite is shown in Figure 8. Montmorillonite is mainly inorganic particles. According to experimental measurement, its surface area is 744.66 m^2 /g while it porosity is 59.4%. A certain amount of Montmorillonite was adding into the original algae solution and compared with the original algal filter cake (Figure 6a). The particle size of the filter cake added with Montmorillonite (Figure 6c) increased obviously which was equivalent to adding an inorganic coarse particle size material. It increased the size of the filter cake. Therefore, the filtration rate of algae solution increases from 0.13 L / h to 0.221 L / h after adding the Montmorillonite. When the amount of Montmorillonite exceeded to a certain limit(10g/L), the filter cake resistance increases with the thickness of filter cake, which slows down the filtration rate.

(3) Diatomite is a siliceous mineral soil with a pore volume of 0.45-0.98 cm^3 / g and a large specific surface area and porosity, which can be generally used as a filter aid [13,14]. Diatomaceous is based on inorganic particles with the specific surface area of 77.48m2 / g and a porosity of 73.28%. The compression deformation is very small. The filtration performance of different particle size is different. And the particle size of the material has certain influence on the filtration rate. In general, the water in the filter cake formed by fine-grained materials is difficult to get out with the slower the filtration rate and the larger the compression index. The porosity of filter cake formed by coarse-grained materials is larger. The probability of clogging the filter medium is smaller. And the filtration rate is relatively larger [15]. Adding diatomite to algae liquor with a certain viscosity is equivalent to add an inorganic coarse-grained material with a porous structure. After adding diatomite, the internal electron microscopy image of filter cake is shown in Figure 9. Compared with the original algal filter cake (Figure 6a), the porosity of filter cake after adding

diatomite (Figure 6d) increases, and the filtration rate is significantly faster than the original filter cake. Excessive dosage of diatomite could also increase the thickness of the filter cake and eventually lead to a decrease of the filtration rate.

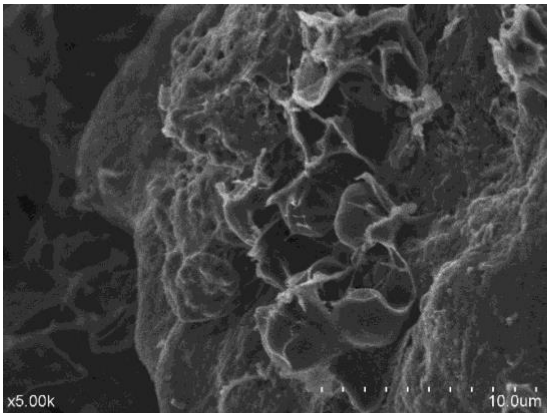

Fig.9 - SEM images of Algae + Diatomite

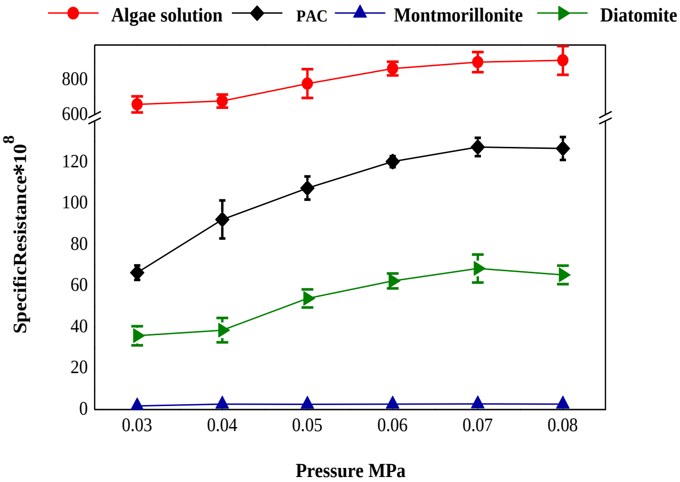

Fig.10 - Effect of Pressure on Specific Resistance of Algae Water

In order to improve the filtration performance of algal liquid, the effect of filter aid on specific resistance, compressibility index and moisture content of filter cake were studied under the optimum dosage condition.

Effect of filter aid on specific resistance

The effects of three filter aid on the specific resistance of the algae solution are shown in Figure 10.

Figure 10 presents that the specific resistance of the filter cake gradually increases with the increasing pressure. After adding filter aid into the algae solution, the specific resistance of the algae solution obviously decreases significantly. In general, a greater specific resistance leads to a worse dewatering efficiency. When the specific resistance is smaller than 0.4×10^9 s^2/g, it is easier to perform the material dehydration. The material has a moderate dehydration efficiency with the resistance is between 0.5×10^9 s^2/g and 0.9×10^9 s^2/g. The material is difficult to dewater with the resistance between 1×10^9 and 1×10^{10} s^2/g [6]. The average ratio of the original algal solution is 7.615×10^{10} s^2/g, which is a difficult dehydrating material. The average specific resistance of algae solution with PAC is 9.32×10^9 s^2/g which is even more difficult to dehydrate compared with the original algal solution. After adding Montmorillonite, the average specific resistance is 4.91×10^9 s^2/g, indicating that the dehydration has a certain degree of improvement. After adding diatomite, the average specific resistance is 2.345×10^8 s^2/g, indicating that the algal solution adding diatomite is relatively easy to dehydrate. The addition of three filter aids reduces the specific resistance of the filter cake, indicating that the filtration performance is improved after adding the filter aids. After adding the filter aids, the inner structure of the filter cake gradually changes as shown in Figure 9. Different particle size with different internal porosity of the filter cake lead to different filtering performance. Compared between coarse-grained material filter cake and the fine-grained material filter cake, the porosity of the former is larger, making it easier for the algae water pass and relatively smaller for the specific resistance. Compared with the three filter aids, the filtration performance of algae with diatomite is the best. Meanwhile, the specific resistance reduces from 7.615×10^{10} s^2/g to 2.345×10^8 s^2/g. The algae with diatomite is easy to dehydration material.

Effect of Filter Aid on the Compressibility Index and Dehydration Efficiency of Algae solution

The effect of different filter aids on the algae solution compressibility index and moisture content is shown in Figure 11:

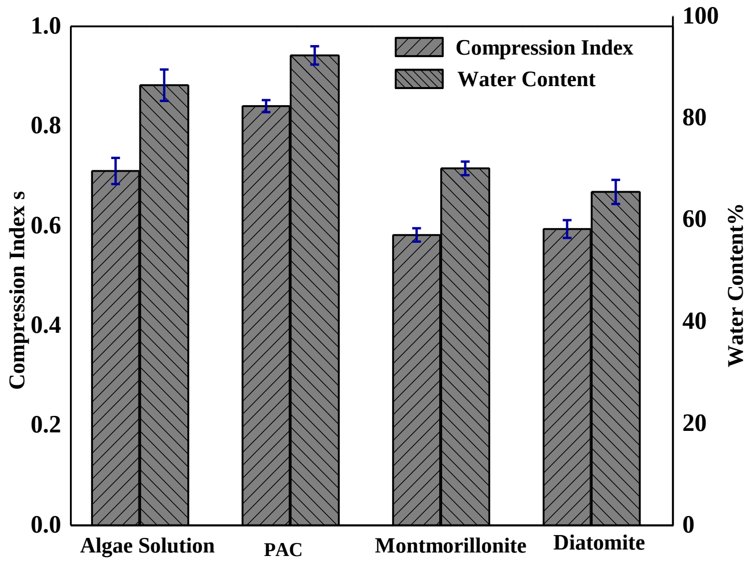

Fig.11 - Effects of Different Aid Filter on Cyanobacteria Compression Index and Dehydration Efficiency

Figure 11 shows that both of the compression index and the cake moisture content have a certain change after adding filter aid. The original algae solution compressibility index is 0.71, while cake moisture content is 86.49%. After adding filter aid of PAC, the compression index increases to 0.84 while the filter cake moisture content increases to 92.28%. After adding filter aid Montmorillonite, the compressibility index was 0.582 and the cake moisture content was 69.94%. These were indicated that the compression index and the filter cake moisture content both decreased. After adding filter aid Diatomite, the compressibility index was 0.594 and the cake moisture content was 66.4%. These were indicated that the compression index and the filter cake moisture content both decreased. The poor compression performance and high water content of the filter cake are mainly caused by the small size and viscosity of Microcystis aeruginosa particle. After adding filter aid of PAC, the flocculation is formed by sedimentation mesh catching. But the structure of the filter cake layer is loose, which results in poor compressibility, higher compressibility index and higher moisture content. After adding filter aid of Montmorillonite or Diatomite, equivalent to adding an inorganic coarse-grained material, which can change the filter cake size and internal structure（Figure 12）, increase the size and porosity of the filter cake as well as improve the filtration performance of the filter cake. Compared with the three filter aids, the compressibility index and moisture content of the filter cake adding Montmorillonite and Diatomaceous are relatively lower, indicating that the filterability is better.

In summary, the filtration rate of original algal liquid and algae solution adding PAC, Montmorillonite and are 0.108 L/h, 0.467 L/h, 0.221 L/h, 0.504 L/h, respectively. The average ratio of resistance are 7.615×10^{10} s^2/g、9.32×10^9 s^2/g、4.91×10^9 s^2/g、2.345×10^8 s^2/g, respectively. Compression index are 0.71, 0.84, 0.582 and 0.594, respectively. The water contents are 86.49%, 92.28%, 69.94% and 66.4%, respectively. Diatomite has the greatest influence on the filtration rate, compression characteristics and dehydration effect of algae solution. Consequently, it can be used as filter aid for the dehydration experiment of algae solution.

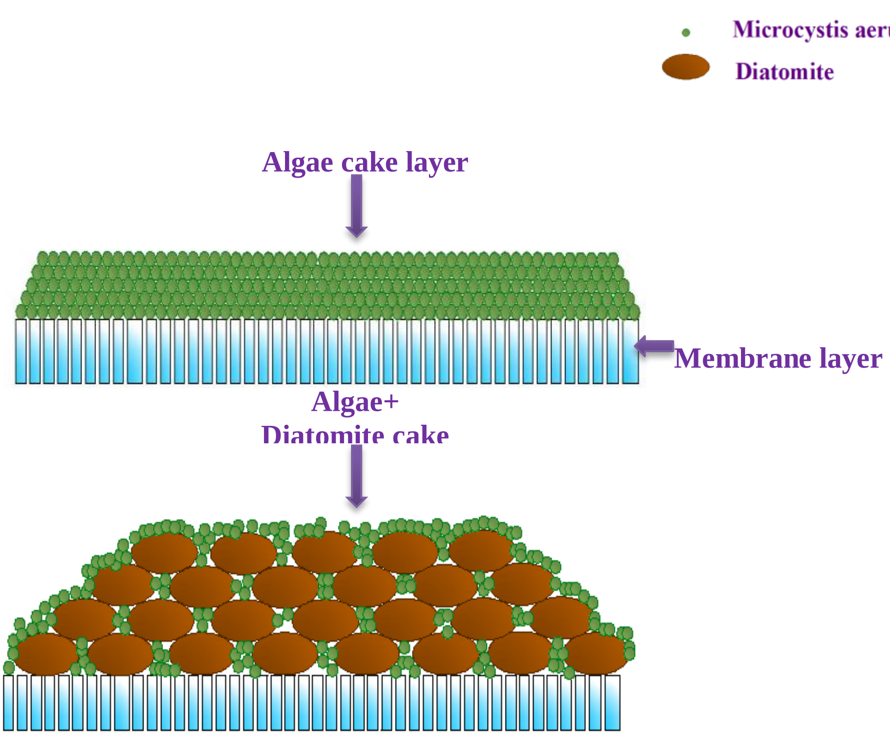

Fig.12 - The shape of the filter cake by two different filtering modes

CONCLUSION

(1) The experimental results of dehydration performance of Microcystis aeruginosa show that the dehydration efficiency is closely related to the compression index and specific resistance. The smaller the compression index of the cake is, the harder it is to be compressed. The larger the filtration rate is, the smaller the specific resistance is. The pore channels formed in the filter cake layer are relatively smooth . The dehydration efficiency is higher.

(2) Microcystis aeruginosa is a fine grain material in the algae solution. Adding inorganic coarse particle material to the algae solution can change the internal structure and porosity of the filter cake layer. According to the variations of filtration rate, filtration specific resistance, compression index, and moisture content of the cake layer, the filter cake filterability is significantly influenced by the particle size and porosity of the material. A largerspecific surface area and porosity can lead to a smaller filtration resistance, a lower compression index and a smaller moisture content of the filter cake. The filtration properties can be strongly improved by adding an inorganic coarse-grained material with high porosity during the dehydration process.

The filtration properties of algal liquid are improved by adding PAC, Montmorillonite and Diatomite. Compared with the three kinds of filters, the filtration rate of algal fluid adding Diatomite increases from 0.108 L/h to 0.504 L/h. The specific resistance significantly decreases from 7.62×1010 s^2/g to 2.35×108 s^2/g. The compression index decreases from 0.710 to 0.594. The dehydration efficiency of filter cake rises from 13.5% to 33.6%. Therefore, diatomite can be used as filter aid for the dehydration process of algal liquid.

(3) At present, there are few studies on the dehydration performance of Microcystis aeruginosa in China. Hence, dehydration of Microcystis aeruginosa has become a key technical issue. In this paper, it is proposed that the addition of Diatomite in algae solution can improve the dehydration efficiency of Microcystis aeruginosa. However, the dosage of Diatomite is relatively large. Taking

into account the economic costs, the future study will focus on the modification of the diatomite on an existing basis to reduce the dosage of filter aid and further improvement of the dehydration efficiency.

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