Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2019.23815

151 (2019) 342–349
May

A novel way of dealing with waste sludge from poly-aluminum chloride (PAC) production

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Received 10 September 2018; Accepted 17 January 2019

ABSTRACT

A novel way of dealing with the highly acidic, solid content waste sludge from production of poly-aluminum chloride (PAC), a famous inorganic flocculent itself, was studied in this paper. In order to investigate the dehydrating performance to the waste sludge, the organic flocculants with different molecular structures including ionic properties, ionicities and molecular weight were compared and selected. The flocculation mechanisms were analyzed by the Zeta potential and the SEM images. The results showed that the copolymer poly (acryloyloxyethyl trimethyl ammonium chloride-acrylamide), P (DAC-AM), with high cationicity of more than 50% and the intrinsic viscosity from 12.69 to 16.67 dL/g displayed the better dispersing ability in the waste sludge and the flocculation and dehydration performance. Especially, the solid content of filter cake could reach to 62.46% from the solid content 52.17% of waste sludge resulting in the filtrate of about 20%–30% volume of total waste sludge and the dehydrated sludge could be recycled easily. Surprisingly, for the acidic waste sludge with highly positive charge and solid content, only the cationic flocculants with positive charge were easily first to disperse in the sludge and then to demonstrate flocculation and dehydration performance, excellently. The results above could create a novel way of dealing with the waste sludge from the PAC production.

Keywords: Poly-aluminum chloride; Waste sludge; Dehydration; Cationic flocculants; P (DAC-AM)

1. Introduction

Poly-aluminum chloride (PAC), known as basic aluminum chloride, is a kind of acidic and inorganic polymer flocculants, and has been produced and applied [1,2] as a flocculent since early 1970's. Now, it becomes one of the most important varieties of flocculation and dehydration agents in the world, and with a top production amount of inorganic coagulants in China [3,4]. The processing methods of PAC production could be divided into three kinds according to the sources of different raw materials, i.e. aluminum oxide method (mainly using bauxite), aluminum ash method and aluminum hydroxide method [5]. But the waste sludge is always produced in the process whatever method used, and there has been no any good method to deal with their processing residues, i.e. acidic and corrosive waste sludge. The aluminum ash method is the earliest method used popularly. This method possesses some characteristics in poly-aluminum chloride production, such as low cost, simple production processes and easily obtained raw materials from wastes or byproducts in metallic aluminum or other industry. However, the waste sludge from the production is irritant sourness and corrosiveness, and too difficult to dehydrate, resulting in inconvenient disposition, such as transportation and reuse or landfilling, directly [6]. The long-term stacked waste sludge has been leading to soul and underground

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water pollution because of acid liquid leaking off and tracing heavy metal. Therefore, how to dewater the waste sludge effectively for its disposition becomes the most important problem of the aluminum ash method toward large scale industrialization and one of the key factors of the production enterprises to survive.

So far, there has been no report on flocculating and dehydrating the waste sludge. Only the report from N. Li etc. [6] used a large amount of quick lime to denature and solidify the waste sludge of PAC production using bauxite as a raw material, and the denatured product was used in the road construction. The research had not concerned dehydration process of the waste sludge, although the waste sludge was similar with that from PAC production with aluminum ash method. Usually, organic polymer flocculants are very popular used in almost all solid and liquid separation procedures involving both flocculating and dewatering in many fields [7,8] based on the basic principles like charge neutralization, double layer compression, bridging and net-capturing. They can be also divided into synthetic and natural organic flocculants. And further, the former includes anionic, cationic, non and amphoteric-ionic flocculants depending on different functional groups [1], which are usually selected for treatment of suspending colloid particles with opposite charges apart from non-ionic flocculants. As the common synthetically organic flocculants, polyacrylamide holds mostly completed ionic sorts, selectable ionicities and molecular weights, being the first choice in application. Among these, the cationic polyacrylamide, poly (acryloyloxyethyl trimethyl ammonium chloride- acrylamide), P (DAC-AM), referred as a copolymer of acryloyloxy ethyl trimethyl ammonium chloride and acrylamide, is a kind of highly efficient water-soluble organic polymer flocculants [9]. It is usually used for the separation processes of solid-liquid systems with suspending colloid particles especially with negative charges.

In present work, the anionic flocculants were first chosen to flocculate the typical waste sludge with positive charge from the aluminum ash method, and different ionic sorts, ionicities and molecular weights of commercial flocculants were also used for comparison. They were selected according to the behavior while flocculating the waste sludge, and then the effects of the ionicities, dosage, molecular weights of selected flocculants on flocculation and dehydration were systematically investigated. The copolymers P (DAC-AM) with different ionicities and molecular weights, synthesized in the laboratory were used as the contrast samples with imported and domestic commercially available samples. Furthermore, flocculation mechanism would also be preliminary explained by means of analyzing the filtrate zeta potential and SEM observation of filter cake microstructures. So that it was expected to obtain an effectively novel method for disposing the waste sludge from PAC production with both aluminum ash method and aluminum oxide method, and to lay the foundation especially for a large scale application of the aluminum ash method in industry.

2. Materials and methods

2.1. Instruments

Zeta potential instrument (JS94H POWEREACH) to determine zeta potential of filtrate, scanning electron microscope (SEM) (LEOL-6380LV) to observe the microstructure of filter cake and electrically heating drying oven (BHX9101–2SA KEER) to dry the waste sludge and filter cake, etc. were used.

2.2. Raw materials

2.2.1. Waste sludge

Waste sludge from poly-aluminum chloride production was a dark grey slurry mixture rich in acidic and corrosive liquid comprising colloid particles of positive charge, and was offered by a company in Ningbo, Zhejiang Province, China. The composition of the waste sludge was α-Al_2O_3, SiO_2 and residual liquid of the PAC. The waste sludge with three different solid contents was prepared from thick bottom slurry and supernatant in a waste sludge pool for comparison. Its typical characteristics are shown in Table 1.

2.2.2. Flocculants

The mentioned flocculants with different ionic properties, ionicities and the different molecular weights represented by intrinsic viscosity were prepared as below:

(1) 10 kinds of anionic flocculants (named as AN), white powder with intrinsic viscosity between 4.54 dL/g and 21.50 dL/g, and the degree of hydrolysis between 3.18% and 72.76%, were purchased from Mitsubishi Heavy Industries Company in Japan;
(2) 3 kinds of non-ionic flocculants (named as NON), light yellow powder with intrinsic viscosity 1.94, 5.66 and 12.95 dL/g, were purchased from Mitsubishi Heavy Industries Company in Japan;
(3) 3 kinds of amphoteric ionic flocculants (named as AM), white powder with intrinsic viscosity 1.84, 6.72 and 13.14 dL/g, and with corresponding cationicity 70%, 50% and 30%, were purchased from Mitsubishi Heavy Industries Company in Japan;
(4) 17 kinds of cationic flocculants with different intrinsic viscosity from 12.69 to 29.63 dL/g, and the corresponding cationicity from 3% to 90%, were purchased from SNF FLOERGER Company (named as CA, 12 kinds) and made by laboratory (named as P (DAC-AM), 5 kinds).

2.3. Experiments

2.3.1. Experimental design

(1) The flocculants with different ionic properties were preliminary compared and selected, respectively, using their dispersing and flocculating phenomenon as the

Table 1
Sludge with different solid contents and its typical characteristics

No.	Relative density ($g \cdot mL^{-1}$)	Solid content (%)	pH of supernatant	Zeta potential (mV)
1	1.533	50.93, low	3.5–4.0	46.81
2	1.573	52.17, mid.	3.5–4.0	43.21
3	1.607	54.34, high	3.5–4.0	47.11

criterion. The flocculants, easily to disperse in the waste sludge and obviously to display flocculating function, were selected for next stage use.

(2) The selected agents with certain ionic properties but different ionicities and molecular weights were used to treat the waste sludge, and the effects of the agent dosage, solid contents of waste sludge and filter time on the performance assessment indexes, such as the solid content of filter cake and the filtrate volume representing dehydration ability were systemically investigated.

(3) The Zeta potential of filtrate was meanwhile determined and the microstructure of filter cake was characterized by SEM, which were used for the mechanism analysis of flocculation and dehydration processes.

2.3.2. Procedures of flocculation experiment

(1) Choosing one kind of solid contents of waste sludge for the flocculation experiment, the consulted procedure of flocculation experiment was as below [10]. Same 100-mL waste sludge was poured into every 250-mL-scaled beaker of a number of beakers in total. Then the same dose of differently prepared flocculants with mass concentration of 1‰ was dropped into the waste sludge, respectively, and the phenomena were observed whether the added droplet of flocculent was well dispersed. Furthermore, the glass rod was used to quickly stir the droplet and it could be completed to observe the floccules with uniform sizes appeared in each beaker. Then, a transparent meter with scales was inserted into the each beaker to measure the size of flocs. Finally, the well dispersed flocculants possessing excellent flocculation performance were selected for the next stage of experiments.

(2) 100-mL of waste sludge was poured into every 250-mL beaker, and a series of certain dose of flocculent was added into the beakers, respectively, then the waste sludge was stirred with a glass rod for about 1 min. After the flocs occurred and transparent liquid separated, the mixture was poured into a sintered discs with Φ4.5~9 μm, filtrated under vacuum of –0.085~–0.100 MPa for 8 min [11,12]. Then, a filter cake was taken out and transferred into a Φ10 cm petri dish for drying to constant weight in 120°C –150°C oven, and its solid content was calculated through the weight loss after drying. Meanwhile, the volume of filtrate and its zeta potential after diluting it to 50 times with water [13] were measured. Finally, both outer surface and transverse section of dried filter cakes were characterized by SEM pictures, together with that of dried waste sludge.

3. Results and discussion

3.1. The results of selection experiments

According to procedure (1) in 2.3.2, the waste sludge of middle solid content was used for the selection experiment. The dispersion and flocculation phenomenon observed are shown in Table 2, there, √: dispersion and flocculation; ×: non or weak-dispersion and –flocculation.

Table 2 shows that anionic polyacrylamide couldn't disperse in the waste sludge and could only flocculate the waste sludge in the interface strongly, which resisted the full of flocculation happened; nonionic polyacrylamide could disperse but couldn't flocculate obviously; cationic and amphoteric ionic polyacrylamide could disperse and flocculate, but the latter showed very weak flocculation performance. Therefore, the cationic flocculants were chosen to flocculate the waste sludge with positive charge further rather than that with the negative charge.

The data in Table 3 show that flocculants with more than 30% cationicity behavior well in the flocculation based on the dispersion and flocculation phenomenon observed and the size of flocs measured, especially which with the middle and high cationicity demonstrated the excellent performance in flocculation. Even among them, the flocculation performance of the cationic polyacrylamide 50% P (DAC-AM), 70% P (DAC-AM), 90% P (DAC-AM), CA-8, CA-11 and CA-12 were better than others. Therefore, they were selected to do research on their flocculation and dehydration performance, systemically and in detail.

3.2. Performance of cationic polyacrylamide on flocculation and dehydration performance

3.2.1. Effect of the dosage and cationicity

According to procedure (2) in 2.3.2 and the results of selection experiment in 3.1, the flocculants, such as CA-12, CA-11, CA-8, 50% P (DAC-AM), 70% P (DAC-AM) and 90% P (DAC-AM) were used in the flocculation experiment of waste sludge with 52.17% solid content. The effect of dosage of the flocculants with different cationicity on the solid content of filter cake and the filtrate volume are shown in Fig. 1.

It is shown in Fig. 1 that the solid contents of filter cakes changed not obviously with dosage variation of 50% P (DAC-AM), CA-8 or CA-12, but they increased and then decreased with that of 70% P (DAC-AM) and 90%P (DAC-AM). The solid content of filter cake always increased with dosage variation of CA-11 within the experimental range. However, the filtrate volume increased with

Table 2
Dispersion and flocculation phenomenon of flocculants

No.	Ionicity	Intrinsic viscosity ($dL \cdot g^{-1}$)	Dosage ($mg \cdot L^{-1}$)	Dispersion phenomenon	Flocculation phenomenon
AN1–10	Anionic	4.54–21.50	90–180	×	√
AM1–3	Amphion	1.84–13.14	60–120	√	×
NON1–3	Nonionic	1.94–12.95	90–120	√	×
CA1–12	Cationic	13.69–29.63	60–90	√	√
P(DAC-AM)1–5	Cationic	12.69–16.67	60	√	√

Table 3
Flocculation performance of CA and P (DAC-AM) flocculants for sludge

No.	Cationicity CD (%)	Intrinsic viscosity (dL·g^{-1})	Dosage (mg·L^{-1})	Dispersion phenomenon	Flocculation phenomenon	Size of floc (mm)
CA-1	3	29.63	90	√	0	
CA-2	5	17.47	90	√	0	
CA-3	10	13.31	90	√	0	
CA-4	10	18.18	90	√	1	1–2
CA-5	10	21.48	90	√	1	1–2
CA-6	15	15.44	90	√	0	
CA-7	25	17.24	60	√	2	3–5
CA-8	**35**	**13.69**	**60**	**√**	**3**	3–5
CA-9	40	16.17	60	√	2	3–5
CA-10	40	21.20	60	√	3	3–5
CA-11	**55**	**12.90**	**60**	**√**	**4**	3–5
CA-12	**80**	**6.12**	**60**	**√**	**3**	3–5
P(DAC-AM)1	10	13.85	60	√	0	
P(DAC-AM)2	30	13.93	60	√	1	1–2
P(DAC-AM)3	**50**	**16.67**	**60**	**√**	**3**	**3–5**
P(DAC-AM)4	**70**	**13.41**	**60**	**√**	**4**	**3–5**
P(DAC-AM)5	**90**	**12.69**	**60**	**√**	**3**	**3–5**

Note: √: Dispersion and flocculation; and flocculation effect was presented by number, 0: non-flocculation; (1): weak flocculation; (2): medium flocculation; (3): good flocculation; and (4): excellent flocculation.

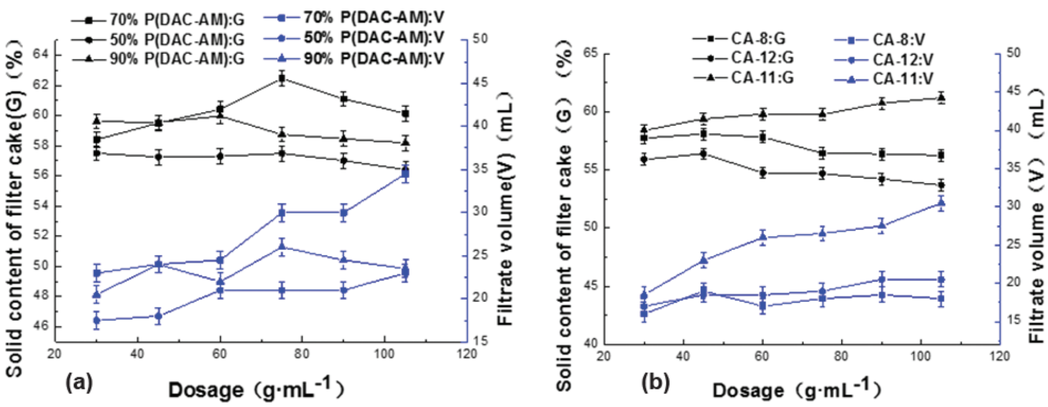

Fig. 1. Effect of dosage of (a) P (DAC-AM) and (b) CA flocculants with different cationicity.

dosage variation of any kind cationicity of flocculants, and herein, the increasing scopes of the filtrate volume could reach their largest values when using 70% P (DAC-AM) and CA-11. Especially, the solid content of filter cake increased from 52.2% of waste sludge to the maximum value 62.5% and the filtrate volume increased from 23.0 to 34.5 mL, when the dosage 75 mg.L^{-1} of 70% P (DAC-AM) was used. It meant the volume of waste sludge could be reduced by 20% and the filtrate poly-aluminum chloride solution of about 20%–30% volume of total waste sludge could be reused as product PAC. In this situation, the appearance of filter cake is shown in Fig. 2(a) and it can be stacked for long time with unchanged shape and weight, easily for further treatments. On the contrary, the appearance of filter cake by without using and using unreasonable flocculants is shown in Fig. 2(b).

The reason for above results might be that the waste sludge with a certain positive charge was a stable aqueous colloidal system. When the cationic polymer flocculants only with proper ionicities were added, they could well disperse, then break up the existing balance of the original aqueous colloid system, even slightly, and absorb large amount of suspending particles together to form flocs based on the entire function demonstration of charge neutralization and double layer compression, bridging and net-capturing [14].

In contrast with the cationic polymer flocculants with proper ionicities, others shown in Tables 2 and 3 of 3.1 might meet some troubles in the process of the entire function demonstration above stated. First, the anionic flocculent couldn't display its ability. Because the difficulty of well dispersion itself caused by too strong charge neutralization and double layer compression. The giant floccules were formed clearly but only in the contact interface of the waste sludge and agent, and further dispersion of flocculent was restricted. Second, unlike the anionic flocculants, the non-ionic flocculants could obviously penetrate into the waste sludge without any resistance of floccules in interface usually caused by destruction of charge equilibrium of suspended colloid particles. And they could surely display the function of flocculation, but weakly, because the flocculation could work merely with the help of weak bridging and without any collapse of double layer which should be a basement of strong flocculation and dehydration. Furthermore, it would be easy to understand that the amphoteric ionic and cationic flocculants with low cationicity could play weakly flocculation depending on its low charge neutralization and gently double layer compression which favor it both in penetration into waste sludge and in slight flocculation.

3.2.2. Effect of the dosage and the solid content of sludge

According to the result in 3.2.1, the flocculation effect was the best when using 70% P (DAC-AM) and CA-11 to treat the waste sludge. Therefore, according to procedure (2) in 2.3.2, the effect of the dosage and the solid contents of waste sludge on the flocculation and dehydration performance were investigated when using 70% P (DAC-AM) and CA-11. The results are shown in Fig. 3.

It is shown in Fig. 3 that the solid content of filter cake changed a little with the dosage of either 70% P (DAC-AM) or CA-11, when treating the waste sludge with low solid content. The solid content of filter cake was increased with the dosage of 70% P (DAC-AM) and CA-11, when treating that with middle solid content. However, the solid content of filter cake was increased with the dosage of 70% P (DAC-AM) and decreased with the dosage of CA-11 when treating that with high solid content.

The reason for above results might be that the dilution of added flocculants would cause double influence of both seeming to need more dosage in obtaining more better flocculation and forming the even variation of dehydration effect with the dosage, within certain dose scope and when treating the waste sludge with low solid content. However, the difficulty of flocculants in dispersion would always a problem, when both treating a waste sludge with high solid content and using flocculants with high molecular weight even with proper cationicity. Therefore, it would be very important to conduct experiments more in an optimum condition once the flocculants will be used in practice.

3.3. Effect of filter time

According to procedure (2) in 2.3.2, the flocculation effect of filter time on the solid content of filter cake and filtrate volume was investigated when treating the waste sludge with low solid content after adding flocculants of 70% P (DAC-AM) and CA-11 selected. The experimental results are shown in Fig. 4.

As Fig. 4 shows the solid content of filter cake and the filtrate volume increased with filter time when using either 70% P (DAC-AM) or CA-11, it meant the flocculation effect

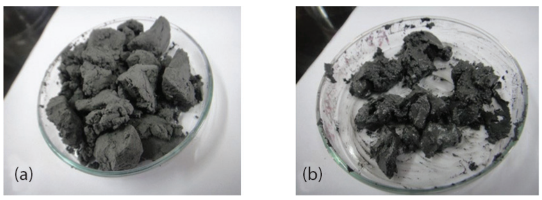

Fig. 2. Appearance of filter cake untreated and treated by flocculants. (a) Treated by reasonable flocculants, and (b) untreated or used unreasonable flocculants.

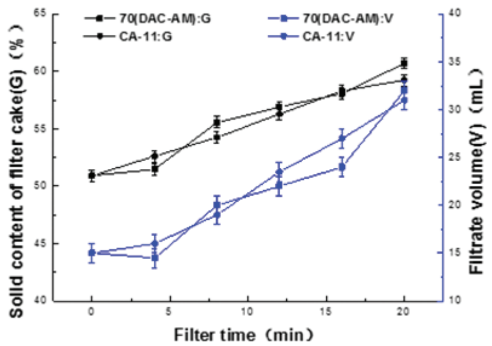

Fig. 4. Effect of different filter time.

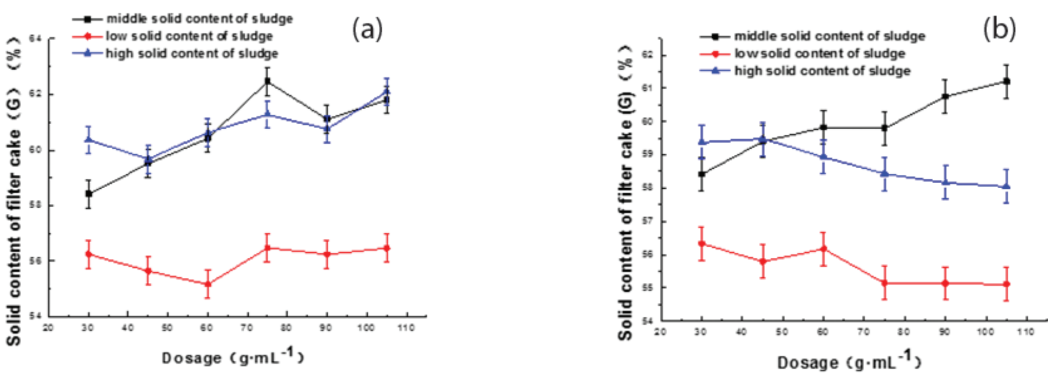

Fig. 3. Effect of dosage of (a) 70% P (DAC-AM) and (b) CA-11 for different solid contents of waste sludge.

of them was almost the same. The solid content of filter cake increased not so strong with the filter time increasing and the cracking phenomenon on the surface of the filter cake often appeared after 8 min, which caused the results unstable, so 8 min was chosen as the filter time for convenience of saving time and stable results in this research.

3.4. Relationship between the zeta potential of filtrate and flocculation performance

3.4.1. Relationship between the zeta potential of filtrate and the flocculent dosage

According to procedure (2) in 2.3.2, the experimental results of the relationship between the zeta potential of filtrate and the dosage of P (DAC-AM) or CA flocculants with different cationicity are shown in Fig. 5 when using the waste sludge of middle solid content for treatment.

As Fig. 5 shows, the range of zeta potential values changed within a certain range between 40 and 55 mV when using P (DAC-AM) and CA flocculants. It was easily observed that the ranges of zeta potential for obtaining the highest or best solid contents of filter cakes under the optimum dosage of P (DAC-AM) and CA were from 40 to 44 mV and from 44 to 47 mV, respectively, when comparing the results in Fig. 5 with 1.

3.4.2. Relationship between the zeta potential of filtrate and the dosage for the different solid contents of waste sludge

According to procedure (2) in 2.3.2, the experimental results of the relationship between the Zeta potential of filtrate and the dosage of 70% P (DAC-AM) or CA-11 selected for treating three kinds of solid contents of waste sludge are shown in Fig. 6.

As Fig. 6 shows, zeta potential values changed within a range from 40 to 55 mV when using both 70% P (DAC-AM) and CA-11 for the treatment of three different solid contents of waste sludge, similarly to the situation shown in 3.4.1. It was also easily observed that the ranges of zeta potential for obtaining the highest or best solid contents of filter cakes under the optimum dosage of 70% P (DAC-AM) were all about from 40 to 44 mV, and that of CA-11 for the waste sludge with three solid contents from low to high were about 41, 46, 48 mV, respectively, when comparing the results in Fig. 6 with 3.

3.4.3. Flocculation mechanism analysis based on zeta potential

The results in 3.4.1 and 3.4.2 show that the range of the zeta potential of filtrate of original waste sludge was from 43.21 to 47.11 mV, and that of the treated waste sludge after flocculation was among 40 to 55 mV either using the P (DAC-AM) or CA flocculants to all three different solid

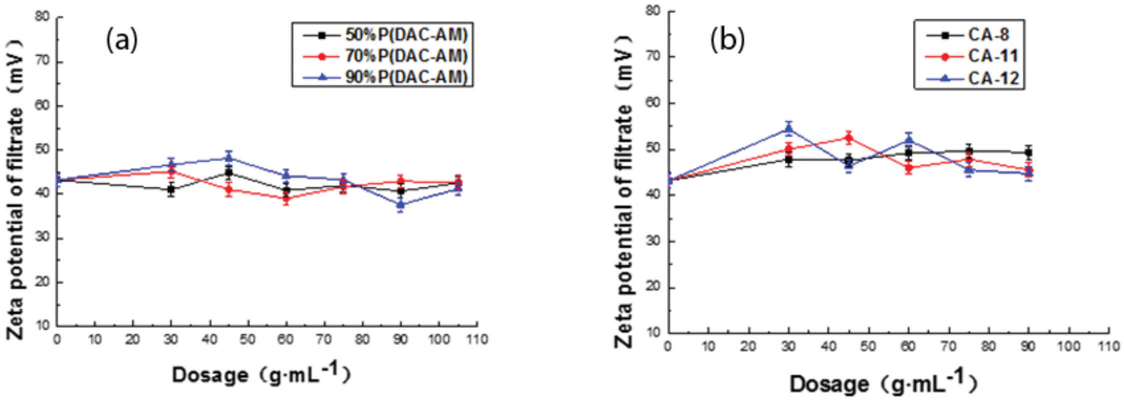

Fig. 5. Relationship between the zeta potential of filtrate and dosage of (a) P (DAC-AM) or (b) CA.

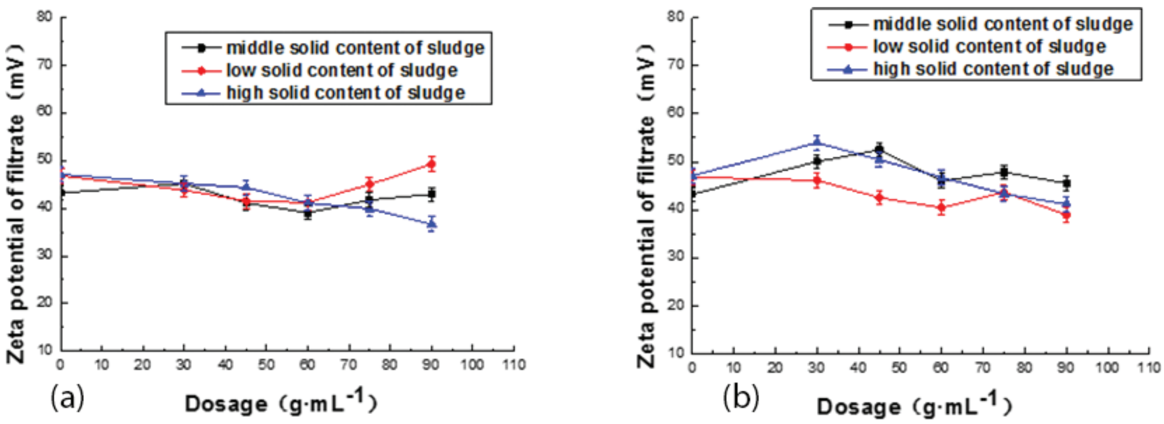

Fig. 6. Zeta potential of filtrate by using (a) 70% P (DAC-AM) or (b) CA-11 for different solid contents of waste sludge.

contents of waste sludge with highly positive charge. The changed range of zeta potential of filtrate was not so big, but it changed. So the results indicated that the charge neutralization of flocculants could work and its effect might not be so extremely, in the flocculation process, but necessary.

However, it was clearly observed that from the flocculation phenomenon after adding the flocculants with different ionic properties. The anionic flocculants showed an obvious flocculation effect just around their droplets of added agents because of excellent charge neutralization. But they were restricted to disperse in the waste sludge of highly positive charge and solid content. They could react only with waste sludge in a limited contact area so as not to display their flocculation and dehydration to the waste sludge based on classically basic theory [1], i.e. charge neutralization, double layer compression, bridging and net-capturing.

In contrast with the situation above, the cationic flocculants named as polyelectrolyte with positive charge, especially with high cationicity after added, could quickly disperse and penetrate into the waste sludge. They might react with suspending particles, then destroy the original aqueous colloidal balance due to the function of bridging and net-capturing [14] combined first with both the possibly weak charge neutralization and double layer compression caused by an electrolyte effect [15]. Above reasons resulted in an obviously separation of water from the waste sludge and an ideal flocculation and dehydration effect.

In general, it is well known that flocculation and dehydration of suspending colloidal particles depend on classically basic theory. Based on these and dissection above, it could be discovered that for flocculation and dehydration of the waste sludge with positive charge and high solid content from PAC production using aluminum ash method, the charge neutralization and double layer compression could be carried out not only by flocculants with usually opposite charge, but also by that with the same charge, and subsequently the bridging and net-capturing could happen. Especially, when the flocculants with opposite charge could not function well because of difficulty in dispersion. There has been some reporting in literature as that the flocculation and dehydration can be conducted by the flocculants with the same charge, but it has been only limited in the treatment of the colloid particles of negative charge with anionic flocculants as an example [16], until now.

Therefore, the research work completed in this paper offered a novel example that cationic flocculants could be used to flocculate and dehydrate the colloid particles with positive charge and high solid content, under the condition of the strong dispersion first. It might not only develop a new effective method to treat the waste sludge with positive charge and high solid content from PAC production, but also enrich the knowledge of the classically basic theory such as charge neutralization, double layer compression, bridging and net-capturing.

3.5. Morphology characteristics of filter cakes by SEM

According to the experimental results from 3.1 to 3.4, the outer surface and transverse section (inside) of both the dried waste sludge and the dried filter cake after treated by using the 70% P (DAC-AM) and CA-11 flocculants were characterized by SEM and are shown in Fig. 7.

It is shown in Fig. 7 that the microstructure of outer surface and transverse section of original waste sludge after dried appeared a smooth and dense structure, respectively, indicating no obvious solid-liquid separation happened in waste sludge before dried. And when the waste sludge was dried in oven at high temperature, a great amount of water molecules homogeneously adsorbed by suspending hydrophilic colloid particles shifted from inner portion to the outer surface and vapored, gently and gradually. It resulted in the formation of a smooth outside and dense inside microstructure of dried waste sludge, respectively.

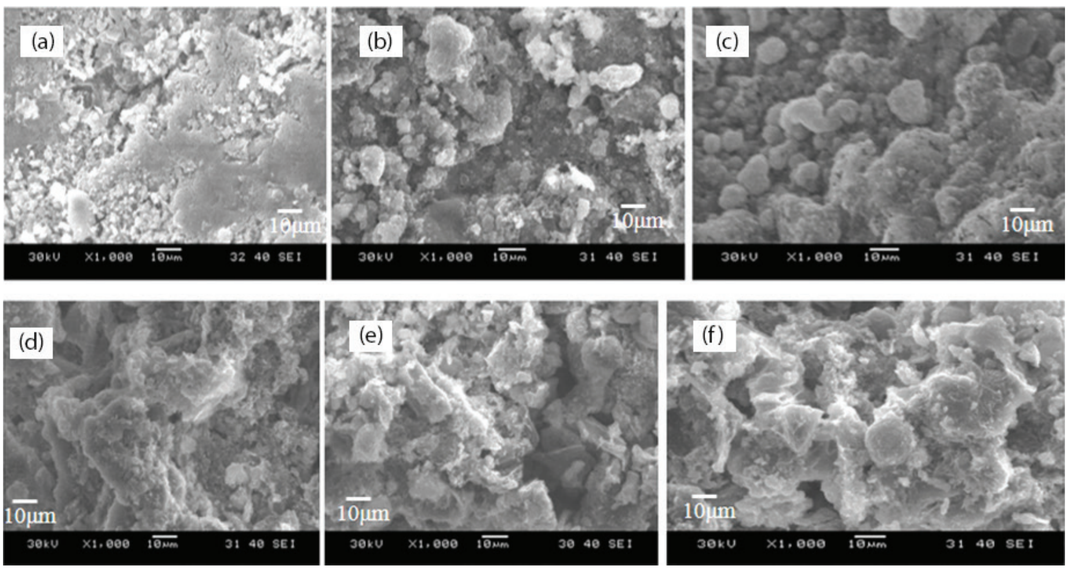

Fig. 7. Outer surface and transverse section of dried waste sludge and filter cake treated by flocculants. (a) The outer surface of dried sludge, (b) the outer surface of filter cake treated by 70% P(DAC-AM), (c) the outer surface of filter cake treated by CA-11, (d) the transverse section of dried sludge, (e) the transverse section of filter cake treated by 70% P(DAC-AM), and (f) the transverse section of filter cake treated by CA-11.

However, once waste sludge was treated by the well dispersed flocculants under the optimum experimental condition, for instance, by using 70% P (DAC-AM) or CA-11, a large number of some small dense flocs and inner space containing rich liquid formed first. These resulted from the flocculants function such as charge neutralization, double layer compression, bridging and net-capturing. The micro empty interspaces and inner canals occurred consequently within dried filter cake during filtrating and drying process, respectively. They indicated well solid-liquid separation happened because of the effect of charge balance destruction of the colloid particles first, and flocs aggregation subsequently, resulting in the filter cake easily to dehydrate and forming both the outer surface and inside morphology.

4. Conclusion

(1) It was discovered that the original waste sludge from poly-aluminum chloride production were of not only high solid content, but also highly positive charge. Only the flocculants with the positive charge and high molecular weight could disperse well in the waste sludge to destroy the charge balance of aqueous colloid particles and form flocs aggregation in the waste sludge, so as to achieve the best flocculation and dehydration performance and create a novel way to reuse the corrosive and acidic residue.

(2) 70% P (DAC-AM) demonstrated the best flocculation performance to increase the solid content of filter cake to 62.5% (w%) from 52.2% (w%) of original waste sludge, when its dosage was 75 mg.L^{-1}, the pressure in vacuum filtration was –0.095 MPa and the filter time was 8 min. The volume of waste sludge was reduced by 20% and the filtrate poly-aluminum chloride solution of about 20%–30% volume of total waste sludge could be recycled by using the cationic polymer flocculants to deal with the waste sludge.

(3) The outer surface and transverse section of dried filter cake and waste sludge characterized by SEM showed that the different densities or the internal interspace existed on the outer surface and transverse section of both the filter cake and the dried original waste sludge, indicating the filter cake easily to dehydrate. Together with the measurement of zeta potential, they explained the working mechanism of the cationic flocculants comprising bridging and net-capturing combined first with both the weak charge neutralization and double layer compression caused by an electrolyte effect.

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