The study of Na_2SiO_3 as conditioner used to deep dewater the urban sewage dewatered sludge by filter press

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Abstract

In this paper, Na_2SiO_3 as new conditioner were used to adjust the urban sewage dewatered sludge （UDSS） and results showed Na_2SiO_3 has no effect to improve dewaterability of UDSS independently, but when adding multivalent salt like $Fecl_3$ can improve the effect of Na_2SiO_3 conditioning UDSS. At the same time, influencing factors in the dewatering process were all systematically studied, including the dosage of $FeCl_3$, molar ratio of Si/Fe, the sequence of adding conditioner. The physico-chemical property such as Zeta potential of UDSS conditioned by Na_2SiO_3 were also researched, which indicated the strong polymerizing power of Na_2SiO_3 with $Fecl_3$ improve the dewaterability of UDSS. At last, the compound use of $FeCl_3$, Na_2SiO_3 and fly ash was also investigated, which could further decrease the moisture content of the filter cakes to about 45%.

Key word: Na_2SiO_3; dewatered sludge; deep dewatering; filter press

1. INTRODUCTION

The urban sewage sludge (USS) has been highly concerned because of its huge production and potential pollution (Vaxelaire and Cezac, 2004). After the first dewatering of USS, the products are called urban sewage-dewatered sludge (UDSS) whose water contents are 75%~85%, which is too high to meet the requires of final treatment and disposal for the waste sludge.

To solve the problems of sludge thoroughly, the moisture contents of the UDSS need be further decreased. Three methods are common, including nature drying (He et al., 2014), direct thermal drying (Wang and Zhang, 2007) and mechanical dehydration(Xia et al., 2014). The nature drying is easy to operate and cost less, but the method uses large area occupied and is easily influenced by weather, worse still, the bad smell and percolate produced in the drying process are difficult to treat. The direct thermal drying also has shortages such as huge instrument investment, high running costs and excessive energy consumption. Relatively, mechanical dehydration can avoid the drawbacks as above, but the low dewatering effect restricts its apply.

$AlCl_3$ as conditioner to adjust the UDSS was researched, which can decrease the water contents of filter cakes to about 60% with suitable dosage (Xia et al., 2014). The mechanism of the multivalent salt such as Fe^{3+} and Al^{3+} conditioning UDSS is that by the charge neutrality function of multivalent ion, the surface charge of sludge particles decrease and more sludge particles gather to become larger and denser flocs, reducing the water-reserving ability of UDSS

The construction of UDSS conditioned by $AlCl_3$ is large and dense and the internal charge is small. If continuing to adding multivalent salt to the sludge, the particles would possess excess positive charge and disperse again, which worsen the dewaterability. While, if adding a type of conditioner, which has small charge and strong polymerization, the sludge flocs of UDSS would maintain dense construction and have larger size. Therefore the percent of surface water adsorbed on the sludge particles would decrease, which can realize the further dewatering of the UDSS.

Silicate just meets above criteria for further dewatering the UDSS, which can form polysilicic acid in acidic condition that has small negative charge and strong adsorption capacity (J.R, 1937). In the area of waste water treatment, silicate has been studied to be used with Fe^{3+} and Al^{3+} for synthesizing polysilicate-metals (PSiM), having impressive effect to treat the waste water (Gao et al., 2002; Gao et al., 2003).

In this study, silicate as a new conditioner to adjust UDSS conditioned by Fe^{3+} was studied. The effect and principle of the silicate conditioning UDSS was studied by observing the changes of physic-chemical property in UDSS such as Zeta potential,. Because of the UDSS is plastic state, the water in the sludge cannot be pressed out at low pressure and therefore both specific resistance of sludge (SRF) and capillary suction time (CST) are unable to express the effect of dewatering. The dehydration rate (DR) of UDSS with high pressure was the main index to judge the effect of further dewatering of UDSS. The optimized conditioning process of dewatering was also discussed.

2. MATERIALS AND METHODS

2.1. Dewatered sludge and reagent

The dewatered sludge samples were collected from the Guangda waste water treatment plants in Jinan (Shandong, China). The dewatered sludge of the plants was produced by belt filter press after adding 0.4% (dry sludge) polyacrylamide (PAM). Samples collected were kept at a room temperature (about 20 ℃) and analyzed
2 days. The characteristics of the sludge are list as follows: moisture content 81.2%, zeta potential -40.53 mv, PH 7.85.

Sodium silicate (AR) was purchased from Tianjin Bodi Chemical Co.Ltd.PR China.

Ferric chloride anhydrous (AR) were purchased from Sinopharm Chemical Reagent Co. Ltd. PR China and the fly ash were bought form Ji'nan power plant in Shandong province China. All the solutions were dissolved by deionized water.

2.2. Dewatering produces

300 g dewatered sludge with a certain amount of $FeCl_3$ and Na_2SiO_3 were mixed in some time in order to identify the optimal conduction for the dewatering. 10 g sample was saved at 4 °C for analyzing i
press cloth and put into the filter press as is showed in Fig.1. After the pretreatment, the press of 3 Mpa was applied. When filtrate was no more removed, the dewatering process was finished.

2.3. Analytical methods

The zeta potential was measured by micro electrophoresis (JS94H, Zhongchen Digital Technology Equipment Ltd., Shanghai). 1 g sample which was after conditioning was added into 50 mL deionized water and stirred for 1 minute. Then 3 mL of the mixture were taken to the electrophoresis pool to measure the value. All measures were carried out for five times.

The dewaterability of the dewatered sludge was measured by moisture contents of the filter cakes which were the product of the sludge dewatering by the filter press. 10~15 g filter cake was taken out and dried at 105 °C for 2 h to det
content (MC) and dehydrate rate (DR) which is determined by Eq.(1).The mean value would be got with the test being performed in three times.

$MC\ (\%) = (M_{CT} - M_{ad})/M_{CT}$

$\mathrm{DR}(\%) = (MC_a - MC_b)/MC_a$

Where M_{CT} is the weight of sample before drying; where M_{ad} is the weight of sample after drying at 105 °C for 2; where MC_a is the moisture content of filter cakes after pressing; where MC_b is the moisture content of filter cakes before pressing.

3. RESULTS AND DISCUSSION

3.1. Effect of Na_2SiO_3 added into UDSS with different multivalent salt

Fig.2 shows the results comparison of Na_2SiO_3 (6g / 300g UDSS) added into the UDSS with 8g $Alcl_3$, 10g $Fecl_3$, 10g $Cacl_2$ and no pretreatment. The results indicate that when Na_2SiO_3 adjusts the UDSS without pretreatment, the dehydration rate becomes worse. But when adding multivalent salt into UDSS, Na_2SiO_3 can improve their dehydration rate. Especially when adding Fe^{3+} into UDSS, the dehydration rate of UDSS with Na_2SiO_3 increases by more than half than UDSS without Na_2SiO_3. The results show that Na_2SiO_3 can improve the dewaterability of UDSS in the absence of multivalent salt in the sludge, but has no effect on UDSS without pretreatment.

3.2. The optimum condition of Na_2SiO_3 conditioning UDSS with $Fecl_3$

3.2.1 Dosage of $Fecl_3$ in the UDSS

As is discussed in chapter 3.1, Na_2SiO_3 has no effect to improve dewaterability of UDSS independently, so the dosage of multivalent salt like $Fecl_3$ can affect Na_2SiO_3 conditioning UDSS. As Fig.3 shows that with different dosage of Na_2SiO_3, the changes of dehydrate rate of UDSS with 4 g, 8 g and10 g $Fecl_3$ are similar, which all rise first and fall later. With the same dosage of Na_2SiO_3, the effect of different dosage of $Fecl_3$ conditioning UDSS is that: 10 g > 8 g > 4 g. To compare results of 10 g $Fecl_3$ and 12 g $Fecl_3$, the maximum value of two curves are almost same, but appear in different dosage of Na_2SiO_3, which means the dosage of Na_2SiO_3 also play a part in conditioning UDSS.

3.2.2 Molar ratio of Si / Fe in UDSS

Fig.4 shows the changes of dehydrate rate with different molar ratio of Si / Fe. Results indicate all the dehydrate rate rise first and fall later, with molar ration of Si / Fe increasing. And all the optimum values of curves in Fig.4 almost appear when Si / Fe is between 0.25~0.3, while when the ratio is over 0.3, the effect become worse. The best dewatering effects appear when10 g $Fecl_3$ with 0.25 molar ratio of Si / Fe and 12 g $Fecl_3$ with 0.3 molar ratio of Si / Fe added into UDSS. Obviously, the 10 g $Fecl_3$ with 0.25 molar ratio save much cost of conditioning the UDSS.

The chapter 3.1 and 3.2 also shows that only adding high dosage of Fe^{3+} which is more than 8 g / 300 g UDSS, the function of Na_2SiO_3 conditioning UDSS is obvious.

3.2.3 Sequence of adding reagent into UDSS

When two or more kinds of conditioners were added, their sequence would be considered. In the present paper, with two different kinds of sequence including $FeCl_3$ being first and Na_2SiO_3 being first, 4 g Na_2SiO_3 and various quantities $FeCl_3$ including 4, 6, 8,10, 12 g were added into 300 g UDSS separately. The changes of dehydrate rate and zeta potential of the sludge are showed in Fig.5 and Fig.6. As is shown in the Fig.5 and Fig.6, both the dehydrate rate and zeta potential change little in two kinds of sequence. The sequence has little effect on the dewatering of the UDSS.

3.3 Principle of Na_2SiO_3 conditioning UDSS

The flocs in UDSS are formed by PAM or CPAM bridging small particles and the inner charge is still high, which would loosen the construction of flocs. So the principle of improving the dewaterability of UDSS should be related to the ZETA potential and particle size, which can reflect changes of inner construction in UDSS

3.3.1 Changes of ZETA potential of sludge particles

Na_2SiO_3 has negative charge, which may worsen the charge neutralization of Fe^{3+} for the sludge particles with negative charge. As is shown in Fig.7, with the dosage of Na_2SiO_3 increasing, the surface potential of sludge particles decrease. But when adding more Fe^{3+} (> 8 g / 300 g UDSS), the trends of curves are not obvious. Adding Fe^{3+} into sludge would make the environment of UDSS acid, which turns SiO_3^{2-} to polysilicic acid that has low negative charge, so the negative charge of Na_2SiO_3 has a little effect on Fe^{3+} neutralizing sludge particles. From Fig.7, the potential of UDSS without Fe^{3+} decrease obviously, so the particles of flocs disperse more and the dewaterability turns worse, which can explain why $NaSiO_3$ has no effect on conditioning UDSS without multivalent salt.

3.3.2 Polymerization and bridge function of polysilicate

Na_2SiO_3 can become polysilicate in acid environment, which can be aids to enhance the effect of Fe^{3+}, because of its strong polymerization and bridge function(J.R, 1937). The combination of Na_2SiO_3 and metal salt are often used in wastewater treatment, which can produce larger flocs. Gao et.al (Gao et al., 2002)used Aluminum-silicate polymer composite (PASiC) to treat micro-SiO_2 particles in water and found the mean floc size treated by PASiC grew bigger and more quickly than treated by poly-aluminum chloride (PAC). Cao et.al (Cao et al., 2010)compared the coagulation effect of polyferric sulphate (PFS) and polyferric silicate sulphate (PFSS) in Yellow river water treatment and found that the flocs formed by PFSS had larger size, higher growth rate and stronger flocs strength. Xin et.al (Huang et al., 2014)also found that when using polytitanium-silicate-sulfate (PTSS) and poly-titanium sulfate (PTS) treated the waste water containing kaolin and fulvic acid, the floc formed by PTSS has larger size than PTS with entire dosage range.

As for changes of flocs size in UDSS conditioned by Na_2SiO_3, it is difficult to observe because of the state of UDSS. The UDSS is plastic state and few methods can used to observe its flocs size. If stirring the UDSS to flow state, the inner construction would be destroyed and the flocs size would be influenced by mixing speed, time and agglomeration degree of UDSS, which would produce errors. So the function of Na_2SiO_3 conditioning UDSS only used the theories in waste water treatment to explain partly.

3.4. Compound use of Na_2SiO_3, $FeCl_3$ and fly ash

To further decrease the water contents of the sludge, the fly ash was considered. As a solid wastes and common coagulant aids, the fly ash has been studies for many years. In recent studies, it can be used a kind of conditioner to condition the sludge. The fly ash can sever as zero-cost raw materials that can reduce the cost of the treatment and this waste can be eliminated in this way (Buyukkamaci and Kucukselek, 2007). Wang et.al (Wang and Viraraghavan, 1998) found fly ash can be used as auxiliary reagents with alum or polyelectrolyte. Buyukkamaci.et.al (Buyukkamaci and Kucukselek, 2007) found that when the dosage of fly ash added in to the raw sludge was 10% of the sludge, the SRT of the sludge would decrease by 27% than the untreated sludge. In addition, Zhang.et.al (Zhang et al., 2014) studied the sludge and fly ash could be the main materials to make active carbon which had good performance in wastewater treatment. Using fly ash to decrease the water contents of the sludge may be good for the final treatment of the sludge. However, the apply of the fly ash may cause problem of heavy metals (Buyukkamaci and Kucukselek, 2007), so the dosage of the fly ash should be not excessive.

4 g Na_2SiO_3, 10 g $FeCl_3$ and various quantities fly ash including 0, 2, 5, 10, 12g were added into 300 g DS separately. As is shown in Fig.8, the moisture contents of filter cakes become more and more low with the fly ash increasing and the trend become not obvious when the dosage is over 5 g. In consideration of the risk of heavy metal existing in the fly ash and the problem of increased dry weight of sludge, 5 g fly ash is the optimal dose. Thus, when the dosage of $FeCl_3$, Na_2SiO_3, fly ash, which were added into the sludge, were 3.3%, 1.3%, 1.6% of the UDDS accordingly, the moisture contents of the filter cake would be decreased to 45%.

4. CONCLUSION

In the paper, the effect and optimal condition of Na_2SiO_3 as conditioner for further dewatering UDSS were studied. The experimental consequences demonstrated that Na_2SiO_3 itself had little effect on improving the dewaterability of UDSS, but Na_2SiO_3 can be used the aids to improve the effect of multivalent salt conditioning UDSS. When the dosage of $Fecl_3$ was 10 g/300 g UDSS and molar rate of Si/Fe is 0.25~0.3, the dehydrate rate of UDSS was the highest and the sequence of adding reagent has little effect on dewatering. At last, for further decreasing the water content of UDSS, fly ash was continued to add into UDSS. When adding 3.3% (w/w UDSS) $FeCl_3$ and 1.3% (w/w UDSS) Na_2SiO_3 and 1.67% (w/w UDSS), the moisture content of UDSS was decreased to 45% and the dehydrate rate reached up to about 40%.

As for principle of Na_2SiO_3 used as conditioner, the charge neutrality function of multivalent salt has been proved to be not weakened by Na_2SiO_3 and the polymerization and bridge function of polysilicate formed by Na_2SiO_3 in acid environment can produce large flocs, which was good for further dewatering. But because of the lack of relevant literature, the role of Na_2SiO_3 playing in the sludge can only be partly explained by the coagulation mechanism of the water treatment. The performance of Na2SiO3 in sludge, especially in dewatered sludge, needs more researches. In addition, the follow-up disposal of the filter cakes in the experimental are also worthy to be discussed.

5. ACKNOWLEDGEMENT

This work was supported by grants from Tai Shan Scholar Foundation(No.ts20151100 3），the National High Technology Research and Development Program (863 Program) of China (Grant No.412 2012AA063501)， the Science and Technology Development Plans of Shandong Province, China (Grant No. 2014GSF117036) and the Natural

Science Foundation of Shandong Province, China (Grant No. ZR2010EL032).

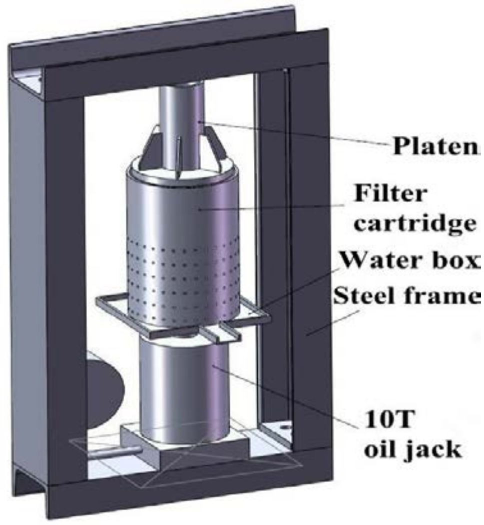

Fig.1 Schematic diagram of the filter press for further dewatering of dewatered sludge

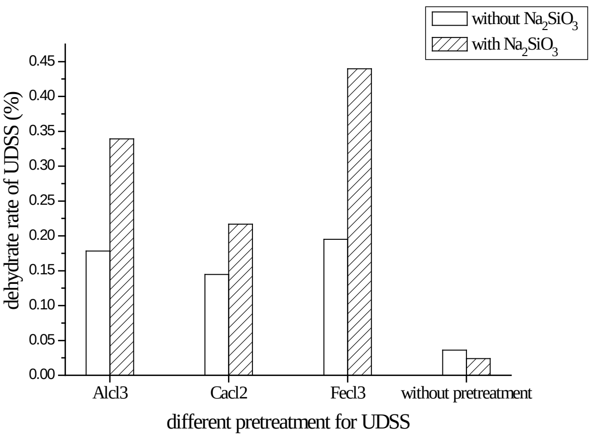

Fig.2 the dehydrate rate of UDSS in series dosages of $FeCl_3$

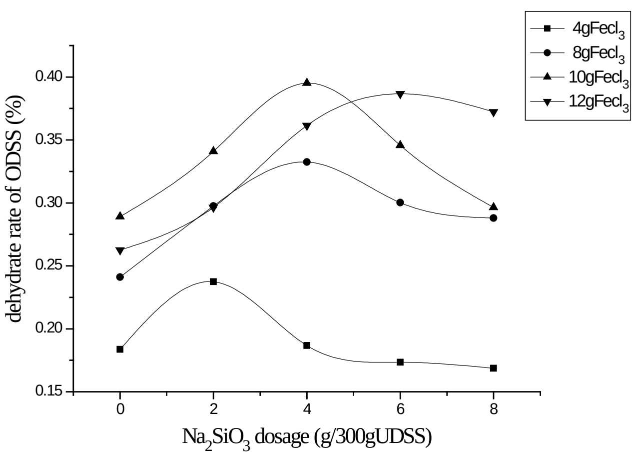

Fig.3 the dehydrate rate of UDSS in series molar ratio of Na_2SiO_3:$FeCl_3$

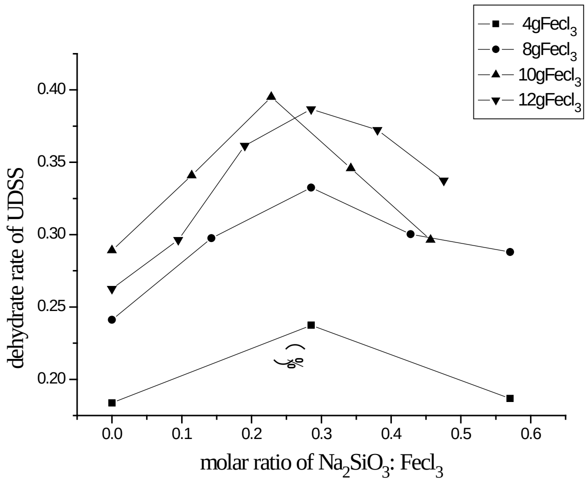

Fig.4 the dehydrate rate of UDSS in different molar ratio of Na_2SiO_3: $Fecl_3$

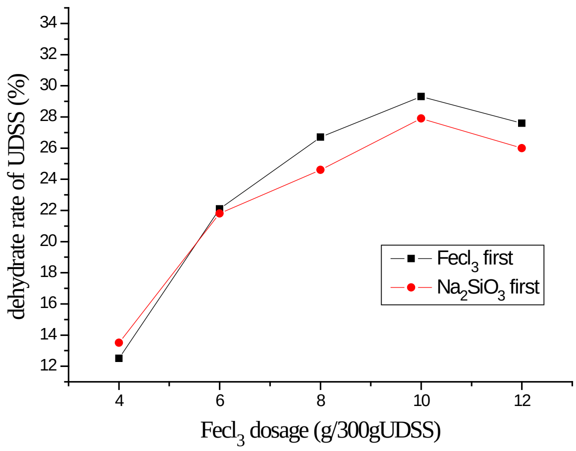

Fig.5 the dehydrate rate of UDSS in series dosages of $FeCl_3$ with different sequences

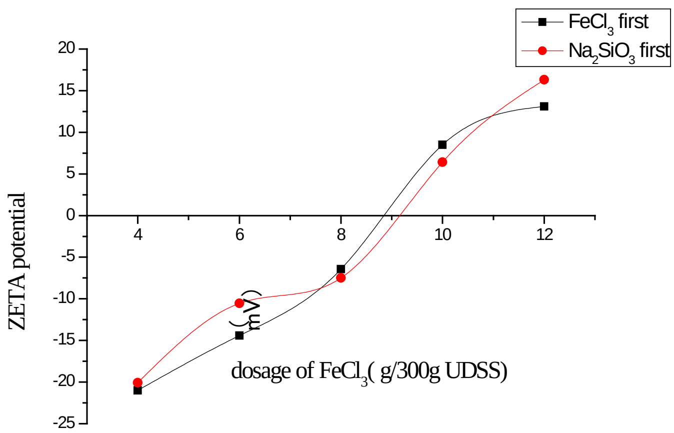

Fig.6 changes of Zeta potential in series dosages of $FeCl_3$ with different sequences of adding reagents

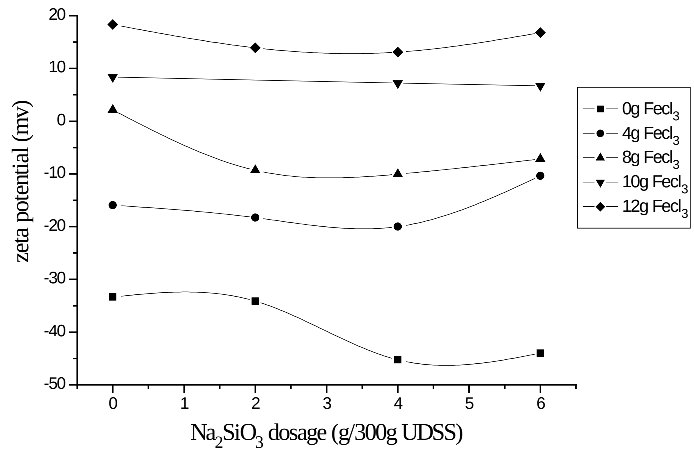

Fig.7 the zeta potential of UDSS in series Na_2SiO_3 and $Fecl_3$ dosage

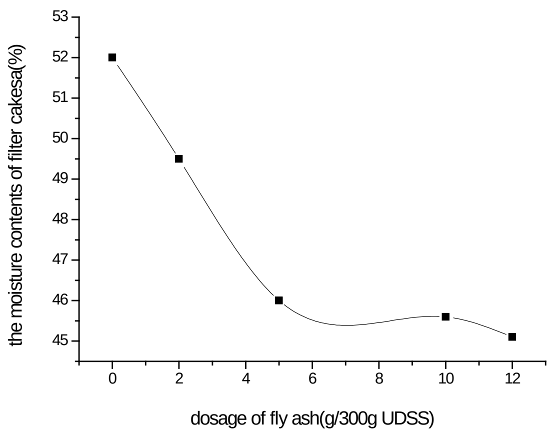

Fig.8 the moisture contents of filter cakes in series dosages of fly ash

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