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Feasibility of sludge deep-dewatering with sawdust conditioning for incineration disposal without energy input

Hongbo Liu [a,b,c,*], Hang Xiao [a], Bo Fu [a,b,c], He Liu [a,b,c,*]

[a] School of Environment and Civil Engineering, Jiangnan University, Wuxi 214122, Jiangsu Province, PR China
[b] Jiangsu Key Laboratory of Anaerobic Biotechnology, Wuxi 214122, Jiangsu Province, PR China
[c] Jiangsu Collaborative Innovation Center of Technology and Material of Water Treatment, Suzhou 215011, PR China

HIGHLIGHTS

- Sawdust conditioning (SC) is feasible in deep-dewatering for sludge incineration.
- SC can decrease sludge moisture content, but finitely accelerate dewatering rate.
- SC can efficiently accelerate sludge cake further dewatering via air drying.
- SC improves the calorific value of sludge cake and makes incineration profitable.

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ABSTRACT

Sludge deep-dewatering could be realized by adding inorganic and chemical conditioners. However, once for the purpose of incineration disposal, the uses of inorganic and chemical conditioners would not only bring about incomplete combustion, equipment corrosion and secondary pollution, but also greatly reduce the heat value of sludge cake. Therefore, the feasibility of sludge deep-dewatering with sawdust conditioning was investigated for incineration disposal without energy input. Firstly, the performance and mechanism of sludge deep-dewatering were studied when conventional conditioners, lime and polyacrylamide, were substituted by sawdust. Then, the superiorities of sawdust conditioning in sludge cake air drying and calorific value increase, as well as economic efficiency were analyzed by comparing with lime conditioning. Results indicate the moisture content of sludge cake can be greatly reduced by sawdust conditioning, which could decrease sludge compressibility, reduce bound water content, improve the porosity of sludge cake, but scarcely influence sludge particle size. Moreover, sawdust conditioning presented high efficiency in further dewatering of sludge cake during natural air drying. The moisture content of sludge cake conditioned with sawdust could decrease to 31.6% after 36 h air drying and its calorific value reached as high as 2239 kcal/kg. By comparing with lime conditioning, sawdust conditioning exhibited slightly higher expense for the conditioner, but much greater profit from energy recovery.

1. Introduction

In recent years, the yield of waste activated sludge (WAS) has increased year by year in wastewater plants (WWTPs) of China, and reached 55 million tons with water content of 80% in 2014 [1]. WAS disposal has became a critical issue. In order to alleviate the pressure of sludge disposal, sludge incineration is still widely adopted in recent years, accounting for 2–3% of total market shares [2]. Thus, optimizing sludge incineration process seems of great practical significance.

Moisture content of sludge cake is the key factor determining the efficiency of sludge incineration, including energy recovery, pollutants emission and combustion completeness [3]. Deep-dewatering can reduce the moisture content of sludge cake to lower than 55%, enabling sludge cake self-sustaining burning [4]. For example, Albertson [5] realized self-sustaining burning of sludge cake and greatly reduced the cost of sludge incineration, in which, the moisture content of sludge cake was reduced to 63–75% by using pulverized coal as the skeleton builder. Moreover, our preliminary studies also showed the organic matter content of WAS is very low in WWTPs of southern China, and moisture

* Corresponding authors at: School of Environment and Civil Engineering, Jiangnan University, Wuxi 214122, Jiangsu Province, PR China.

E-mail addresses: liuhongbo@jiangnan.edu.cn (H. Liu), liuhe@jiangnan.edu.cn (H. Liu).

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content of approximately 50% is the threshold value for sludge cake to incineration without fuel input. In order to obtain deep-dewatering, chemical conditioning together with physical conditioning is widely applied. The former, such as adding ferric chloride, lime, polyacrylamide and so on can speed up sludge dewatering process [5–7]. The latter, such as adding gypsum, lignite, slag, construction waste and so on can reduce the final moisture content of sludge cake [8–11]. However, the import of chemical and inorganic conditioners into sludge cake would seriously lower the efficiency of sludge incineration. For example, chloride may play the role of flame retardant and reduce sludge combustion completeness. Iron ions is strongly corrosive to pipe and incinerator. The addition of lime can reduce the calorific value of the sludge cake.

Therefore, biologic materials is used as skeleton builders to substitute inorganic physical conditioners for sludge deep-dewatering. For example, Wu et al. [12] enhanced sludge dewaterability by rice husk biochar and improved its capacity by modifying with $FeCl_3$. Lin et al. [13] improved sludge dewaterability by adding organic waste solids (wood chips or wheat dregs) to sludge after chemical preconditioning (with ferric chloride or alum). However, most of those researches just focus on simply application of biological skeleton builder on sludge dewatering, which has no obvious superiority. There is little information on the feasibility of sludge deep-dewatering, for the purpose of incineration disposal, by adding biological materials as the sole conditioner. Comparing with other sludge disposal technologies, such as composting, landfill and agricultural utilization, the influence of high moisture content on sludge incineration is much more obvious, which would result in the increases of energy input and secondary pollutants discharge [4]. Thus, the first challenge of this study is to achieve sludge deep-dewatering for incineration disposal by adding sawdust as the conditioner, avoiding the usage of chloride, iron ions and other inorganic matters.

Besides moisture content, calorific value is another key factor influencing the incineration efficiency of sludge cake. In most of the WWTPs of China, the VSS/TSS ratio of residual sludge is as low as 0.4–0.5 [14], and this situation even further deteriorates with the import of chemical and inorganic conditioners. Jader et al. [15] showed that it is possible to use sludge for generation of energy once the material presents a significant biodegradable portion of 65%. Therefore, a large amount supplementary fuel is often needed for sludge incineration [3]. Biologic materials, such as sawdust, rice husk and wheat dregs contains high calorific value, the use of which as the conditioner can greatly improve the heat value of sludge cake. For example, Mayur et al. [16] used biogenic flocculant to substitute PAM for sludge conditioning, improving the sludge calorific value by 13%. Thus, the second challenge of this study is to realize self-sustaining incineration of sludge cake without fuel input.

In this paper, the performance of sawdust in sludge deep-dewatering, including improving dewatering rate and reducing the moisture content of sludge cake, was investigated by comparing with lime and polyacrylamide. Sludge compressibility, particle size and SEM photograph were observed to analyze the mechanisms. The air drying efficiency and calorific value of sludge cake were studied to evaluate the feasibility of sawdust as the conditioner for sludge incineration disposal without energy input.

2. Materials and methods

2.1. Materials

Waste sludge (WS) was taken from the sludge storage tank of a local WWTP in Wuxi city, China. An intermittent cycle extended aeration/membrane bioreactor process is used in this WWTP. The fresh WS had pH of 6.5–7.5, TSS concentration of 18.0–19.0 g/L, VSS concentration of 9.0–9.5 g/L, SRF of 0.8–0.85 $\times 10^{13}$ m/kg, CST of 92.0–93.0 s, and volume particle diameter of 29.0–30.0 μm. A kind of cationic polyacrylamide (CPAM) with molecular weight of 8×10^6 MW and charge density of 20–30% was purchased from Sinopharm Chemical Reagent Co., Ltd in Shanghai city, China. Sawdust was purchased from a local timber Co., Ltd in Wuxi city, China. The sawdust was sieved by a metal sieve with 1.0 mm aperture before used.

2.2. Sludge conditioning and dewatering

The procedure of sludge conditioning referred to the report of Wu et al. [12], but the operation indexes, including agitation rapid, reaction time and reagents addition, were obtained by bench-scale tests before this study. Waste sludge of approximately 1.0 m^3 was pumped from sludge storage tank into a conditioning tank with volume of 1.5 m^3. Then, sludge conditioning was implemented according to different tests.

- CPAM conditioning: CPAM was added into the conditioning tank at rapid agitation of 300 rpm for 30 s and then at slow agitation of 60 rpm for 5 min.
- Sawdust (or lime) conditioning: Sawdust (or lime) was added into the conditioning tank at rapid agitation of 300 rpm for 3 min and then at medium-speed agitation of 150 rpm for 2 min.
- Composite conditioning with sawdust (or lime) and CPAM: Sawdust (or lime) was added into conditioning tank with the sludge pretreated by CPAM conditioning at slow agitation of 60 rpm for 3 min.

The procedure of sludge dewatering in this experiment referred to the report of Zhang et al. [17]. After conditioning, sludge was pumped into a plate-and-frame filter press by the pneumatic diaphragm pump. The plate-and-frame filter press with filtering area of 5.0 m^2 has three diaphragm plates (800 mm $\times$ 800 mm $\times$ 30 mm depression) and can obtain six sludge cakes at each test. The dewatering procedure comprised of a free filtration phase (0.6 MPa for about 10 min), a feed compression phase (0.6 MPa for about 50 min) and a hydraulic press phase (0.9 MPa for 30 min). A certain amount of sludge cake was sampled for measuring moisture content, compressibility and SEM structure at end of each test.

2.3. Analytical methods of conventional indices

Conventional indices, including pH, VSS, TSS and sludge moisture content, were analyzed according to the standard methods issued by the standard methods [18]. A standard buchner funnel test apparatus with a 9 cm buchner funnel and qualitative filter paper was used for SRF determination [19]. Compressibility coefficient of sludge cakes was measured according to the report of Qi et al. [20]. The microstructure of sludge cakes was characterized with the Hitachi Su1510 scanning electron microscope. Particle sizes of sludge conditioned by different tests were analyzed by BT-2003 laser particle size analyzer. The calorific value of sludge cake was determined according to GB/T 213-2008. The sludge cake samples were dried for 12 h under 105 °C, and then crushed into 2 mm particle size. The heat value of sludge samples (−0.6 g) were determined by employing oxygen bomb type-calorimeter [21].

2.4. DSC analysis for bound water measurement

A differential scanning calorimeter (DSC) coupling with the liquid-nitrogen cooling system was used to determinate the bound water content in sludge. Sludge sample of 5–10 mg was added to the thermal analyzer (Mettler Toledo DSC 30). The temperature was firstly decreased at a rate of 2 °C/min from 25 to −20 °C and then raised to 10 °C at the same rate, during the process of which, the heat absorbed and released by the sample was recorded. The phase transition from water to ice was assumed to correspond to free water. The amount of free water was determined by the area of the heat absorption curve and calculated by Eq. (1). Then, the bound water content was determined by calculating the difference between the total water content (measured by gravimetric method) and the free water [22].

$$FW = K \times A \quad (1)$$

where FW is the quality of the free water in sludge (mg), A is the area of heat absorption curve (mJ) and K is the conversion coefficient (mg/mJ) and calculated by the thermal analysis curves of pure water with known quality.

2.5. Further dewatering of sludge cake via natural air drying

In most of sludge incineration plants, sludge cake will be stacked for a period of time before incineration for further dewatering via natural air drying. Therefore, the further dewatering efficiency of the sludge cake conditioned with sawdust via natural air drying was evaluated by simulating the practical situation of sludge incineration plant. Sludge cake with volume of about 1.0 m^3 was stacked in the covered court of good natural ventilation. Room temperature was about 20 °C and air humidity was 50–70%. Sludge cakes was sampled at certain time intervals, and the moistures of those samples were measured to analyze the dewatering efficiency of sludge cake during the process of natural air drying.

3. Results and discussion

3.1. Performance of sludge deep-dewatering with sawdust conditioning

Both of dewatering rate and the moisture content of sludge cake were used to evaluate the performance of sludge dewatering process. Firstly, as shown in Fig. 1, sludge dewatering rate could be enhanced to some extent by the addition of sawdust, and quickened with the increase of its dosage. However, the efficiency of sawdust is lower than that of CPAM. Composite conditioning with CPAM and sawdust presents obvious synergistic effect, obtaining the largest sludge dewatering rate. After appropriately 80 min, the dewatering processes, including three phases of free filtration, feeding press and hydraulic press reach stable. At the end of those processes, the volumes of the filtrate from raw sludge, sludge conditioned with CPAM of 2.5‰ DS dosage, sludge conditioned with sawdust of 60% DS dosage and sludge compositely conditioned with CPAM (2.5‰ DS) and sawdust (60% DS), were 225 L (2.8 L/min), 369 L (4.6 L/min), 311 L (3.9 L/min) and 467 L (5.8 L/min), respectively. The high dewatering rate of the sludge conditioned by CPAM may attribute to the formation of large particles, the process of which can transform some bound water into free water. But this high dewatering rate can be seriously hindered by the high compressibility of the sludge conditioned with CPAM. Sawdust acting as the skeleton builders can decrease sludge compressibility. Therefore, the sludge under composite conditioning with CPAM and sawdust obtained the highest dewatering rate.

Then, as shown in Fig. 1(d), the moisture content of sludge cake could be greatly reduced by the addition of sawdust, and the more dosage, the lower moisture content. However, the efficiency of CPAM is not as obvious as sawdust. Composite conditioning with CPAM and sawdust obtains similar performance as sawdust conditioning, which further indicates the contribution of CPAM addition is limited on the decrease of moisture content of sludge cake. As shown in Fig. 1(d), the moisture content of sludge cake could be reduced from 85.0% to 66.4% by increasing sawdust dosage from 0% to 60% DS, and the decline trend turned to slow down gradually by further increasing the dosage to 100% DS. Finite decrease of moisture content of sludge cake was also obtained by increasing CPAM dosage, from 85.0% to 76.7% with the dosage of 0‰ to 2.5‰ DS. In the process of composite conditioning, with stable CPAM dosage of 2.5‰ DS, the moisture content of sludge cake decreased from 76.5% to 64.5% as the dosage of sawdust increased from 0% to 60% DS. Therefore, results indicate sludge conditioning with sawdust can efficiently decrease the moisture content of sludge cake, but only finitely accelerate dewatering rate. Composite conditioning with sawdust and CPAM can simultaneously reduce the moisture content of sludge cake and improve sludge dewatering rate, which seems feasible to be adopted in the process of sludge deep-dewatering for incineration disposal.

3.2. Mechanisms of sludge deep-dewatering with sawdust conditioning

3.2.1. Sludge compressibility

Compressibility is usually used to describe the physical structure of sludge, the low compressibility suggesting high porosity and large permeability. The internal water of the sludge cake with low compressibility could flow out under press. So, keeping sludge under low compressibility is the key to realize deep-dewatering.

As shown in Fig. 2, sawdust addition could reduce sludge compressibility, and the more dosage, the lower compressibility. Raw sludge presented high compressibility and compressibility coefficient reached as high as 0.97. By increasing sawdust dosage, compressibility coefficient of sludge was gradually reduced and reached 0.52 under sawdust dosage of 60% DS. Mechanism analysis indicate sawdust addition can improve the overall hardness of sludge. Sawdust of a rough and irregular surface can peel off sludge EPS, puncture cells and make sludge particles uniformly adhere to the sawdust, which may accelerate forming a rigid network skeleton structure in sludge, avoiding the deformation of sludge under high pressure during dewatering process, and finally reduce sludge compressibility.

3.2.2. Sludge floc size

Effect of sawdust addition on sludge particle size is shown in Fig. 3. Results indicate there exist a positive correlation between particle size and dewatering rate of sludge, which is in accordance with the results reported by Richard [23]. The average volume diameter of raw sludge was 29.53 μm and increased to 82.12 μm by the conditioning with CPAM, which is correspondent to the enhanced dewatering rate of the sludge conditioned by CPAM. Conditioning with sawdust seems to have little influence on the particle size of sludge, and the average volume diameter of sludge almost remained the same, from 29.53 μm to 29.34 μm, after the addition of sawdust.

However, particle size is not the only factor determining sludge dewatering rate [24]. As shown in Fig. 3, the average volume diameter of raw sludge increased to 76.27 μm by the composite conditioning with CPAM and sawdust, which is smaller than that of the sludge conditioned by CPAM. But as shown in Fig. 1, the sludge compositely conditioned with CPAM and sawdust had much larger dewatering rate than that of the sludge conditioned with CPAM.

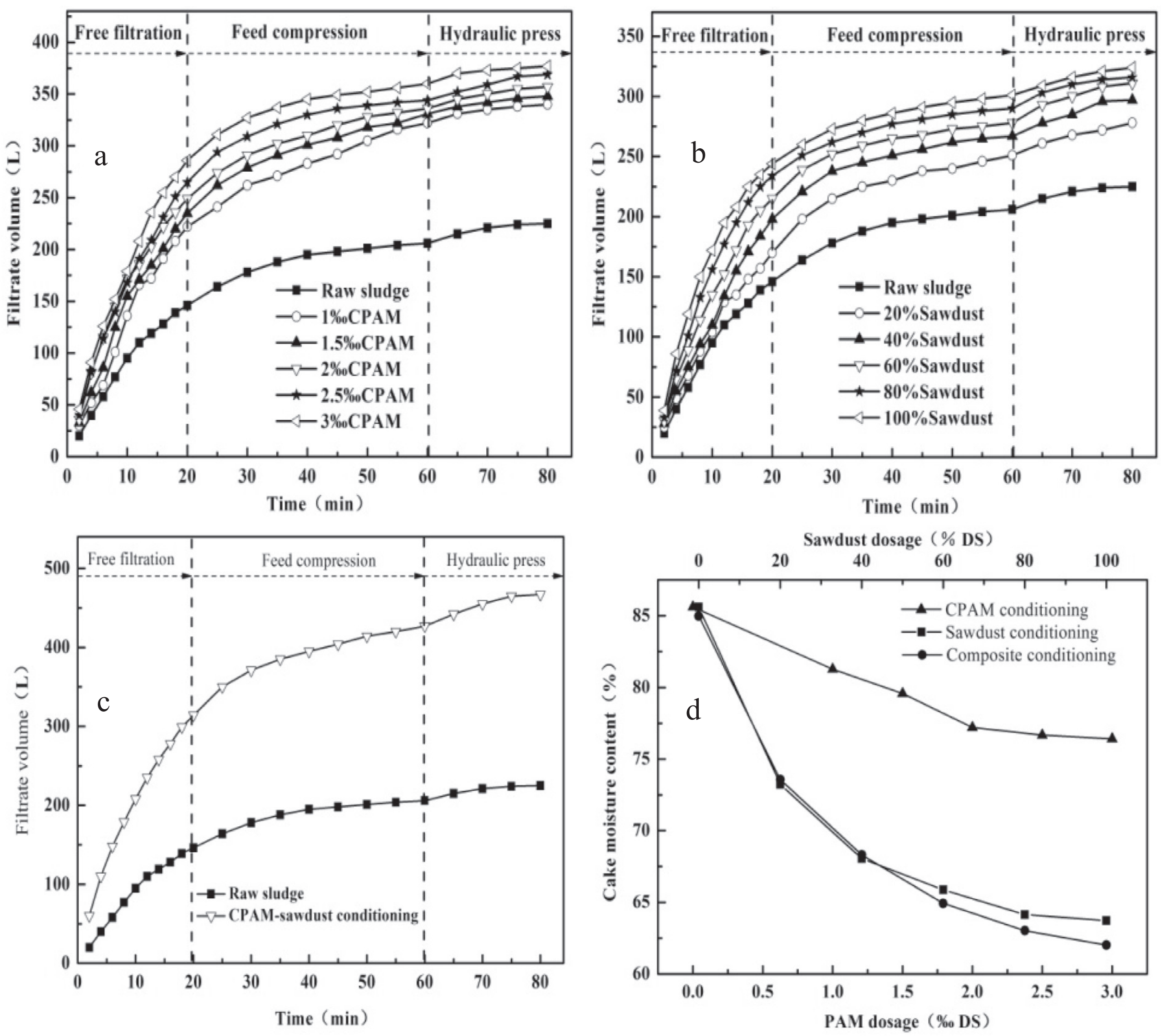

Fig. 1. Dewatering rates and moisture content of the sludge cake conditioned by different methods. (a), (b) and (c) Are the dewatering rates of the sludge conditioned with CPAM, sawdust and CPAM-sawdust, respectively, and (d) is the cake moisture content.

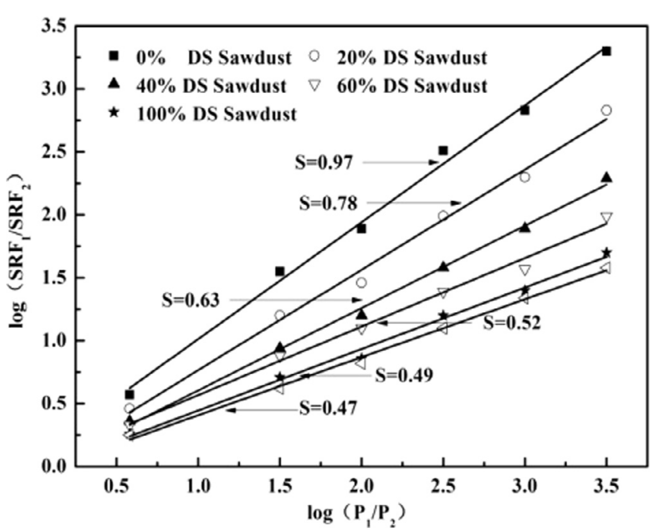

Fig. 2. Effect of sawdust dosage on sludge compressibility.

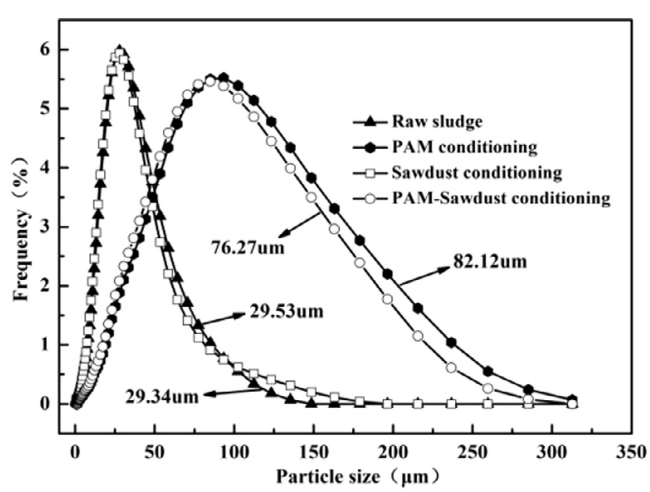

Fig. 3. Effect of sawdust dosage on sludge particle size.

Therefore, results indicates that although sawdust addition could not improve the dewatering rate of sludge via increasing its particle size, the channels between the sludge particles could be widened and a loose structure would be formed by the addition of sawdust.

3.2.3. Bound water content

Fig. 4(a) illustrates the DSC thermograms of sludge samples with different sawdust dosages. K in Eq. (1) was calculated to be 0.00299 mg/mJ in this study from the thermograms of pure water. When heating from −20 to 10 °C at the rate of 2 °C/min, the heat absorption occurred in the range of −2.5 to 7.5 °C, which is narrower than that reported by Hao Zhang [17], probably due to the difference of heating rates. All of the sludge cake samples had similar thermograms, except that the starting time and the region area of the curves, which should be attributed to the changes of sludge particle sizes and bound water contents.

As shown in Fig. 4(b), the bound water contents of sludge cakes decreased with the increase of sawdust dosage and finally stabled at about 1.17 g/g DS with sawdust dosage of 80% DS. The efficiency of sawdust is obviously lower than those of lime and ferric ion [25], probably due to the reduce of osmotic pressure outside of sludge cell because of the addition of ionic-state conditioner. However, approximately 50% of the bound water originally retained in the EPS structure could be released and converted into free water by the addition of sawdust, which is also conducive to improve the dewaterability of sludge.

3.2.4. SEM observations

The microstructure of sludge cakes was tested by ESEM. As shown in Fig. 5. the surface of raw sludge cake shows typically compact. After conditioned with CPAM, the surface of sludge cake becomes smooth and those pores on the surface completely closes, which will prevent the inner layer water discharging and result in high moisture content of the sludge cake. However, large cracks and pores were found on the surface of sludge cake conditioned with sawdust (60% DS), obtaining a sponge-like structure. After compositely conditioned with PAM and sawdust (Fig. 5(d)), the compact surface of the sludge cake conditioned with PAM (Fig. 5(b)) was broken, irregular-shaped particles uniformly embedded into sludge flocs and a mesh structure with rigid skeleton was built. However, comparing with the sludge cake conditioned with sawdust (Fig. 5(c)), the surface of the sludge cake in Fig. 5(d) presented less porous. Therefore, these images indicate that the sawdust plays a supportive role in the sludge cake, while CPAM increases sludge floc diameter but reduces sludge porosity.

3.3. Further dewatering efficiency of sludge cake via natural air drying

Due to the low content of organic matters in sludge cake with VSS/TSS of less than 0.5, only when the moisture content of the sludge cake is reduced to less than 50%, incineration without external energy input is feasible for sludge disposal. As shown in Fig. 6, the moisture contents both of the sludge cakes conditioned by lime and sawdust kept decreasing during the process of natural air drying, whereas sawdust conditioning prompted a quicker decrease and obtained a much lower moisture content of the sludge cake. For example, after 72 h air drying, the moisture content of the sludge cake conditioned with lime of 40% DS decreased to 44.9% and weight reduced by 33.2%. However, after only 36 h air drying, the moisture content of the sludge cake conditioned with sawdust of 60% DS decreased to 31.6% and weight reduced by 57.8%. The porous and loose structure of the sludge cake conditioned with sawdust may be the main reason to the high efficiency of sludge cake dewatering during air drying process, in which moisture can easily lose by evaporation. Therefore, results indicate comparing with lime conditioning, sawdust conditioning presents much higher efficiency in accelerating sludge cake further dewatering via air drying.

3.4. Calorific value of sludge cake

The revenue of sludge incineration closely related to its calorific value. Generally, in China, sludge with calorific value of about 70 kcal/kg has to expend 22.5 $ per ton for the incineration disposal, sludge of about 1100 kcal/kg is often popular to waste incineration plant and its incineration disposal is free, and sludge of more than 2000 kcal/kg could be sold at the price of 7.5–22.5 $ per ton. As shown in Fig. 7, the calorific values of the dry sludge are higher than 2000 kcal/kg, which indicate all the sludge samples, namely raw sludge, sawdust conditioned sludge and PAM-lime conditioned sludge have the potentiality in incineration disposal for thermal energy recovery. Moreover, the conditioning with sawdust could greatly improves this potentiality while conditioning with lime would reduce the calorific value of dry sludge. However, due to high moisture content, the wet sludge cakes, namely the sludge cakes obtained from sludge dewatering, present low calorific value. The wet

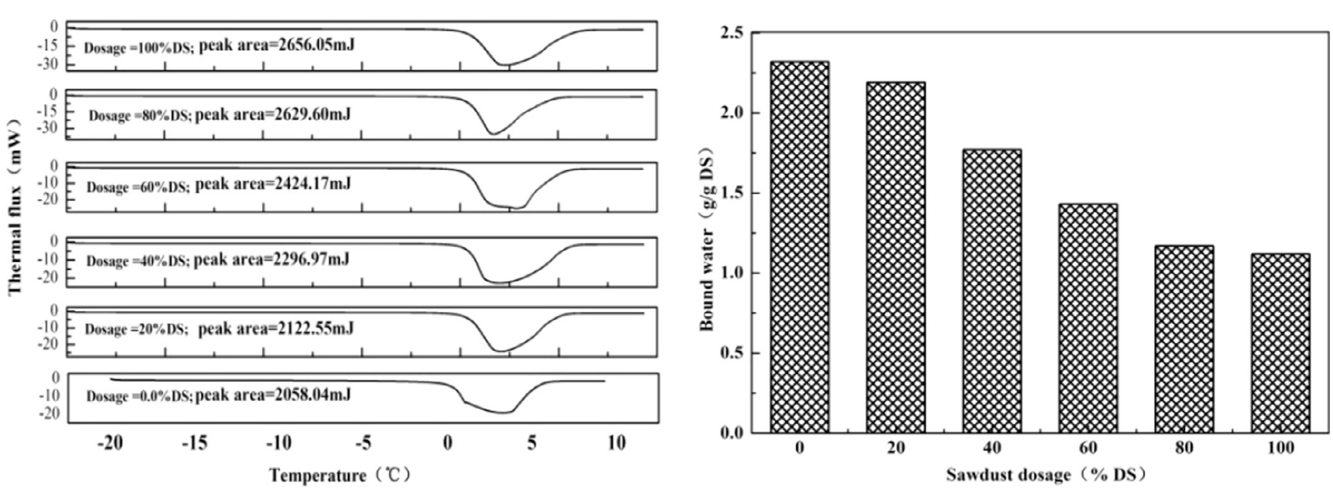

Fig. 4. Effect of sawdust dosage on bound water content, (a) DSC thermograms of sludge, (b) bound water content of sludge.

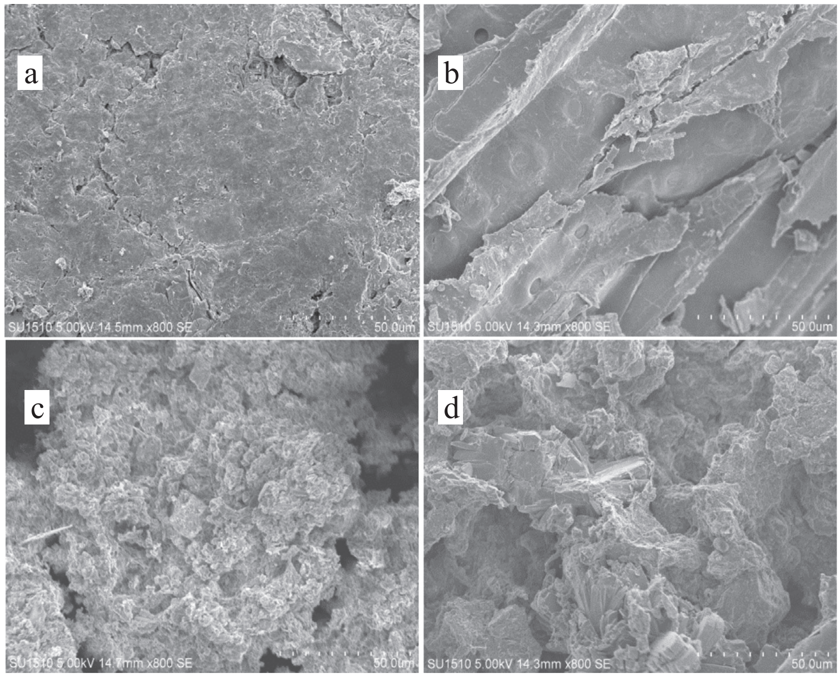

Fig. 5. Microscopic morphology of sludge. (a) Raw sludge, (b) sludge conditioned with PAM, (c) sludge conditioned with sawdust and (d) sludge conditioned with PAM and sawdust.

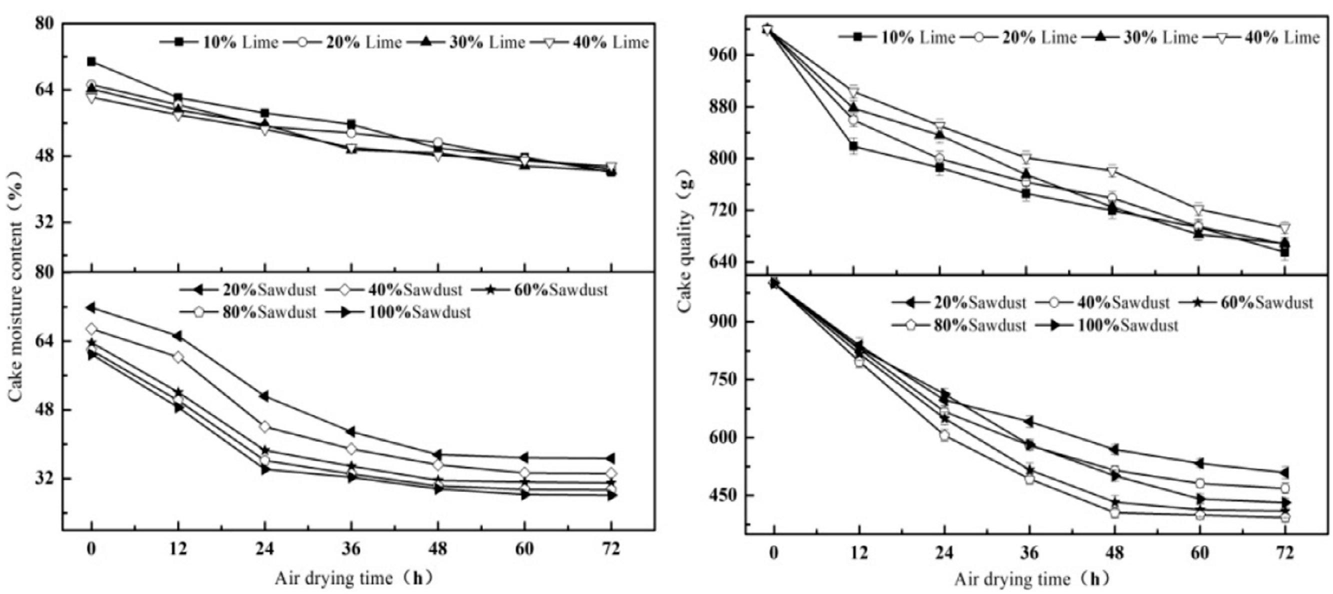

Fig. 6. Effect of air-dry on sludge cake moisture conditioned by different methods.

sludge cake under sawdust conditioning has the highest calorific value of nearly 1000 kcal/kg, and saw sludge cake has the lowest calorific value of approximately 145 kcal/kg. Air drying can reduce the moisture content and greatly improve the calorific value of sludge cake. As shown in Fig. 7, after air drying for 72 h, the sludge cake with sawdust conditioning obtains calorific value of approximately 2239 kcal/kg while both of the raw sludge cake and the sludge cake with PAM-lime conditioning obtain the calorific value of less than 1100 kcal/kg. Therefore, results indicate sludge deep-dewatering with sawdust conditioning not only greatly improves the potentiality of sludge in incineration disposal for energy recovery, but also makes the technology of sludge incineration profitable.

3.5. Economic assessment

The economic feasibility of sludge deep-dewatering with sawdust conditioning was analyzed by comparing with that of lime conditioning. Since incineration disposals of the sludge with sawdust and lime conditionings have similar operation cost, except for conditioner expense and energy recovery profit, which were thus evaluated based on above results. The cost of the conditioner used for per ton sludge with water content of 80% (C) is calculated by Eq. (2), the profits of the energy recovery obtained from per ton sludge with water content of 80% (P) is calculated by Eq. (3), and the calorific value of the sole sludge in the air-dried sludge cake is calculated by Eq. (4).

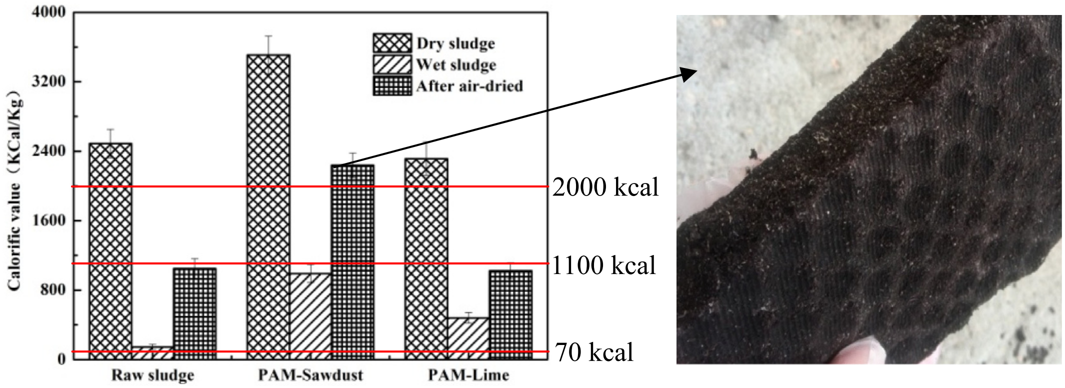

Fig. 7. Calorific values of sludge cakes conditioned by different methods.

$$C = (1 - 80\%) \times d \times e \quad (2)$$

$$P = 1200 \times \frac{[(1 - 80\%) + (1 - 80\%) \times d]}{4000 \times W} \times K_{sludge\ cake} \quad (3)$$

$$K_{sole\ sludge} = \frac{K_{sludge\ cake} - K_{sole\ sawdust} \times 20\%}{80\%} \quad (4)$$

where d is the conditioner dosage (% DS), e is the unit price of the conditioner ($/ton), W is the moisture content of the air-dried sludge cake (%), and $K_{sludge\ cake}$,$K_{sole\ sludge}$ and $K_{sole\ sawdust}$ are the calorific values of the air-dried sludge cake, the sole sludge in sludge cake and the sole sawdust in sludge cake, respectively (kcal/kg).

As shown in Table 1, due to the larger dosage and higher price of sawdust, sawdust conditioning presents slightly higher cost than lime conditioning. However, as shown in Fig. 7, the calorific value of the air-dried sludge cake conditioned with sawdust reaches as high as 2200 kcal/kg, 2 times more than that of lime-conditioning sludge cake. The high efficiency of sawdust-conditioning sludge cake in natural air drying is the main reason. Moreover, as sawdust itself can produce energy [26] and its existing would improve the calorific value of the air-dried sludge cake, sole sawdust was thus adjusted to the same moisture content as air-dried sludge cake (35%) and its calorific value was measured. Therefore, the calorific value of the sole air-dried sludge was obtained by excluding the influence of sawdust. As shown in Table 1, although the VSS/TSS of the sludge is only 0.4–0.5, its calorific value was improved to be as high as 1867 kcal/kg by the help of sawdust conditioning. Finally, to evaluate the economic effects of sawdust conditioning, the profits of the heat recovery obtained from sludge cake incineration were exhibited as the quantity of coal that could release equivalent heat. As shown in Table 1, one ton of sludge (with water content of 80%) after conditioned with sawdust (or lime) and dewatering could release the same heat as that of 0.4 (or 0.11) ton coal. Therefore, results indicate sawdust conditioning is also economically feasible in sludge deep-dewatering for incineration disposal.

Table 1
Cost and energy recovery of sludge conditioning with sawdust and lime, respectively.

Indexes	Conditioning with sawdust	Conditioning with lime
Conditioner dosage (% DS)	40	20
Moisture content of the sludge cake (%)	70	60
Moisture content of the air-dried sludge cake (%)	35	55
Calorific value of the air-dried sludge cake (kcal/kg)	2200	1000
Calorific value of conditioners with same moisture content as that of the air-dried sludge cake (kcal/kg)	2700	–
Calorific value of the air-dried sludge cake excluded the influence of conditioners (kcal/kg)	1867	–
Unit price of the conditioner ($/ton)	97.5	75.0
Cost of the conditioner used for per ton sludge with water content of 80% ($/ton)	7.8	3.0
Profits of the heat recovery obtained from per ton sludge with water content of 80% ($/ton)	79.2 (equivalent of 0.4 ton coal[a])	19.6 (equivalent of 0.11 ton coal)

[a] Industrial coal: calorific value is 4000 kcal/ton and price is 180 $/ton.

4. Conclusions

Sawdust conditioning was confirmed to be technically and economically feasible in sludge deep-dewatering for incineration disposal without energy input. Sawdust conditioning can decrease sludge compressibility coefficient from 0.97 to 0.52, reduce bound water content from 2.32 to 1.17 g/g DS and improve its porosity, but has little influence on sludge particle size, from 29.53 to 29.34 μm, which thus efficiently decreased the moisture content of sludge cake, from 85.0% to 66.4%, but only finitely improved sludge dewatering rate, from 2.8 to 3.9 L/min. Moreover, the moisture content of the sludge cake conditioned with sawdust could further decreased to 31.6% after 72 h air drying, obtaining calorific value as high as 2239 kcal/kg, which makes the sludge incineration profitable. By comparing with lime conditioning, sawdust conditioning for sludge deep-dewatering exhibits slightly higher expense for conditioner, 7.8 $/ton sludge with water content of 80%, but can obtain much greater profit from energy recovery, 79.2 $/ton sludge with water content of 80%.

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