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Wall-sticking characteristics of paper sludge

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ABSTRACT

The production of sludge has been sharply increasing in China. Drying is a good treatment method for its resource utilization, however, the process to deal with sludge inevitably generates wall-sticking phenomenon thus corrodes drying devices and reduces drying efficiency. In this paper, by applying free-falling detection, sludge adhering quantity was derived to represent the wall-sticking characteristics with respect to the influence of moisture, temperature and cathodic heat wall. The results show that paper sludge adhering quantity first rises then reduces according to the increase of moisture and reaches the peak at about 65%. Temperature tends to increase due to the joint impact of overtemperature and microbial protein to decrease the sludge adhering quantity which finally gets to a steady state. However, Sludge adhering quantity can be curtailed to acceptable twenty percent of its origin value resulted from cathodic heat wall which creates a water film isolating sludge and wall.

KEYWORDS

Paper sludge; Microbial protein; Cathodic heat wall; Wall-sticking characteristics.

PREFACE

The production of sludge has been sharply increasing due to more and more sludge treatment plants in China. How to properly deal with the increasing sludge has been a tough problem. After drying, not only is the sludge volume efficaciously reduced, but negative attributes such as bad smell and pathogens are largely eliminated as well[1]. However, during this process sludge often sticks to the equipment surface causing the erosion and energy loss thus reducing the heat transfer efficiency and drying efficiency. Consequently, it is of great importance exploring the relation between sludge drying and wall-sticking phenomenon. Some researchers[2-5] have studied the relationship of wall-sticking characteristics with the viscosity of the sludge microorganisms.

Wang[6] studied sludge adhering quantity through experiments of sludge type, moisture content, drying methods, and drying temperature on the thermal sludge drying process. Yu[7] through the municipal wastewater treatment plant sludge anaerobic organisms investigated sludge extracellular polymeric composition after cathodic heat wall. Mechanical aeration is critical to sewage sludge bio-drying, this study was conducted to investigate the effects of forced air volume on the evaporation of water from a sewage sludge bio-drying pile[8]. Bart Peeters[9] presents a new application of polyaluminiumchloride (PACl) as a conditioner for waste activated sludge prior its dewatering and drying. This paper focuses on the relations between sludge adhering quantity with the moisture content, drying temperature, cathodic heat wall.

MATERIALS AND METHODS

There is not a uniform way to detect sludge adhering quantity while most of the time it is considered to be the mass of remnant after heating the sludge on a plate. But uncertainties exist in this method such as the way and times of scraping sludge out of the plate. In order to improve the precision, free -falling detection is adopted to measure sludge adhering quantity.

The samples are paper sludge which come from a certain papermaking sewage treatment plant in Guangzhou and measurements of sludge adhering quantity are implemented on such sludge with certain temperature and moisture. Several steps are in the process of free-falling: filling a square iron box, side of which is 5.8cm, with fresh sludge to occupy half of the volume, drying the box and then falling it from 30cm high 10 times, detecting the weight of M (total weight of box and sludge) and m(weight of box) and the area S(contacting area of sludge and wall). Sludge adhering quantity is defined as (M-m)/S and its unit is g/cm^2. In the experiment, moisture content is derived by drying sludge till its steady mass at 105℃ and the value is the portion of reduced weight versus total weight.

RESULTS AND ANALYSIS

Influence of moisture content, temperature on sludge adhering quantity

Figure 1- Figure 3 show sludge adhering quantity and moisture content versus time at different drying temperature. With moisture content belows 65%, sludge adhering quantity and moisture content have similar tendency: both tend to decrease in the time scale.

Water which serves as the medium between sludge and wall can increase their contact areas and thus augment sludge adhering quantity. Under drying temperature 110℃, the slopes of both are well consistent while under 130℃and150℃ sludge adhering quantity tends to be larger. Besides, the decrease speed of both becomes faster as the temperature increases because higher temperature accelerates water evaporation resulting in shortage of water near wall.

Figure 4 is the curve of sludge adhering quantity versus moisture content under different drying temperature. It reveals that sludge adhering quantity increases first and then decreases with ascent of moisture content. There are many microorganisms in sludge secreting sticky substance that enhances sludge adhering quantity. But when moisture content exceeds the boundary value 65%, sticky substance is diluted and sludge adhering quantity becomes inverse proportional to moisture content. Increasingly

reducing the moisture will change the nature of microorganism and make them enervated because there is not enough water to lubricate the wall and consequently, sludge adhering quantity proceeds to go down. After the moisture content below 50%, sludge adhering quantity is lower than 0.01g/cm^2 and when it is below 35%, sludge is totally dried out and the value of sludge adhering quantity is zero.

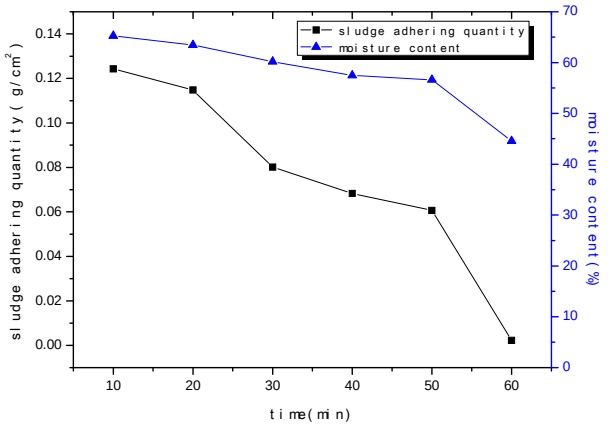


Figure 1 : Curve of sludge adhering quantity and moisture content versus time at drying temperature 110°C

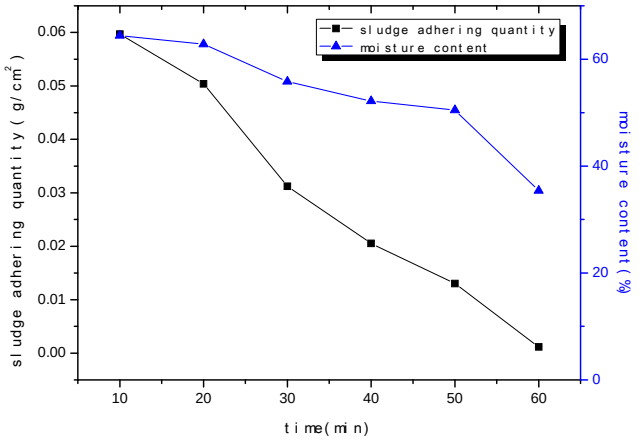


Figure 2 : Curve of Sludge adhering quantity and moisture content versus time at drying temperature 130°C

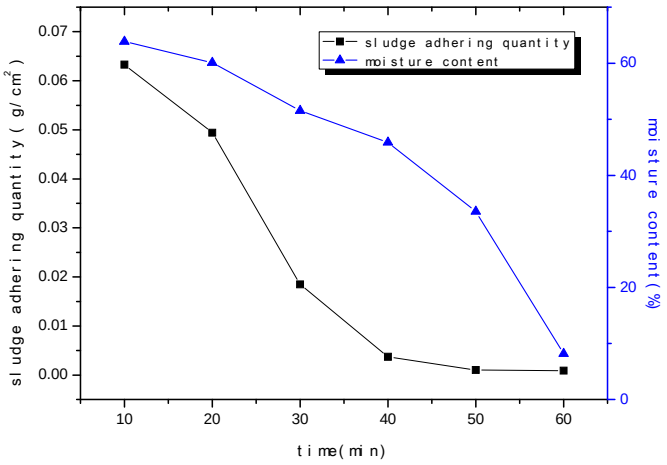


Figure 3 : Curve of Sludge adhering quantity and moisture content versus time at drying temperature 150°C

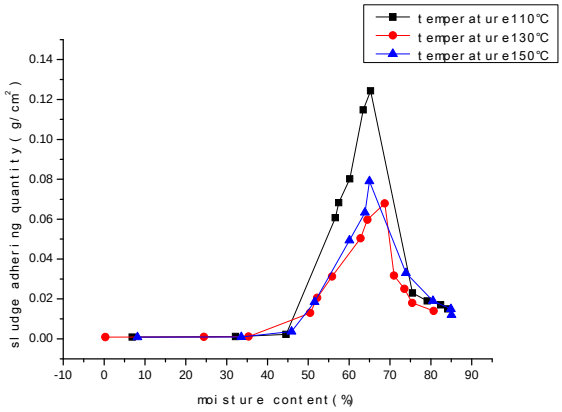


Figure 4 : curve of sludge adhering quantity versus moisture content under different drying temperature

Figure 4 also shows the complicated influence of drying temperature. Sludge adhering quantity is larger at 110℃ than at 130℃ or 150℃ and the latter two stay close which may be resulted from effect of microorganism and overtemperature （higher than the boiling temperature of water) of wall. At high temperature, microorganisms die easily and release protein, polysaccharide and humus. Compared to the condition at 110℃, it experiences a larger overtemperature and quicker evaporation which impair the contact between sludge and wall, in other words isolating water from wall. In a sense, reaching the maximum speed of evaporation and elimination of microorganism stabilize the value of sludge adhering quantity which explain the close value at 130℃ and 150℃.

Fitting of adhering quantity of paper sludge

The fitting of sludge adhering quantity versus moisture content under different drying temperature shows that they are followed by Gauss formula, and the details are shown in TABLE 1.

TABLE 1 : The coefficient value of paper sludge under different temperature

Temperature Coefficient	110°C	130°C	150°C
y_0	0.00661	0.00645	0.00639
x_c	64.66722	64.44428	64.72011
w	14.49212	14.82542	14.13668
A	1.74134	1.05652	1.13134
R^2	0.96446	0.97796	0.93066

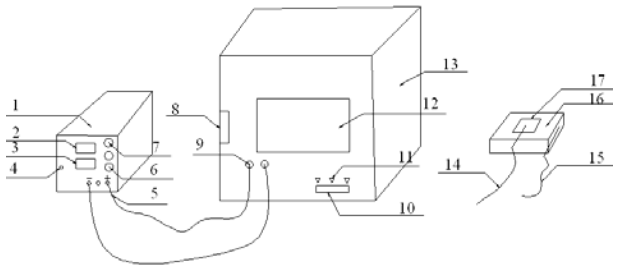
Gauss formula : $y = y_0 + \frac{A}{w\sqrt{\pi/2}} e^{-2\frac{(x-x_c)^2}{w^2}}$

With y—sludge adhering quantity; x—moisture content; y_0, x_c, w—constant; A—correlation coefficient of temperature.

Its values vary with different temperature presented in TABLE 1 and R^2 is coefficient of association. As depicted by TABLE 1, x_c is the moisture content when paper sludge adhering quantity reaches the peak and A is related to drying temperature. The different A shows that sludge adhering quantity is larger at 110℃ than at 130℃ or 150℃ and the latter two stay close.

Influence of cathodic wall on sludge adhering quantity

Figure 5 is the setup of cathodic heat wall, the main three parts respectively : 1- Power, 13- Oven, 16- Experimental tin. Power 1 provided cathode voltage gradient both ends in 14, 15, and oven formed a constant temperature condition for sludge drying, put black sludge into experimental tin 16. we can easy adjust cathode voltage with voltage knob 7 and drying temperature with temperature setting button.



1 – Power; 2- Voltage display; 3 - Current display; 4 - Power switch; 5 - Electric wire; 6 - Current Knob; 7 - Voltage knob; 8 - Oven knob; 9 - Wire perforation; 10 -Temperature display; 11 - Temperature setting button; 12 - Perspective screen; 13 - Oven; 14 - Anode wire; 15 - Cathode wire; 16 - Experimental tin; 17 - Cathodic pad

Figure 5 : The setup of cathodic heat wall

Figure 6 shows the curve of sludge adhering quantity versus voltage gradient after same drying time under 120℃. Cathodic heat wall can effectively reduce the sludge adhering quantity. Generally, voltage gradient is inversed proportional to adhering quantity and when above 10V/cm, sludge adhering quantity is 0.0069g/cm^2. Figure 7 shows a obvious decrease of sludge adhering quantity less than twenty percent of its origin value. The microorganisms in sludge are with negative electrons that in order to be balanced, positive ions are attracted to negative pole removing water in the sludge. As water being accumulated, it isolates sludge and wall significantly reducing sludge adhering quantity. To prove the speculation, detections of moisture content are implemented on various distance from negative pole.

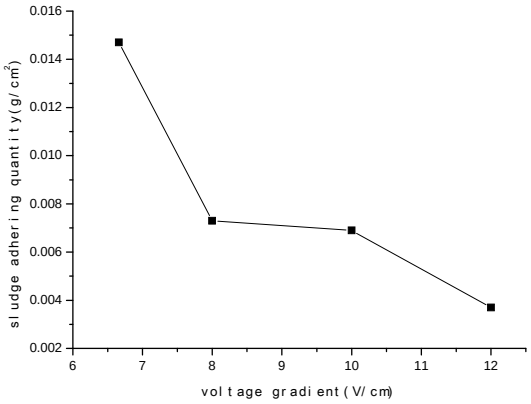


Figure 6 : Curve of sludge adhering quantity versus voltage gradient after same drying time under 120°C

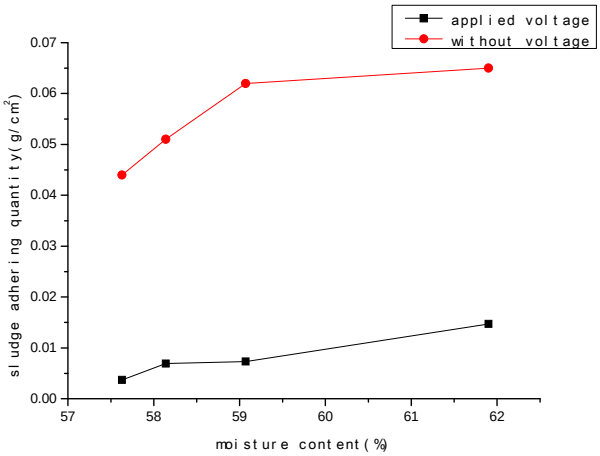


Figure 7 : Curve of sludge adhering quantity versus moisture with and without voltage gradientunder 120°C

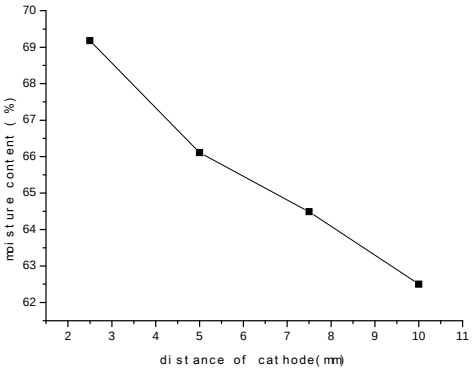


Figure 8 : Curve of moisture distribution after cathodic heat wall

Figure 8 is drawn under a condition of initial moisture content 70%, 12V voltage, and 40 minutes drying time at 120℃. It is presented that the shorter of the distance from anode, the larger amount of water contained. In details, after cathodic heat wall, water is driven by electrode towards metallic plate and formed to be a film that stops direct contact with the plate. Consequently, acting time and sludge adhering quantity are significantly curtailed.

CONCLUSIONS

1) Sludge adhering quantity of papermaking sludge has a maximum value of 65% and it reaches first and then reduces as the moisture content increases.
2) Sludge adhering quantity reduces to a steady stage after an increase of temperature which has a huge influence on overtemperature and microbial protein
3) Twenty percent of the origin value of sludge adhering quantity can be achieved by cathodic heat wall which generates isolation between sludge and plate.

ACKNOWLEDGMENTS

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REFERENCES

[1] Yin Jun, Tan Xuejun. Dispose and resource utilization of sewage sludge treatment. Beijing: Chemical Industry Press., 1-26 **(2005)**.
[2] Isabelle Seyssiecq, Jean-Henry Ferrasse, Nicolas Roche; State-of-the-art: Rheological characterization of wastewater treatment sludge. Biochemical Engineering Journal, **16**, 41–56 **(2003)**.
[3] S.Murat Hocaoglu, G.Insel, E.Ubay Cokgor; Effect of sludge age on simultaneous nitrification and denitrification in membrane bioreactor. Bioresource Technology, **102**, 6665–6672 **(2011)**.
[4] Sun Kejun, Zhang Juntao, Ruan Lin; The mechanism of improving the dehydration and viscosity of municipal activated sludge (MAS) with calcined magnesia. Chemical Engineering Journal, **165**, 95–101 **(2010)**.
[5] Surindra Suthar; Pilot-scale vermireactors for sewage sludge stabilization and metal remediation process: Comparison with small-scale vermireactors. Ecological Engineering, **36**, 703–712 **(2010)**.
[6] Wang Weizhi, Xu Hui, Wu Zhaoqing,etc; Analysis on Influencing Factors and Mechanism of Sludge Adhering Behavior during Thermal Drying. China Water&Waste Water, **25(17)**, 1-4 **(2009)**.
[7] Yu Xiaoyan, Wang Runjuan, Zhi Suli; Influence of Extracellular Polymeric Substance on Electroosmotic Dewatering Behavior of Biological Sludge. China Water&Waste Water, **28(15)**, 1-5 **(2012)**.
[8] Lu Cai; Tong-Bin Chen, Ding Gao; Influence of forced air volume on water evaporation during sewage sludge bio-drying. Water Research, **47**, 4767–4773 **(2013)**.
[9] Bart Peeters, Raf Dewil, Luc Vernimmen; Addition of polyaluminiumchloride (PACl) to waste activated sludge to mitigate the negative effects of its sticky phase in dewatering-drying operations. Water Research, **47**, 3600 – 3609 **(2013)**.