Industrial Engineering and Innovation Management (2023)
Clausius Scientific Press, Canada

DOI: 10.23977/ieim.2023.060201
ISSN 2522-6924 Vol. 6 Num. 2

Research on Municipal Sludge Dewatering and Modified Catalytic Combustion Technology

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Keywords: Low carbon energy, Dehydration, Catalytic oxidation, Modification adjustment, Energization

Abstract: Aiming at the problem that high moisture content of municipal sludge with flocculation structure and high water retention capacity, which makes dewatering and drying difficult, this paper carries out research on dewatering, drying and modified combustion technology of municipal sludge with the goal of resource and energy utilization. The sludge dewatering agent ZC-2T and catalytic oxidation nitrification agent ZC-4R were preferably selected as the main components of modified adjusting agent ZC-1W for industrial application of sludge energy disposal. The compounded modified adjusting agent ZC-1W has a positive contribution to improve the combustion performance of sludge mixed with raw coal, which providing important theoretical support and practical data for the large-scale industrial development and application of municipal sludge. The study will generate significant economic and social significance.

1. Introduction

With the innovation of China's wastewater treatment technology and the rapid growth of the wastewater treatment industry, the production of sludge has increased, thus the harmless elimination of sludge has become a key environmental problem that needs to be solved urgently [1]. 5,476 sewage treatment plants were built and put into operation by the end of 2019, with a sewage treatment capacity of 65.65 billion m^3/a [2]. If the treatment of 10,000 m^3 sewage produces 5-10 tons sludge (80% moisture content), the amount of sludge produced is nearly 60 million t/a[3-4] . According to statistics, China's dry sludge generation was 11.63 million tons in 2020[5]. As the final product of sewage treatment, sludge contains a large number of toxic and harmful substances, such as pathogens, heavy metals and persistent organic substances, etc., and nearly 80% of them were not disposed in a harmless and stable manner, which is likely to cause secondary environmental pollution [6]. Municipal sludge is a municipal sewage treatment product, which contains a large amount of hydrocarbons and organic substances. The most difficult part of the energy utilization is the high moisture content sludge with flocculation structure and high water retention capacity, which is difficult to dewater and dry after aerobic and anaerobic treatment in wastewater treatment plants, the municipal sewage mainly formed by muddy organic substances and microbial clusters[7-8].The practice of existing sludge drying lines shows that: dried and dewatered 1 ton sludge(80% moisture content) to a dried sludge(40% moisture content), the drying coal

consumption was about 1 ton raw coal[9].

In addition to the traditional techniques of concentration, digestion, natural drying, mechanical dewatering and disinfection, the current sludge disposal technologies include atomization and incineration, dry incineration, coal-water slurry blending, industrial coal blending, blending in cement kilns, pyrolysis, supercritical oxidation and adsorbent production, but all these methods have many disadvantages such as high disposal cost or potential secondary pollution[10-11]. The main research of this paper includes the modification study of sludge bacteriophage breaking dewatering and the combustion characteristics of modified sludge, as well as the development and application of sludge modification adjusting agent.

2. Study of the dewatering performance of municipal sludge

The sludge produced by the aerobic and anaerobic biochemical treatment of municipal wastewater after dewatering, which mainly contains organic substances consists of giant microbial clusters and dead disintegrating clusters. The huge amount of microbial clusters and the protein-containing sludge produced by the dead clusters and microfine clay-like inorganic minerals together, which formed a high moisture content flocculation and water retention structure that is extremely difficult to dewater. China has invested heavily in this area for decades, but the effect of drying sludge is not satisfactory. From the operation of several modern sludge drying plants built in China with advanced technology, the energy consumption is high, the minimum moisture content of industrial production drying can only reach about 20%, generally can only be dried to a moisture content of 30-40%, and the diffusion of odor in the drying process is still not as desired by the advanced gas purification equipment.

The comprehensive evaluation index of sludge dewatering performance can usually use the sludge specific resistance (SRF) and the sludge moisture content. The sludge dewatering performance can be determined by the sludge specific resistance value. The poorer the sludge dewatering performance, the higher the SRF value. The lower the sludge moisture content, the better the dewatering performance. The sludge specific resistance and sludge moisture content can be measured to compare the dewatering effect of each sludge dewatering agent, so that the best sludge dewatering agent can be selected.

2.1 Analysis of the sludge dewatering performance

The main organic substances in sludge is microbial colonies, followed by sludged organic substances such as plant stems and leaves, and also contains a large number of pathogenic microorganisms. The effect of four sludge dewatering agents (commercially available polyacrylamide PAM, anhydrous $A1C1_3$, sludge dewatering agent ZC-1T and sludge dewatering agent ZC-2T) on sludge dewatering performance was investigated, by measuring indicators including temperature, moisture content, specific resistance and filter cake moisture content using sludge from a wastewater treatment plant in Chongqing as the test samples. In the study, on the basis of determining the feasibility of the four sludge dewatering agent addition options, the moisture content of the filter cake was used as the basis for evaluation, and then the sludge specific resistance was used as the evaluation index for the dewatering rate of vacuum filtration, so as to preferably select the sludge dewatering agent addition option with a significant reduction in sludge moisture content, and specify the optimal amount of sludge dewatering agent addition.

By summarizing the influence of different sludge dewatering agent dosages on sludge moisture content and the comparative analysis of different sludge dewatering agent dosages on sludge specific resistance, the sludge dewatering agent with the best dewatering effect can be selected more visually and intuitively, and the comparative analysis of the influence of different sludge

dewatering agent dosages on sludge moisture content is shown in Figure 1, and the influence of different sludge dewatering agent dosages on sludge specific resistance is shown in Figure 2.

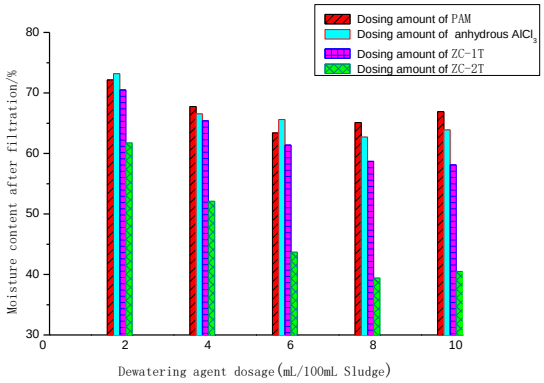

Figure 1: Effect of different sludge dehydrating agent dosage on sludge moisture content

From the comparative analysis of the effect of sludge dewatering agents PAM, anhydrous $AlCl_3$, ZC-1T and ZC-2T on the moisture content of sludge in Figure 1, the result shows that the sludge dewatering agent ZC-2T has a better effect on sludge dewatering than the sludge dewatering agents ZC-1T, PAM and anhydrous $AlCl_3$.

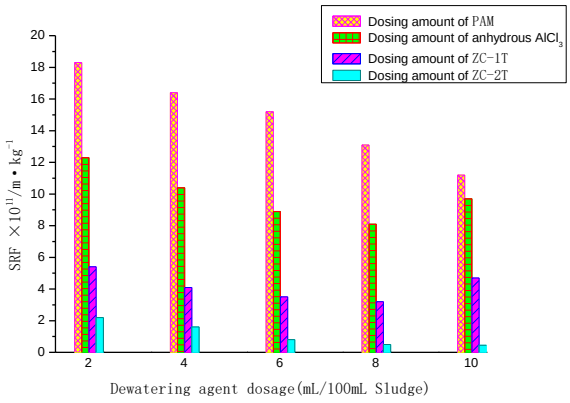

Figure 2: Effect of different sludge dehydrating agent dosage on sludge specific resistance

From the comparative analysis of the effects of sludge dewatering agents PAM, anhydrous $AlCl_3$, ZC-1T and ZC-2T on sludge specific resistance in Figure 2, the result shows that the sludge dewatering agent ZC-2T has a better effect on the reduction of sludge specific resistance than the first three.

2.2 Selection of sludge dewatering agents

The above comparison result shows that: the sludge dewatering agent ZC-2T has a better effect on the improvement of sludge dewatering and the reduction of sludge specific resistance, and the addition amount of sludge dewatering agent ZC-2T is less and will not reduce the calorific value of the sludge,, and when the addition amount of sludge dewatering agent ZC-2T is 6mL/100mL sludge, the dewatering effect of sludge is better and the economic benefit will be significantly improved. Thus sludge dewatering agent ZC-2T is preferably selected as one of the modified adjuster components for sludge energy disposal industrial application.

3. Combustion characteristics of sludge

3.1 Sludge flammability issues

Sludge is difficult to dehydrate high moisture content flocculation and water retention body cause it composed of huge amounts of microbial clusters and protein-containing colloids, which were muddied organic substances and high internal water clusters of organic substances that were difficult to burn and directly affected the combustion performance. At present, the incineration of dried sludge in specialized sludge drying plants still requires the addition of coal or oil injection to combustion furnance, with the problem of high energy consumption for disposal.

The combustion characteristics of municipal sludge were studied using catalytic oxidation nitrification agents acting in conjunction to improve the combustion performance and make it as fuel component for combustion by oxidising and nitrifying sludged organic substances and bacteriophage organic substances.

One of the most important reference indicators in the combustion process of fuels is the ignition point, which is influenced by a number of factors.The higher the volatile content of the fuel, the lower the ignition point.The higher the volatile content of the fuel, the larger the specific surface area of the remaining part of the fuel and the better connection with air, which resulting in a lower ignition point. The ignition point varies depending on the type of fuel. Typically fuels with high fixed carbon and low volatile fraction tend to have higher ignition temperatures.

In this study, four catalytic oxidation nitrification agents were used to modify the sludge with catalytic oxidation nitrification agents ZC-1R, ZC-2R, ZC-3R and ZC-4R. The ignition points of the modified sludge powder were measured to verify and select the most effective catalytic oxidation nitrification agent and the optimum amount of the agent to be added to the sludge.

3.2 The effects of different catalytic oxidation nitrification

By summarizing the comparative analysis of the effect of different catalytic oxidation nitrification agent additions on sludge ignition temperature, the catalytic oxidation nitrification agent with the best catalytic oxidation nitrification effect can be more clearly analyzed, and the comparative analysis of the effect of different catalytic oxidation nitrification agent additions on sludge ignition temperature is shown in Figure 3.

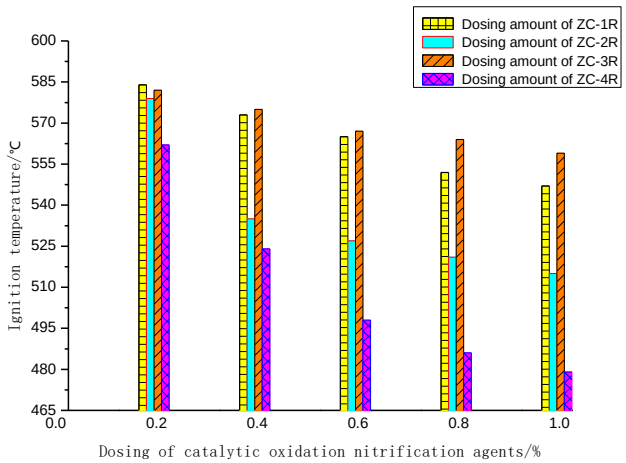

Figure 3: Effect of different catalytic oxidation nitrification agent addition on ignition point

The comparative analysis of the effects of catalytic oxidation nitrification agents ZC-1R, ZC-2R, ZC-3R and ZC-4R on sludge ignition temperature shows that catalytic oxidation nitrification agent ZC-4R has a significant improvement on sludge ignition temperature, which is better than the other three agents.

3.3 Selection of catalytic oxidation nitrification agents

The above analysis shown that: catalytic oxidation nitrification agent ZC-4R has a better improvement effect on sludge ignition point than catalytic oxidation nitrification agent ZC-1R, ZC-2R and ZC-3R; and the dosage of catalytic oxidation nitrification agent ZC-4R is less than other three, the economic efficiency is significantly improved, and the comprehensive economic effect is best when the addition amount of catalytic oxidation nitrification agent ZC-4R is 0.6%. Thus catalytic oxidation nitrification agent ZC-4R was preferably selected as one of the modified adjuster components for sludge energy disposal industrial applications.

4. Development and application of sludge modification and adjustment agents

Based on the results of the study on the dewatering performance of municipal sludge and the combustion characteristics of sludge, a combination of the preferred sludge dewatering agent ZC-2T and the preferred catalytic oxidation nitrification agent ZC-4R was combined to form the sludge modifying and adjusting agent ZC-1W. The ratio of each reagent was based on the optimal addition ratio from the study results, and no physical or chemical reaction occurred between the sludge dewatering agent and the catalytic oxidation nitrification agent.

4.1 Development of application solutions

The addition amount of modifier ZC-1W was 0.2%, 0.4%, 0.6%, 0.8% and 1% of the mass of the dried and ground sludge powder respectively, after thorough mixing, the sludge and raw coal fuel mixture specimens were put into the ignition point tester to determine the ignition point of each sludge and raw coal fuel mixture specimen. The results of the ignition point of the sludge and coal fuel mixture specimens are shown in Figure 4.

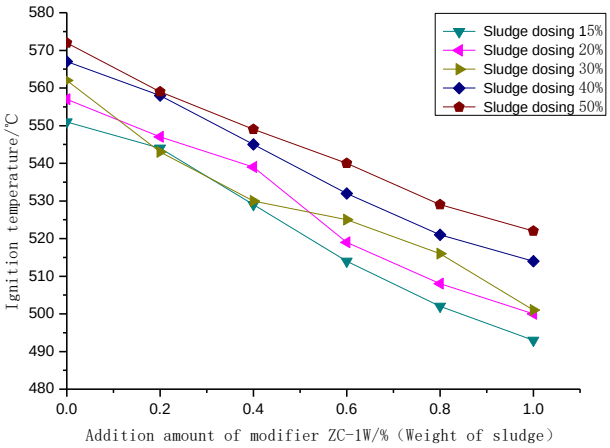

Figure 4: Effect of modifier ZC-1W addition on mixed fuel of sludge and coal ignition point

From the analysis of Figure 4, which can be seen that the addition of modifier ZC-1W has a significant effect on the reduction of the ignition point of sludge mixed with raw coal. When the

modifier ZC-1W was added at 1% of the sludge volume, the lowest ignition point of the 15% blended sludge and raw coal fuel was 495 ℃.

By analyzing the above research process, which can be seen that with the increase of the addition of modifier ZC-1W, there is a obvious effect of reducing the ignition point of sludge and raw coal mixed fuel, which indicates that the modifier ZC-1W has a positive contribution to improving the combustion performance of sludge and raw coal mixed fuel. Thus the amount addition of modifier ZC-1W in the range of 0.1-1% of the sludge volume is adjusted reasonably in the application research test.

5. Conclusion

With the continuous development of China's wastewater treatment industry, the production of sludge has increased dramatically, as there is no suitable technology to break the biofilm of a large number of microorganisms such as high water-bearing clusters in the sludge and precipitate out the water inside the sludge, which resulting in high energy consumption for sludge drying and incineration disposal. The core problem solved by municipal sludge dewatering, drying and modified catalytic combustion technology is the destruction of the biofilm walls of the large number of microorganisms in the sludge such as high water-bearing clusters, so that the water inside the sludge can be easily and quickly dewatered and dried after leaching out. The following conclusions can be drawn from the basic tests of municipal sludge dewatering and drying and modified catalytic combustion:

(1) The improvement effect of sludge dewatering agent ZC-2T on sludge dewatering and the reduction effect on sludge specific resistance are both ideal, and the amount addition of sludge dewatering agent ZC-2T is less and will not reduce the calorific value of sludge, so the sludge dewatering agent ZC-2T is preferably selected as one of the modified adjusting agent components for the industrial application of sludge energy-based disposal.

(2) Catalytic oxidation nitrification agent ZC-4R has a better effect on the sludge ignition point than catalytic oxidation nitrification agents ZC-1R, ZC-2R and ZC-3R, thus catalytic oxidation nitrification agent ZC-4R is preferred as one of the modified adjusting agent components for sludge energy-based disposal industrial applications.

(3) The combination of the preferred sludge dewatering agent ZC-2T and the preferred catalytic oxidation nitrification agent ZC-4R is combined to form the sludge modifier ZC-1W, which has a positive effect on improving the combustion performance of sludge mixed with raw coal.

(4) The success of the technical research on municipal sludge dewatering, drying and modified combustion opens up a new way of sludge utilization, which shows that municipal sludge can be used as a productive resource. The next step can be to try to use sludge modification adjuster to other types of sludge or other organic waste such as petrochemical sludge or coking sludge, etc.

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