

# Analysis on the change factors of organic matter in sludge heat treatment process

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**Abstract:** In the steady development of social economy, the urbanization process is getting faster and faster, the discharge of urban domestic sewage continues to rise. Sludge, as a solid waste produced during sewage treatment, will generally produce 1.5 to 2.0 tons of sludge per 10,000 tons of sewage. As the sludge directly affects the quality and environment of the city and the application efficiency of resources, how to properly dispose of the sludge is the main problem of scientific research. In this paper, based on the understanding of sludge heat treatment process and research status, according to the change of organic components in the analysis, the underlying law is deeply discussed. The final experimental results show that the sludge hydrolysate can violate the nitrification system and provide carbon sources.

**Keywords:** Sludge; Water heat treatment; Organic matter; Reaction mechanism; Organic ingredients

## 1. Introduce

From the perspective of long-term development, problem treatment has the characteristics of pollution-free, stabilization and reduction, a large number of recovery and use of resources and energy contained in the sludge, comprehensive use of sludge on the basis of safety and environmental protection, to avoid adverse impact on the ecological environment. From the perspective of practical research, since the sludge itself contains a large number of organic matter and is relatively viscous, it is impossible to achieve the separation of mud and water, which brings great difficulty for the practical treatment work. Therefore, researchers put forward the use of hydrothermal pretreatment to make the sludge and water separation easier. This technology first appeared in the 1930s. After the sludge was heated, the microbial structure in the activated sludge would continue to disintegrated, the microbial cells would also break down, the organic matter in the cells would be released, the annual decline of the sludge solution would continue, and the binding ability of the viscous organic matter to the water would be lower and lower. When the heating temperature rises to more than 170 degrees Celsius, the microbial cells in the sludge begin to break down, which will release macromolecular organic matter inside the cells, and release free water in the hydrolysis, which leads to the easy separation of sludge particles and water in the activated sludge, further improving the dehydration rate of the activated sludge. Before the 1980s, the water treatment method was mainly to control the water content of sludge; [1-3]However, after the 1980s, this method was used to improve the nitrification performance of sludge anaerobic digestion system. After entering the 1990s, carbon sources will be obtained according to the high-concentration supernatant formed during hydrothermal pretreatment, so as to ensure the orderly conduct of denitrification experiments.

LOP process was proposed by domestic and foreign scholars in the study of hydrothermal treatment process. This process refers to a low pressure oxidation technology, mainly to reduce the water content of the sludge, during the operation temperature will be below 200°C; Zimpro process requires hydrothermal treatment at 250°C, in the process of continuous injection of oxygen, can make 65% of organic matter oxidation treatment; Zimpro et al. used the hot water solution method to further optimize the anaerobic nitrification performance of the sludge. The final experimental results showed that at the temperature of 100°C, the amount of methane in the anaerobic digestion of the sludge after hydrothermal treatment was 14% higher than that of the original sludge. When the sludge is treated at 175°C, the amount of methane produced increases by 60% to 70% compared

to the original sludge. When studying heat treatment experiments of sludge, Chinese researchers used high pressure reaction to conduct hydrolysis research, in which the temperature is controlled between 130 and 210°C and the time is controlled between 15 and 75 minutes. The final experimental results show that the treatment method of thermal hydrolytic depression can help the organic matter in the sludge to degrade as soon as possible, control the viscosity of the sludge itself, and improve the performance of settlement. Some scholars also used autoclaved POTS to achieve thermal pretreatment of sludge waters at 121°C with 1.5 atmospheres. The final experimental results showed that this treatment method could increase the sludge crushing rate to 46.38% and the soluble carbohydrate to 353.2mg/L. Some scholars used alkali-thermal combination to treat the remaining sludge, focusing on the analysis of the influence of different heat treatment temperature, alkali quantity, time and other factors on the composition of physical properties. The final experimental results proved that with the continuous increase of temperature and time, the concentration of soluble SCOD inside the sludge would continue to rise. At 170°C and 30 minutes, The concentration can reach 10,350mg/L and the dissolution rate can reach 43%. This result proves that the flocculation structure of the sludge will be destroyed in the process of hydrothermal treatment, and a large number of dissolved substances will appear, which will change the water distribution of the sludge, so as to improve the dewatering performance of the sludge. On the basis of understanding the principle of sludge water heat treatment, this study used experiments to analyze the change factors of organic matter, in order to provide an effective basis for the follow-up scientific research activities.[4-6]

## 2. Method

### 2.1 Organic Components

Municipal sludge, as a precipitating substance obtained from the practical work of sewage treatment plant, contains a large number of organic components, which is not only the main factor polluting the ecological environment, but also the key to the utilization of sludge resources. Therefore, when scholars study the process of physical hydrothermal treatment, organic matter is the main influencing factor. However, the organic components contained in sludge in different regions are significantly different, as shown in Table 1 below:[7-9]

Table 1 Organic composition analysis

Type of organic composition	Primary settling sludge	Surplus activated sludge	Anaerobic digestion of sludge
Organic content /%	60-90	60-80	30-60
Cellulose content (dry weight) /%	8-15	5-10	8-15
Hemicellulose content (dry weight) /%	2-4	-	-
Lignin content (dry weight) /%	3-7	-	-
Oil and fat content (dry weight) /%	6-35	5-12	5-20
Protein (dry weight) /%	20-30	32-41	15-20
Carbon nitrogen ratio	(9.4-1.0) ;1	(4.6-5.0) ;1	-

According to the types of organic components known in the above table, the specific content inside the sludge is measured and analyzed. There are two common methods:

One refers to the weight method. The sludge inspection Method of our municipal sewage treatment plant is clearly defined. In a porcelain crucible with determined weight, a balance was used to weigh 10 grams of samples, and the samples were put in a water bath in the porcelain crucible to evaporate. After the moisture was dried, the samples were transferred to the oven and

baked at 103°C to 105°C for two hours. Then the samples were taken out and placed in a dryer and cooled for 0.5 hours before being weighed. After repeated operations, the dried samples and porcelain crucible were put in the furnace and burned for 1 hour, the temperature was controlled between 500°C and 600°C, after the power was turned off, the samples were taken out when the temperature in the furnace dropped to 200°C, and then put into the dryer for cooling and weighing again.

Another refers to the potassium dichromate capacity method, which is analyzed according to the relevant requirements in the pollutant discharge standard of the urban sewage treatment plant. The organic carbon in the sample was oxidized with a quantitative solution of potassium dichromate and sulfuric acid under the state of heating. The excess potassium dichromate was titrated with a standard solution of ferrous sulfate. Meanwhile, silica was used as an additive for a blank experiment. According to the amount of oxidant consumed before and after oxidation, the amount of organic carbon is accurately calculated, and then multiplied by the coefficient of 1.724, the content of organic matter is obtained.[10-13]

## 2.2 Composition Change

According to the organic composition changes of sludge treatment in recent years, the specific situation involves the following:

First, aerobic composting. In the aerobic state, aerobic microorganisms are used to promote the stability and humus changes of organic substances. The basic principle is shown in Figure 1 below:

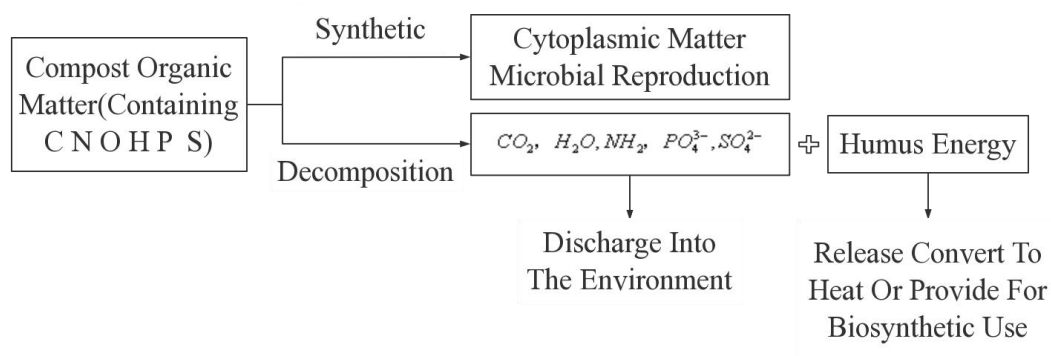


Figure 1 Basic principles of aerobic composting

When studying the change of this composition, Chinese scholars proposed that the organic matter content showed a decreasing trend, while the humus content gradually increased.

Next, anaerobic compost. In the anaerobic state, the use of intersex bacteria and anaerobic bacteria to achieve anaerobic biochemical reaction, effectively decompose the organic matter contained in the sludge, in order to ensure the stability of sludge treatment. The actual operation principle is shown in Figure 2 below:

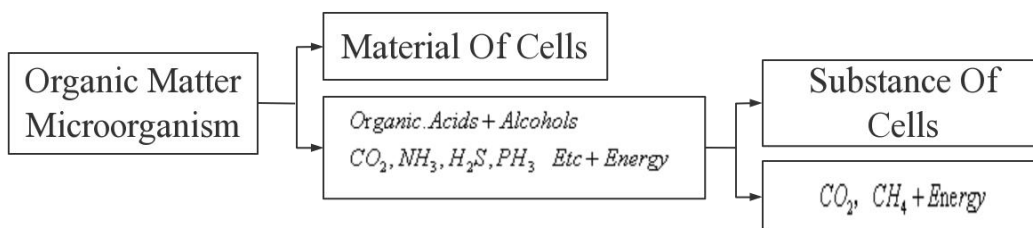


FIG. 2 Basic principles of anaerobic compost

Finally, hydrothermal treatment. As the main method discussed in this paper, hydrothermal treatment is to hydrolyze the viscous organic matter contained in the sludge at a certain temperature and pressure, break the colloidal structure of the sludge, and optimize its own dehydration

performance and anaerobic digestion performance. During this process, the changes of various organic components are shown in Table 2 below:

Table 2 Changes of various organic components

Category of Technology	Main reaction mechanism of organic components	Composition and properties of organic components in products
Hydrolysis by heat	The dissolution of solid organic matter, the hydrolysis reaction of dissolved organic matter, the side reaction is Maillard reaction	A variety of organic compounds, related to the degree of hydrolysis reaction; Polypeptide, dipeptide, amino acid, volatile fatty acid (vfa), ammonia and $CO_2$ ; Polysaccharides, monosaccharides, glycerol, fatty acids, polyammonia, can be used as anaerobic digestion raw materials
Wet oxidation	Oxidation of organic matter in the liquid phase; Organic matter $O_2 \rightarrow CO_2 + H_2O + RCOOH$ Organic $C1 + O_2 \rightarrow C1^{-1} + CO_2 + RCOOH$ Organic $N + O_2 \rightarrow NH_3 + CO_2 + RCOOH$	Solid products are mainly inorganic, liquid products contain short chain organic acids, easy to be degraded by main substances, gas products are $CO_2$ , residual oxygen, $NH_3$ , trace CO and VOC, solid products can be used as landfill covering soil
Partial wet oxidation	Oxidation of easily degradable organic matter such as protein is achieved in the liquid phase	Solid products contain relatively high organic matter content, containing more crude fiber and insoluble humic acid, and protein and other easily degradable organic matter content is very little, solid products have good biological stability, can be used as soil amendments or fertilizer components, liquid, gas products and oxidation method is similar

### 3. Result analysis

After understanding the basic principle of physical hydrothermal treatment process, this paper studies the use of ultraviolet spectrophotometer, acidity meter, spectrophotometer and other instruments and equipment to collect the dehydrated sludge provided by a sludge treatment plant in a region, of which 70 grams of dehydrated sludge, after adding 210 ml of water, the use of polytetrafluoroethylene high-pressure digestion tank hydrolysis at 170 degrees Celsius for 60 minutes. Hydrolysate and sediment were obtained by centrifugation. After the experimental test, it can be found that the change factors of organic matter involve the following points:

First, water content. The residual sludge contains protozoa, metazoa, fungi, bacteria and other contents, and the mixed sludge also contains crude fiber, granular protein and other contents. In the state of heating, microbial floc disintegration occurs, cell wall will be broken by environmental changes, and gradually release more organic matter, resulting in the dissolution of organic matter by water. Under the condition that other conditions do not change, the ratio of the silt and the added water mass is scientifically adjusted. The final result shows that after the sludge is hydrothermal treated, the volume of the hydrolytic solution will continue to increase, the mud particles will be smaller, and the water content will continue to decrease, ensuring that the silt is prone to dehydration. At the same time, thermal hydrolysis also adjusted the distribution structure of water inside the sludge, which could increase the free water in the mechanical separation and optimize the dewatering performance of the sludge.[11-15]

Second, temperature. When studying the influence of temperature on the composition of sludge water heat treatment, it is necessary to ensure that time and solid-liquid ratio remain unchanged, and focus on analyzing the changes of total nitrogen and reduction rate in liquid phase at different

temperatures. The final results show that this factor has great influence on the composition of sludge hydrolysis. With the increasing of temperature, the reduction rate of sludge will gradually increase. When the hydrolysis temperature exceeds 150°C, the reduction rate will continue to decrease, but when the hydrolysis temperature exceeds 170°C, the reduction degree does not change much. In the process of sludge reduction, all kinds of organic matter will be dissolved in water for decomposition, and the organic matter in the suspended solid will be transferred to the liquid phase, resulting in the total nitrogen concentration in the liquid phase will continue to rise.

Thirdly, hydrolysis time. In order to study the effect of time on the composition of hydrolysis degree, it is necessary to ensure that the temperature and solid-liquid ratio do not change. The final experimental results show that the digestibility of sludge will continue to rise when the time of water heat treatment of sludge increases gradually. During the process of sludge dissolution and organic hydrolysis, the concentration of liquid seed eggs will continue to increase. In the first 15 minutes, the sludge dissolution rate is the fastest; After 30 minutes, the dissolution rate of sludge will continue to decrease; After more than 60 minutes, the digestibility of sludge and total nitrogen concentration did not change significantly. Therefore, consider 30 to 60 minutes as the optimal practical time during the experimental analysis.

And finally, the hydrolysates. In the process of sludge water heat treatment, with the continuous dissolution and liquefaction of solid organic matter, fats will be hydrolyzed into glycerol and fatty acids, carbohydrates will be transformed into small molecules of polysaccharides or monosaccharides, proteins will be transformed into peptides, amino acids, and amino acids will be further decomposed into small molecules of organic acids, carbon dioxide and other contents. It can be seen that the sludge after heat treatment can be recycled as small molecular organic compounds. Among them, the sludge organic matter hydrolyzed at 170°C for 60 minutes is shown in Table 3 below:

Table 3 Test results of organic matter under experimental conditions

	Liquid hydrolysate $mg/L$	Mud $mg/Kg$
Organic matter	$1.63 \times 10^4$	$4.66 \times 10^4$
Total nitrogen	1270	6355
Ammonia nitrogen	532	-
$C/N$	12.8	7.33
Protein ammonia	237	3166
Total sugar	39.8	524
Reducing sugar	12.9	60
TP	347	2376

#### 4. Conclusion

In summary, as the focus of current urban construction and development, sludge treatment directly affects the stability of natural ecological environment and the long-term development of social construction. Therefore, scholars have put forward a variety of treatment methods in practice. In this paper, after understanding the basic principles of aerobic compost, anaerobic compost, hydrothermal treatment of these three methods, mainly discussed the organic matter change factors during the sludge hydrothermal treatment, which can not only provide more valuable content for the new era of urban construction and development, but also reduce the impact of sludge on ecological stability in practice. Nowadays, Chinese scholars mainly discuss the heat treatment process of sludge water and make effective solutions according to the main factors affecting the change of organic matter.

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