Research on Aerobic Composting Using Biological Enhanced Dewatered Sludge

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Abstract. Aerobic composting experiment was carried out by using bio-enhanced dewatered sludge as raw material. The experiment was carried out on the aerobic composting of sludge and crop conditioner. Studied on the changes of physical and chemical indexes in the process of composting. The results showed that the temperature of stack rose rapidly in the initial stage, it could be maintained at high temperature stage (>50°C) for 5 days; at the end of composting, the water content of stack decreased to 37.35%, the sludge reduction effect was remarkable; the organic matter of the stack was 40.28%, pH value rose to 7.33; ammonia nitrogen and total phosphorus increased by 548.4% and 60.6%, compared with those before composting, the nutrient index has been improved; sludge physical and chemical indexes, nutrient indexes and pollutant indexes all meet the regulations, the composted sludge could be used for landscaping.

1. Introduction
By the end of March 2016, more than 3,910 sewage treatment plants have been built in towns and cities in China, sewage treatment capacity has reached 167 million m³/d, the sludge was produced in 3,000-4,000 t/year (the rate of water content was 80%). It was expected to 2020, sludge production in China will reach 6,000-9,000 t/year. If the large number of sewage sludge can not get standardized disposal, it was likely to cause secondary pollution to the environment, therefore, in order to avoid the environmental pollution, sludge must be disposed [1]. Biological enhanced dewatered of sludge originated from microbial hydrometallurgy [2], compared with the conventional physical dewatered technology, it had the advantages of high removal rate of heavy metals, the organic matter and calorific value of the sludge almost unchanged, and the operating costs was low. After microorganism dewatered treatment, the water content of sludge cake, which produced by pressure filtration of excess sludge was less than 60%. In this study, we used rice husk and straw as conditioning agent and bio-enhanced dewatered sludge cake for aerobic composting [3], studied on the effect of composting, and appraised the feasibility of applying composted sludge in landscaping.
2. Device and methods

2.1. Aerobic composting device
The aerobic composting device used in this experiment was a cuboid, which made of organic glass. The length and the width of the device was 100cm, the height of the device was 105cm, the effective volume was 0.85 m$^3$, there was an aeration plate with a diameter of 0.5cm at the bottom of 5cm, the lower part of the aeration plate was a 1cm diameter aeration tube, which used to be the ventilation buffer layer. The composting device was showed in Figure 1.

![Figure 1. The device of aerobic sludge composting.](image)

2.2. Analyses
The temperature of 3 points in the center of the stack was analyzed every 24h, and the average temperature was taken as the daily stack temperature; The rate of water content and the organic matter of the stack were analyzed by weight; The pH value of the stack was analyzed by WTW Multi3320 portable water quality analyzer; According to *Methods of Soil Agricultural Chemical Analysis* to analyze total phosphorus, ammonia nitrogen and heavy metals.

3. Results and discussion

3.1. Variation of temperature, water and organic matter
The temperature change of the stack was showed in Figure 2. In the process of sludge composting, microorganisms degraded organic matter in the stack and produced heat. The initial temperature of the stack was 25.5°C, reached the maximum temperature of 57.3°C on the 7th day, and it could keep above 50°C for 5 days. Due to the addition of conditioning agent, the sludge porosity increased, the stack ventilation was sufficient, the organic matter in the reactor was fully degraded by aerobic microorganisms, therefore, the temperature of the stack rose rapidly in the initial stage. With the development of composting, the degradation of organic matter and the activity of microorganisms decreased [4], the temperature of the stack decreased, and it stabilized after 23 days.
The change of water content of aerobic composting sludge was mainly determined by two factors, one is microorganisms carried out metabolism, organic matter was degraded and produced water, the other is continuous forced ventilation and regular artificial tipping, which took away the water from the sludge. The change of water content during composting was showed in Figure 3. The initial water content of sludge was 58.56%, during the whole composting, the water content of sludge showed a downward trend. In the initial stage of composting, the water content of sludge decreased slowly, at this stage, microorganisms degraded organic matter and produced a large amount of water, after 17 days, the water content decreased rapidly, it showed that continuous forced ventilation and tipping were the main factors to affect the decrease of sludge water content. At the end of composting, the sludge water content decreased to 37.35%, and the effect of sludge reduction was remarkable. In the process of composting, organic matter was the material basis for microorganisms survival and reproduction. The organic matter of the stack changed was showed in Figure 3. During the whole composting process, organic matter showed the downward trend, the organic matter of sludge decreased from 46.40% to 40.28%, this was mainly because the normal metabolic activity of microorganisms needed to degrade organic matter.

3.2. Variation of pH, ammonia nitrogen and total phosphorus
The pH value will affect the effect of composting [5], the suitable pH value could provide a good living environment for microorganisms, while also retained the effective ammonia in the stack.

Figure 2. Variation of temperature during the composting.

Figure 3. Variation of rate of water content and organic matter during the composting.

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3 is the change curve of pH value during composting, at the beginning of compost, the pH value of the sludge was 4.11, and rose rapidly. On the 13th day, the pH value reached a maximum of 8.24, this was mainly due to the decomposition of nitrogenous organic compounds, and produced a large amount of NH$_4^+$-N. After 13th days, the pH value of the stack decreased and stabilized. At the end of composting, the pH of the stack was 7.33. Ammonia nitrogen content was an important indicator of composting and reacted the composting progress [6]. NH$_4^+$-N content was showed in Figure 4. In the early stage of composting, due to the degradation of organic nitrogen in the stack, NH$_4^+$-N content increased, reached the highest value of 9.09mg/g on the 6th day. Since then, NH$_4^+$-N has been lost due to aeration, the reduction of degradable organic nitrogen and the lower temperature increased the activity of nitrifying bacteria, NH$_4^+$-N was translated into NO$_3^-$-N by nitrification, these changes led to the decrease of NH$_4^+$-N content. At the end of composting, the NH$_4^+$-N content was 7.20 mg/g, which was 548.4% higher than before composting.

![Figure 4. Variation of pH and ammonia nitrogen during the composting.](image4)

As an important nutrient element, phosphorus has very important research value in the process of sludge composting. As showed in Figure 5, during the whole composting, total phosphorus content increased, the initial total phosphorus content of the stack was 6.168mg/g, because of the high temperature, microbial activity was frequent, organic matter was continuously degraded to organic acids, which contained phosphorus. Total phosphorus rose faster in the initial stage, with the progress of composting, organic matter in the stack decreased gradually. In addition, due to temperature fell, microbial activity declined, stack no longer produced the organic acids, at the end of composting, the total phosphorus content reached 9.906mg/g, increased 60.6% higher than before composting.

![Figure 5. Variation of total phosphorus during the composting.](image5)
3.3. Feasibility evaluation of the application of composted sludge in landscaping

From the composting test, the bio-enhanced dewatered sludge was used as the raw material, aerobic composting was carried out on sludge mixtures with the ratio of sludge to rice husk and straw was 15 to 1, the temperature of the stack could be reached above 50°C on the third day, and could maintain 5d, at the same time, nutrition indexes have been improved. In order to explore whether the composted sludge can be applied to landscaping, according to the Disposal of Sludge from Municipal Wastewater Treatment Plant-Quality of Sludge Used in Gardens or Parks (GB/T 23486-2009) to evaluate the resource utilization of the composted products. As showed in Tables 1 to 3, the physic-chemical index, nutrient index and pollutant index of the composted sludge accorded with the standards, this showed that composted products could be used for landscaping.

### Table 1. Physical and chemical indexes and limit.

| Physic-chemistry index | Compost samples | Acid soil (pH<6.5) | Neutral and alkaline soil (pH≥6.5) |
|------------------------|-----------------|--------------------|-----------------------------------|
| rate of water content/%| 37.5            | <40                |                                    |
| pH                     | 7.34            | 6.5-8.5            | 5.5-7.8                           |

### Table 2. Nutrient indexes and limit.

| Nutrient index | Compost samples | Limit value |
|----------------|-----------------|-------------|
| Organic matter/% | 41.09           | ≥25         |
| Total nitrogen/(mg/kg dry sludge) | 33.9 | - |
| Total phosphorus/(mg/kg dry sludge) | 9.91 | - |
| Total potassium/(mg/kg dry sludge) | 21.3 | - |
| Total nutrient (in terms of N) + Total phosphorus (in terms of P<sub>2</sub>O<sub>5</sub>) + Total potassium (in terms of K<sub>2</sub>O) | 9.8 | ≥3 |

### Table 3. Pollutant indexes and limit.

| Pollutant index | Compost samples | Acid soil (pH<6.5) | Neutral and alkaline soil (pH≥6.5) |
|-----------------|-----------------|--------------------|-----------------------------------|
| Pb and its compounds/(mg/kg dry sludge) | 0.14            | <5                 | <20                               |
| Cd and its compounds/(mg/kg dry sludge) | 4.11            | <5                 | <15                               |
| Total Hg/(mg/kg dry sludge) | 16.8            | <300               | <1,000                            |
| As and its compounds/(mg/kg dry sludge) | 16              | <75                | <75                               |
| Cr and its compounds/(mg/kg dry sludge) | 34              | <600               | <1,000                            |
| Cu and its compounds/(mg/kg dry sludge) | 52.1            | <800               | <1,500                            |
| B and its compounds/(mg/kg dry sludge) | 42.2            | <150               | <150                              |
| Zn and its compounds/(mg/kg dry sludge) | 177             | <2,000             | <4,000                            |
| Fe/(mg/kg dry sludge) | 42.2            | <100               | <200                              |
4. Conclusion
Using bio-enhanced dewatered sludge as raw material, mixed with crop conditioner in a certain proportion for aerobic composting test, the stack could keep above 50°C for 5 days; at the end of composting, the water content of stack decreased to 37.35%, the sludge reduction effect was remarkable; the organic matter of the stack was 40.28%, pH value rose to 7.33; ammonia nitrogen and total phosphorus increased by 548.4% and 60.6%, compared with those before composting, the nutrient index has been improved. The application of the composted products in landscaping was evaluated, physical and chemical indexes, nutrient indexes and pollutant indexes all meet the limits in *Disposal of Sludge from Municipal Wastewater Treatment Plant—Quality of Sludge Used in Gardens or Parks (GB/T 23486-2009)*, the composted products could be used for landscaping.

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