The Application Research on Sludge Lime Drying Process for Municipal Wastewater Treatment Plant

Abstract The technology of sludge lime drying is researched and applied widely in China. It is used as the sludge treatment process in Fangzhuang Wastewater Treatment Plant successfully. The Advantage of Lime Drying Process is that it makes the sludge meet the requirement. The moisture content of sludge can decrease to 40% after sludge drying, then decrease to approximately 5% after 8 day’s storage in open air. The organic material of sludge can decrease from 45.58% to 8.27% after sludge drying. Both coliform and fecal coliform are totally gotten rid of after 5 day’s storage in open air.

Keywords: sludge; lime; drying; cost
With the city development and more serious of environment pollution, the municipal wastewater treatment facilities in China developed very fast. In 2003, the national wastewater treatment ratio was 42.39%, in which approximately 27.4% was treated in municipal wastewater treatment plant. Municipal wastewater treatment ratio has reached 56% according to the data from National Bureau of Statistics of China, 2006.

With the advance of wastewater treatment ratio, a great lot of sludge was produced every day, and the sludge treatment and disposal have become a big problem. In order to meet the requirement of reduction, stabilization, harmless, resource utilization, the technology of sludge treatment and disposal is still in research and development.

The application of sludge lime drying is clean, safe, cheap and profitable. Since 1960, lime is widely used in advanced treatment in wastewater treatment plant.

1. The Situation of Sludge Treatment and Disposal

Sludge drying technology is applied widely abroad. Due to the more strict limit for agricultural, landfill and sea disposal in Late 1980s., the technology of sludge hot drying is applied successfully in European and other Western countries. In early 1980s, there were only a few sludge drying treatment plants in EU, but the number increased to 110 in 1994.

Compared to foreign countries, the sludge treatment and disposal engineering in China developed very late. The higher moisture content make the sludge difficult to transport and may pollute the environment around. Therefore, the environmental policy and technology of sludge disposal is payed more and more attention in recent years.

2. The Introduction of Demonstration Project in Fangzhuang WWTP

2.1. The mechanism of sludge lime drying

Due to the Advantage of Clean, cheap, safe and profitable, the technology of sludge Lime drying is suitable for China national conditions.

The lime additive is mixed with dewatered sludge firstly. Then sludge temperature could rise to 100℃ and the water moisture of sludge will be decreased sharply. At the mean time, organic component reduced and pathogens were killed. After drying the mixture can replace the limestone which is the cement raw materials.

In a word, the technology of sludge lime drying can realize sludge reduction, stabilization, harmlessness, and resource utilization.

The main reaction:
\[
\text{CaO} + \text{H}_2\text{O} = \text{Ca(OH)}_2 + Q
\]

The calculation of system temperature
(1) The calculation of Standard heat of formation
Standard heat of formation of CaO: \( Q = 151.9 \text{ kcal/mol} \)
Standard heat of formation of H\(_2\)O: \( Q = 68.32 \text{ kcal/mol} \)
Standard heat of formation of Ca(OH)\(_2\): \( Q = 235.8 \text{ kcal/mol} \)
\[
Q' = 235.80 - 151.9 - 68.32 = 15.58 \text{ kcal/mol}
\]
\[
= 1.168 \times 103 \text{ kJ/kg}
\]

(2) The calculation of Specific heat capacity of sludge (65%):
Specific heat capacity of sand : \[ c = 0.92 \times 10^3 \text{ J/kg·K} \]

Specific heat capacity of dry soil : \[ c = 0.84 \times 10^3 \text{ J/kg·K} \]

Specific heat capacity of sludge : \[ c = 0.9 \times 10^3 \text{ J/kg·K} \]

Specific heat capacity of water : \[ c = 4.2 \times 10^3 \text{ J/kg·K} \]

Specific heat capacity of sludge (65%) :
\[ c' = 4.2 \times 10^3 \times 0.65 + 0.9 \times 10^3 \times 0.35 = 3.045 \text{ kJ/kg·K} \]

If the original temperature is 25 °C and add 20% lime, the temperature can increase 76.6K and the temperature in the drier can be to 101.6 °C.

2.2. The process of sludge lime drying

Fangzhuang WWTP was completed in the early 90's. The plant undertakes the task of wastewater treatment for a total catchment area of 180 hectares. The capacity of Fangzhuang WWTP is 40,000 m³/d and approximately 10~20m³ (65% moisture content) sludge cake was produced every day. The sludge consists of the primary sedimentation sludge, the residue sludge and the chemical sludge.

The technology of sludge lime drying is used as the sludge treatment process in Fangzhuang WWTP in January 2008. The main process is showed in figure 1.

The system is mainly composed of drying reaction system, additives feeding system, transportation system and gas treatment system. The ratio of lime adding is approximately 20%. The temperature can increase to 100 °C and pH to 11. In order to avoid the secondary pollution, the lime dust and exhaust gas is treated by the washing tower with capacity of 2300 m³/h.
2.3. The effect of sludge lime drying

(1) The effect of Reduction

The moisture content of dewatering sludge is approximately 65%. After adding 20% lime, the temperature can reach to 100 °C in 10 minutes. In order to reflect the moisture content changes during the drying process, the moisture content of reaction process and the storage process is tested.

Test results shows that the sludge moisture content is decreased rapidly from 63.12% to 40.52% in the drum drier. The sludge transportation time from the outlet of drum drier to sludge Storehouse is less than 2 minutes, therefore the sludge moisture content only changes from 40.52% to 38.12% during this process, showed in figure 2.

Test results of sludge moisture content varies with time shows that it can be decreased from 39.44% to 5.11% after 8 day’s storage in the open air, showed in figure 3. The density of the dewatering sludge is about 1.06 kg/m³ and the density of drying sludge after 8 day’s storage is about 2000 kg/m³, volume after lime drying only accounts for 1/3 of that after dewatering, approximately achieve 66% of sludge volume reduction.
1-dewatering sludge; 2-outlet of drum; 3-inlet of transport equipment; 4-middle of transport equipment; 5-outlet of transport equipment

**Figure 2** Moisture content of sludge varies with Process

**Figure 3** Moisture content of sludge varies with time

(2) The effect of stabilization and harmlessness

Because the sludge temperature can rise to 100°C and pH can be to 11, the organic component of the sludge reduced markedly and pathogens were killed. That makes the sludge stable and safe, as showed in table 1.

The calculation shows that just due to lime adding, the organic content can decrease to 29%, and reduce to 8.27% finally because of the organic decomposing. The nitrogen content can reduce to 1.1% just due to lime adding, and reduce to 0.541% finally because of the organic decomposing, as showed in figure 4.
Figure 4 Organic material and TN in sludge

Table 1 Micro-organism in sludge

<table>
<thead>
<tr>
<th></th>
<th>Fecal coliform (number/g)</th>
<th>Coliform (number/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>dewatering sludge</td>
<td>2.31E+07</td>
<td>3.33E+08</td>
</tr>
<tr>
<td>drying sludge</td>
<td>1.77E+05</td>
<td>5.22E+07</td>
</tr>
<tr>
<td>storage 5 days after drying</td>
<td>should not be detected</td>
<td>should not be detected</td>
</tr>
<tr>
<td>storage 8 days after drying</td>
<td>should not be detected</td>
<td>should not be detected</td>
</tr>
</tbody>
</table>

2.4. Cost

The cost of the process is showed in table 2. The total cost of lime drying of Fangzhuang WWTP is 86.7 yuan/t.

Table 2 The drying cost of Fangzhuang WWTP (Capacity: 25t/d, C=65%,)

<table>
<thead>
<tr>
<th></th>
<th>Cost (yuan/t)</th>
<th>Unit price</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>4.8</td>
<td>0.8 yuan/k.W.h</td>
<td>150 k.W.h/day</td>
</tr>
<tr>
<td>Additive salary</td>
<td>70</td>
<td>350 yuan/t</td>
<td>20%</td>
</tr>
<tr>
<td>Maintenance</td>
<td>6.6</td>
<td>2,000,000</td>
<td>Account for 3.0%</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>86.7</td>
<td></td>
</tr>
</tbody>
</table>
3. Conclusions

Sludge stabilization, reduction and harmlessness are achieved on this demonstration project of sludge lime drying in Fangzhuang WWTP. The demonstration study of sludge drying technology provided an economical and effective solution for sludge disposal in WWTP in China consequently. After lime drying, the moisture content of sludge can decrease to 40% after sludge drying, then decrease to 5% after 8 day’s storage in the open air. The organic material of sludge can decrease from 45.58% to 8.27% after sludge drying. Both coliform and fecal coliform are totally gotten rid of after 5 day’s storage in the open air. The total cost of lime drying of Fangzhuang WWTP is 86.7 yuan and is cheaper compared to hot drying.

References