Theoretical basis for dewatering of sewage sludge

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Abstract

Sewage sludge is formed as a by-product of the treatment of raw sewage from domestic households, but may also include industrial and commercial effluent. There is currently substantial interest in generating energy from sewage sludges. Compare to the fossil fuels, the biomass energy has been experiencing a surge in interest in many countries of the world. Water is the main component of sludge. Its amount depend on the sludge sort and the way of stabilization. Therefore a dewatering or drying can be necessary for a further utilization. This work is giving short overview of findings from literature concerning the dewatering and drying of sludge.

Keywords

Sludge characterization, dewatering and drying

Introduction

Industrial and domestic activities produce large quantities of residual sludge. It is estimated that the average production of dehydrated sewage sludge is around 0.2-0.3 kg per inhabitant day. The estimated production of sludge for the year 2005 for the European Union is around 8-10 Mt dry matter per year. [2].

The sludge composition can vary considerably depending on the main source of sewage. Where industrial sewage systems contribute to the domestic waste loadings, significantly concentration of heavy metals such as lead, zinc and cooper, or high levels of soluble organic matter may result. [8]

According to the requirements of EU Council Directive concerning urban wastewater treatment (91/271/EEC), the multiplication of wastewater treatment plants across Europe lead to a drastic increase of the production of sludge. Because of the future ban on the landfilling of organic wastes, two major issues will remain for sludge disposal after mechanical dewatering: incineration and landspraying. In both cases, the drying of sludges after dewatering is an essential preliminary treatment. Drying can reduce the water content below 5%, which offers several advantages. First of all, the reduction of mass and volume leads to cost reduction in transport, handling and storage and to an increase of concentration of the fertilizer matter. Moreover, the dried sludge is stabilized and is free of pathogen germes due to the high temperature treatment. Finally, the removal of water increases the lower calorific potential.

There is currently substantial interest in generating energy from sewage sludges. Compare to the fossil fuels, the biomass energy has been experiencing a surge in interest in many countries of the world. Since its combustion is the reserve of the photosynthesis reaction for tree growth, biomass is regarded as a “CO$_2$-neutral” fuel. Compare with other fossil fuels, the biomass has a high amount of alkali and trace elements. Furthermore, the large amounts of calcium, phosphorus and even chlorine can found in the sewage sludge. All the above listed elements may cause the severe corrosion and erosion problems in combustion. The biomass including sewage sludge contains a large amount of volatile matter, which might range from 60% to 80% and more.

1 Sludge characterization

Municipal wastewater treatment plant sludges are most readily characterized by their source, such as primary sludge, or waste activated sludge. This stereotyping is useful because often sludges from similar sources exhibit similar characteristics, and these may be fairly predictable. [7]

1.1 Particle size

It has been known for some time that the size of particles will directly affect how well the sludge will dewater. The pioneering work of Karr showed that particles ranging from 100 to 1 $\mu$m seem to have a direct effect on dewaterability. Thus, if a sludge is composed of a large number of particles in this range, its dewatering will be difficult [7].

1.2 Distribution of water

Another means of characterizing basic sludge properties is by means of how the water is attached to the particles. A number of researchers have developed schemes for classifying such water. One scheme that is useful, shown in Figure 1, divides water in sludge into four categories. Description of water in sludge, is extracted by centrifugal acceleration.
In figure shown four categories are:

1. **Free water** – the water that escapes when the sludge settles and the particles, under their own weight, force the water out. This water is not associated in any way with the particles themselves. In wastewater treatment, free water is removed by gravitational thickening.

2. **Floc water** – the water trapped in the flocs, removed when the flocs are squeezed so that they expel the water trapped in the lattice structure. Floc water is removed by mechanical dewatering.

3. **Capillary water** – the water which is attached to the particle lattice by capillary force. This water will not be removed by mechanical means unless extreme pressures are used.

4. **Particle water** – the water chemically attached to the particle, removed only by chemical or thermal means, and only if the particle is altered.

1.3 Composition of sewage sludge

In literature is found the composition of sewage sludge which is shown in Table 1.

<table>
<thead>
<tr>
<th>Property</th>
<th>Index</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorific value</td>
<td>MJ/kg</td>
<td>21,3</td>
</tr>
<tr>
<td>(dry, ash free)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ash Content</td>
<td>%</td>
<td>37,0</td>
</tr>
</tbody>
</table>

**Composition of combustible fraction (dry, ash free)**

<table>
<thead>
<tr>
<th>Property</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>53,0</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>7,7</td>
</tr>
<tr>
<td>Oxygen</td>
<td>33,5</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>5,0</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0,8</td>
</tr>
</tbody>
</table>
Therefore, selection must depend on the sludge characteristics and volume, the type of disposal the ultimate usage, the location of disposal site, and the cost. Russe (1966) discussed the process of mechanical sewage-sludge filtration in depth, and concluded that the choice of a specific filtration system would depend greatly on the required degree of dewatering and the cost-effectiveness. Gregorio and Gerald (1976) evaluated vacuum filtration and single-stage centrifugation and concluded that vacuum filtration of alum-primary sludge is less costly than centrifugal dewatering. Furthermore, vacuum filtration of lime-primary sludge without lime recovery was found to be the most economical means for dewatering sludge produced by physical-chemical treatments. [1]

Mechanical filtration could increase the solids content of the sludge to between 20 and 35%, depending on the nature of the sludge. [1]

The mechanical dewatering by pressure filters or centrifuges is not always sufficient to satisfy new environmental regulations and thermal drying step is often needed.

3 Sludge drying

Sludge drying procedures are based particularly on contact-, convection or radiation procedures.

Heat drying is a widespread operation, e.g. in textile industries, agro-industries and ceramic processing. This operation is also increasingly used in wastewater treatment plants in order to reduce the mass and the volume of sludges produced in these plants. [4]

Drying by convective heat supply is a process used in order to eliminate water from a solid material by evaporation. The quality of this separation depends mainly on two parameters:

- drying agent operating conditions (temperature, relative humidity, velocity);
- nature and texture of the material.

Drying behavior is well known and has been reported in the literature for other materials. [5]

The usual way to characterize the drying behavior is to estimate the evaporation mass flux density. The evolution of mass flux vs. the moisture content characterizes the drying kinetics. It is generally divided in two main parts:

- a constant rate drying period corresponding to the evaporation of free water at the surface of material, this phase is characterized by the operating drying agent conditions;
- decreasing drying rate period depending both the material transfer properties and operating drying agent conditions.

The convective drying into a moist drying agent atmosphere is widely dependent on the external transfer resistance, then it can be controlled by two thermodynamical parameters: the dry bulb temperature and the humidity, and one aerodynamic parameter: the drying agent velocity. The influence of those three factors on the process is quite difficult to evaluate at first. [6]

For the choosing the suitable drying method one should pay attention to:

- Adherence to security
- Environmental compatibility
- Flexibility of the drying method in relation to variable sludge quantities

Because of their high investment and operating costs, sludge drying is mainly used in large wastewater treatment plants.

4 Tallinn Wastewater Treatment Plant

4.1 Process description

Mechanical treatment of sewage in Tallinn began in 1980. Four years later, in 1984, the second facility concerning chemical treatment was put into service. Biological treatment installations were taken into operation at the end of 1993. At present the biological treatment capacity is 350 000 m³ a day. In 2003 was treated 45,6 mln m³ wastewater. The production of sludge was 28 000 t with average water content 28% in dry solids. During the fermentation process in methane tanks sludge produces biogas that is collected into the gas storage. In process evolve 250 – 300 m³ biogas per day. Fermented sludge is dried with centrifuges and pressed. Gas from fermentation process is used as fuel for air compressors.

In Table 2 is given composition of sewage sludge from Tallinn Wastewater Treatment Plant.

<table>
<thead>
<tr>
<th>Table 2 Composition of sewage sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw sludge</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>H</td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>S</td>
</tr>
<tr>
<td>O</td>
</tr>
<tr>
<td>Dry mater</td>
</tr>
</tbody>
</table>
Conclusion

This work has given brief overview of sewage sludge characterization – particle size, distribution of water and composition. For comparing the data which are found from literature are shown composition of combustible fraction sewage sludge from Tallinn Wastewater Treatment Plant. Also are introduced the basis dewatering and drying of sewage sludge. Future work is currently to make laboratory analysis for assigning calorific value of sludge from Paljassaare treatment plant.

References

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