SLUDGE

The efficiency of the process also depends on the drying technology, e.g. conductive or solar. The proper design of an efficient dryer for sludge is therefore far from obvious.

What is sludge?
The largest part of sewage sludge is formed by the excess of biomass generated through the assimilation of biodegradable materials by microorganisms during the biological treatment. Treating the wastewater of one population equivalent (PE), will produce between 15 and 20 kg of sludge per year, expressed as dry matter. These solids and biosolids are in the form of a liquid or semi-solid liquid, which contains 0.25 – 12 % solids by weight. According to regulations, the sludge is a waste product that first has to be treated before it can be re-used or disposed of.

What can be done with it?
The selection of the optimal sludge management strategy should take into account available technologies, legislation, economy, culture and social structure of the society. The main ways of valorization are shown in Fig. 2. Agriculture and composting allow recovery of the available nutrients for reuse. Incineration refers to the various ways of recovering energy, mainly by using sludge as a fuel or co-fuel in cement kits, coal-fired power plants, municipal waste incinerators and mono-incinerators. Sludge gasification or pyrolysis are still under development or exist only at small scale. The part related to landfilling is continuously shrinking in the European Union according to the European Landfill Directive, which stipulates that material with an organic content greater than 5 % must no longer be disposed to landfill. Other methods of sludge treatment and disposal are wet oxidation, storage and dumping at sea, this latter being now prohibited in Europe.

HOW TO GO ABOUT IT?
In WWTPs the first series of treatment consists of reducing the water content of the sludge by thickening, conditioning and mechanical dewatering. This results in water contents of 18-35 % DS, depending on the technology. Fig. 1 shows a typical example of dewatered sludge. The use of a drying step is considered essential after mechanical dewatering, prior to agricultural or energy valorization. Conventional combustion technologies require a minimum lower heating value of 6-10 GJ/t to compensate thermal losses and incomplete combustion. This minimum dictates at least partially drying of the sludge. Sludge drying is also of interest for countries still promoting the use of sludge in agriculture as drying produces pellets which are easy to store, handle and transport, contrary to pasty dewatered sludge. The product is also stabilized due the low water activity and will not produce bad odors in the field. Destruction of pathogens may even be reached provided the drying temperature and the residence time are sufficient.

Dryers
Most sludge dryers are adaptations of standard dryers, but this adaptation is not straightforward due to the unusual stickiness of the sludge (for indirect dryers) or to the bad odors and risk of explosion (for direct dryers). Nowadays, few companies possess expertise and sufficient experience in the thermal processing of sewage sludge. Dryer design relies too often on empirical considerations, sometimes leading to inefficient systems, unable to handle changes in the properties of the sludge due to any modification within the WWTP. More details about sludge dryer performances can be found elsewhere.

Drying waste water sludge is an expense that must be minimized. About 13 million tons of municipal sludge (expressed as dry matter) are expected to be produced yearly by 2020 in the European Union. This indicates the size of the problem. Wastewater treatment plants (WWTP) remove screenings, grit, scum, solids and biosolids, collectively called sludge. Its properties are affected by many factors such as origin, history of treatment, duration and conditions of storage, etc. Drying this sludge is a difficult process. A look into the main practical problems.

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A COMPLEX MATERIAL TO DRY

Sewage sludge is quite different from the products usually dried in industry. It is a heterogeneous mixture of microorganisms, mineral particles, colloids, organic polymers, cations, fibers, etc., where the composition varies considerably depending on the origin, the season, etc. The maximum drying flux in convective drying can vary by a factor of three, depending on the origin, as can be seen in Fig. 3. These results were obtained in a micro-dryer specifically designed to treat samples of a few grams (Fig. 6).

The rheological properties of sludge also change dramatically with the water content as shown in Table 1. The glue phase is the most documented one, as it can dramatically affect the operation of indirect dryers and can lead to damage to equipment. It also affects the hydrodynamic characteristics of the dryer, the gas to solid contact area, and the local solids hold-up. Other problems in relation to sludge rheology are also encountered, such as pumping and liming.

Simply pumping the sludge with a cavity pump completely upsets the drying behavior resulting in a significant decrease of the drying rate. This can be counteracted by a well-known stabilization step called ‘liming’. Fig. 4 shows that adding lime to the sludge strengthens the texture and can partially counteract the negative effect of pumping. The way the liming step is carried out, either before dewatering (‘pre-liming’) or after dewatering (‘post-liming’), also has an impact as illustrated by Fig. 5. The texturing effect of lime is partially lost during post-liming due to shear stresses produced by the mixing device. The results obtained with a discontinuous pilot scale convective dryer (Fig. 7) confirmed earlier observations by industrial dryer operators. The negative effect of mixing has also been recently observed in a project aiming at producing new biofuels by mixing sludge and sawdust.

In addition to all these variables, specific phenomena may occur due to the organic content of sludge. Aerobic and anaerobic fermentation will change the product during storage, affecting rheology and drying behavior. Also heating causes break down of part of the organic matter, leading to the emission of volatile organic compounds and malodorous substances such as hydrogen sulfide. The non-condensable parts of the vapor have to be treated in bio filters, bio washers, absorption/adsorption facilities or by thermal oxidation while the condensates are sent back to the head of the wastewater treatment plant. These drying characteristics, along with the legal status of waste influence the energy consumption of drying and the dryer design.

CONCLUSIONS

Sludge drying is an essential step before incineration or agricultural use. The whole treatment chain, from sludge production, dewatering, drying to energy recovery must be optimized. Each stage and their coupled effects have to be examined for the design of a sustainable ‘zero energy wastewater treatment plant’. One of the most challenging parts remains the better understanding of the mechanisms governing sludge drying, depending on sludge origin and previous treatment. Any improvement of the knowledge in this area should lead to the conception of dedicated sludge dryers in a more rational way, contributing to success of the whole valorization process.

TABLE 1: APPEARANCE OF SLUDGE AS FUNCTION OF DRY SOLIDS CONTENT

<table>
<thead>
<tr>
<th>% DS</th>
<th>State</th>
<th>10 – 40</th>
<th>40 – 60</th>
<th>60 – 90</th>
<th>&gt; 90</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10</td>
<td>Liquid</td>
<td>Viscous</td>
<td>Glue phase</td>
<td>Granular solid</td>
<td>Dry solid</td>
</tr>
</tbody>
</table>

References


