ADVANTAGES OF THE PNEUMATIC PULSE METHOD FOR DEHYDRATION OF THE SEWAGE SLUDGE

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Abstract
Utilization of the sewage sludge is pressing and crucial environmental and economic challenge. High moisture content of the sludge is one of the main difficulties during the process of the sewage sludge utilization. Experimental drying module has been designed and manufactured to identify and verify effectiveness of the main parameters of the thermal drying of the sewage sludge with application of the pneumatic pulse method. The pulser is supposed to be part of the technological scheme in order to speed up the process of drying and saving energy. The pulser supplies hot air into the drying chamber with time intervals by pulse. In the drying chamber the airflow dislodges water molecules from the material by means of pulses and then they are taken away from the drying chamber. For the convenience of the comparison and evaluation of the executed experiment the following general characteristics were selected: drying rate – \( i \) – kg min\(^{-1}\); power consumption – \( q \) – kWh kg\(^{-1}\). The greatest effect in application of the pneumatic pulse method for dehydration of the sewage sludge was achieved at the angle of incidence equal to nearly 90° of the airflow on the dried sample and higher temperature. The experiment showed that application of the pneumatic pulse method for dehydration of the sewage sludge allows to reduce power consumption and speed up the process of drying. The process of drying can be executed at lower temperatures.

Key words: sewage sludge, pneumatic pulse method, dehydration of the sewage sludge.

Introduction
Utilization of the sewage sludge (SS) is pressing, and it is crucial environmental and economic challenge.

Over the last years more than 50% of the SS produced in Latvia every year remain on the temporary storage grounds near the treatment facilities or in other places (Gemste and Vucāns, 2010). It means that year by year a growing amount of the SS impedes proper work of the treatment facilities and causes aggravation of the environmental situation.

High moisture content of the sludge is one of the main difficulties during the process of the SS utilization. Mechanical methods of removing moisture from the SS allow to reduce its percentage up to 800 g kg\(^{-1}\). However, in the condition of shrinkage of required land plots for the sludge sites application of the mechanical methods of the SS dehydration require increased power consumption. Thermal drying of the SS is not applied in Latvia.

Thermal drying of the SS is executed mainly upon completion of the mechanical dehydration. After the thermal dehydration the SS is clean, free from worms and pathogens bulk material with 100-500 g kg\(^{-1}\) moisture content (Gusarevs, 2012). Upon completion of the thermal drying, the SS can be considered as treated according to the conditions of the Cabinet Council № 362 of May 2, 2006 (Noteikumi par noteikšanu dūņu…, 2006). After the completed dehydration the overall amount and volume of the SS decreases several times, and all this significantly reduces cost of its further utilization. Dehydrated and decontaminated SS may be considered a valuable product and used as either a fertilizer or fuel.

The task of the modern technology on treatment of the SS is to meet the contemporary challenge and transform SS into the environmentally safe product as well as apply the SS valuable components with the significant reduction of the sludge amount as a result of dehydration. Selection of the method applied shall be determined by local conditions and taking into account physical and chemical properties of the sewage sludge, sanitary and epidemiological requirements, and technical and economic calculations (Gusarevs, 2012).

Application of the pulse technology of the dehydration for the utilization of the SS may allow to speed up the process of drying, reduce power consumption and capital investment executing the process of dehydration at lower temperatures and in less hazardous explosive conditions.

Taking into account the novelty of the method, comprehensive studies are required to determine fundamental parameters and factors during the process of design, production and operation of the pulse equipment applied for the dehydration of the SS.

Materials and Methods
It is a well-known fact that thermal drying with application of the pneumatic pulse method significantly speeds up the process of drying bulk materials (Engelbrechts et al., 2003). Mechanically dehydrated SS is a large-capacity homogenous mass. An experimental drying module has been designed.
and manufactured to identify and verify effectiveness of the main parameters of the thermal drying of the SS with application of the pneumatic pulse method. A diagram of the experimental drying module is shown in the Figure 1.

First, the blower delivers the airflow into the heat generator. While passing through the heat generator heated air enters into the pulser. Then, the pulser supplies hot air into the drying chamber with time intervals by pulse. In the drying chamber the airflow dislodges water molecules from the material by means of pulses and they are then taken away from the drying chamber.

The pulser is supposed to be a part of the technological scheme in order to speed up the process of drying and saving energy. The pulser is a hollow cylinder rotating in the close body. The cylinder is divided on the perimeter into four equal sectors. Two opposite sectors are open, and airflow freely comes through them. By rotating pulser sectors open and close, the outgoing air duct in the body from time to time, thereby producing regular breaks in the airflow delivery – pulses (Figure 2). One rotation of the pulser axis produces two pulses.

Parameters of the main parts of the experimental drying module were selected upon determination of the dried sample weight required for the experiment as well as executed preliminary calculations.

**Blower.**
- Type – AAVA 400/P T2.
- Power – $N = 0.55$ kW.
- Amount of airflow – $Q = 200$ m$^3$ h$^{-1}$.
- Pressure – $P = 2650$ Pa.
- Diameter of the outlet of the air channel – $d = 54$ mm.

**Electric heat generator.**
- Power, max. – $N = 2.4$ kW.
- Amount of airflow – $Q = 140$ m$^3$ h$^{-1}$.
- Temperature regimes – $T_1 = 50$ °C, $T_2 = 100$ °C.
- Diameter of the air channel – $D = 160$ mm.

The blower is connected to the heat generator by means of the cone with an angle of 10°. Operating temperature mode was determined as $T_1 = 50$ °C.

Drive of the pulser is executed by means of the geared

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Figure 1. Scheme of the experimental drying module.
1 – a blower; 2 – an electric heat generator; 3 – a pulser; 4 – a drying chamber.

Figure 2. Pulser.
1 – a body; 2- a hollow cylinder.
motor HU 40S 72K4, 122 rotations per minute. The pulser provides 4 pulses per second. The above-mentioned parameters are closely linked, their characteristics were recorded simultaneously during the experiment. Research was carried out in a fixed rectangular drying chamber and in a rotating cylindrical drying chamber.

Structure and dimensions of the rectangular drying chamber (Figure 3) were determined based on the characteristics of the airflow and taking into account access to the dried sample. Angle of incidence of the airflow on the dried sample was defined in 30° and 45°. Subsequently, upon making structural changes,
a supply of the airflow to the drying chamber was delivered from the bottom.

A rotating cylindrical drying chamber (Figure 4) was applied in view of the fact that the drying chamber taken as a prototype of the industrial equipment for drying and burning SS has the same cylindrical shape. Dimensions of the rotating cylindrical drying chamber were determined based on the airflow characteristics.

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<th>Drying rate (i), kg min⁻¹</th>
<th>Energy consumption (q), kWh kg⁻¹</th>
<th>Note</th>
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<td>1.</td>
<td>Rectangular shape. With pulser.</td>
<td>30° to the airflow.</td>
<td>18</td>
<td>0.00125</td>
<td>10.929</td>
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<tr>
<td>2.</td>
<td>Rectangular shape. With pulser.</td>
<td>30° to the airflow.</td>
<td>18</td>
<td>0.00105</td>
<td>13.932</td>
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<td>Rectangular shape. Without pulser.</td>
<td>45° to the airflow.</td>
<td>19</td>
<td>0.00130</td>
<td>11.000</td>
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<td>Rectangular shape. With pulser.</td>
<td>45° to the airflow.</td>
<td>19</td>
<td>0.00159</td>
<td>9.430</td>
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<td>45° to the airflow.</td>
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<td>0.00140</td>
<td>38.000 Indoor + 19 °C</td>
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<td>Rectangular shape. With pulser.</td>
<td>45° to the airflow.</td>
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<td>24.290 Indoor + 24 °C</td>
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<td>Airflow from the bottom</td>
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<td>0.00225</td>
<td>20.000 Indoor + 24 °C</td>
<td></td>
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<td>Rectangular shape. Without pulser.</td>
<td>Airflow from the bottom</td>
<td>50</td>
<td>0.00200</td>
<td>24.793 Indoor + 20 °C</td>
<td></td>
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<td>10.</td>
<td>Rectangular shape. With pulser.</td>
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<td>0.00173</td>
<td>26.974 Indoor + 20 °C</td>
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<td>Rotating cylinder. Without pulser.</td>
<td>Expanded in a cylinder.</td>
<td>50</td>
<td>0.00527</td>
<td>9.159 Indoor + 20 °C</td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>Rotating cylinder. With pulser.</td>
<td>Expanded in a cylinder.</td>
<td>50</td>
<td>0.00540</td>
<td>9.850 Indoor + 20 °C</td>
<td></td>
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<td>13.</td>
<td>Rotating cylinder. Without pulser.</td>
<td>Expanded in a cylinder.</td>
<td>50</td>
<td>0.00542</td>
<td>9.840 Indoor + 16 °C</td>
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<td>0.00565</td>
<td>9.428 Indoor + 16 °C</td>
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<td>15.</td>
<td>Rotating cylinder. Without pulser.</td>
<td>Airflow is directed to the sample.</td>
<td>50</td>
<td>0.00487</td>
<td>10.950 Indoor + 7 °C</td>
<td></td>
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<tr>
<td>16.</td>
<td>Rotating cylinder. With pulser.</td>
<td>Airflow is directed to the sample.</td>
<td>50</td>
<td>0.00648</td>
<td>8.226 Indoor + 7 °C</td>
<td></td>
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</tbody>
</table>
The airflow was delivered in parallel with the dried sample in the cylinder or alternatively was directed towards the dried sample.

For the convenience of the comparison and evaluation of the executed experiment the following general characteristics were selected:

- drying rate – $i$ – kg min$^{-1}$;
- power consumption – $q$ – kWh kg$^{-1}$.

**Results and Discussion**

Main characteristics obtained in the process of the executed experiments are produced in Table 1.

The experiment has shown the following:

- when the angle of incidence of the airflow on the dried sample was 30°, the pneumatic pulse method showed no advantages;
- when the angle of incidence of the airflow on the dried sample was 45°, the drying rate of the pneumatic pulse method increased, and power consumption reduced in relation to the non-pulse delivery of the airflow;
- when temperature of the airflow increased up to 50 °C, the drying rate of the pneumatic pulse method increased, and power consumption reduced in relation to the non-pulse delivery of the airflow;
- when the airflow was supplied from the bottom in this experiment, the pneumatic pulse method showed no advantages;
- when the airflow was delivered to the rotating cylindrical drying chamber parallelly to the dried sample, the pneumatic pulse method showed no significant advantages;
- when the airflow was directed towards the dried sample in the rotating cylindrical drying chamber, the drying rate of the pneumatic pulse method increased, and power consumption reduced in relation to the non-pulse delivery of the airflow.

The greatest effect in application of the pneumatic pulse method for dehydration of the SS was achieved at the angle of incidence equal to nearly 90° of the airflow on the dried sample and higher temperature.

**Conclusions**

The experiment has confirmed the following:

- the pulse airflow does speed up the process of the SS drying;
- when the pneumatic pulse method is applied, the drying rate of the SS tends to speed up at the higher temperature of the airflow;
- an angle of incidence of the airflow equal to nearly 90° is the most effective when the pneumatic pulse method is applied for dehydration of the SS.

The experiment showed that application of the pneumatic pulse method for dehydration of the SS allows to reduce power consumption and speed up the process of drying. The process of drying can be executed at lower temperatures. Taking into account results of the experiment and interest on the part of the process equipment, manufacturers (company VOMM) mutual development of the technologies and equipment is intended at the next stage of the research.

**References**