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1. Introduction

The legal framework conditions at European level, such as the IPPC directive (2008/1/EC), have led to a broad discussion on sustainable solutions for disposal of sewage sludge in the past few years.

Legislation clearly demands that sewage sludge has either to be used to generate energy or has to be recycled.

Recycling of essentially untreated sewage sludge for uses in agriculture has received more and more criticism recently in the media (EHEC). The general expectation is that lawmakers will react by significantly reducing tolerance limits. And this process has already started. For the first time, there are proposals to apply uniform and binding limits for sewage sludge in the planned amendment to the sewage sludge directive (86/278/EC) [1].

The question is, therefore, which means of disposal can provide sustainable solutions for the future? Numerous articles [1 – 5] have already explained that mono-incineration of sewage sludge can meet many of the expectations.

The following provides a rough overview of the utilization methods available and also looks briefly at large-scale incineration plants. The main focus lies on a description of the Ecodry process, which provides technology for decentralized mono-incineration of sewage sludge. Different process variants are presented, including custom-tailored options for sustainable and cost-efficient sewage sludge utilization.

2. Methods of sewage sludge utilization

At a basic level, a distinction is made between disposal (landfill) and utilization of sewage sludge. Mere disposal of sewage sludge by landfill is severely restricted by the Landfill Directive (1999/31/EC) and is now only used in exceptional cases. The following diagram shows the possible methods and the classification of sewage sludge utilization.

Utilization of sewage sludge in the cement or brick-making industry is a combination of energetic use and recycling because it makes use of the energy content of the sewage sludge to generate process heat, but also includes the inorganic components in the respective product, thus utilizing them too. On the other hand, mono-incineration provides an opportunity to recover the potential recyclables contained in the ash (particularly phosphor) by including the appropriate treatment stages. To this extent this method can also be considered a combination of recycling and energetic utilization. In particular, the sustainability aspect in mono-incineration of sewage sludge is coming increasingly to the fore due to the prospect of phosphor recovery [1, 6].
2.1. Recycling

Recycling makes use of the potential recyclables contained in the sewage sludge (e.g. nutrients, minerals) [1].

When utilized in the cement industry, the sewage sludge is usually dried and fed to the rotary kiln. It is an advantage to use fully dried sludge in order to guarantee the very high process temperatures in the rotary kiln and to achieve high efficiency levels [1]. A cement works also has a means of drying the sludge at low cost on site by using various waste heat sources. Examples of this can be found in the plants operated by Schwenk Zement in Germany and Nuh Cimento in Turkey, where the waste heat from the clinker cooler is used in the belt dryer to dry sewage sludge.

The amounts used are limited by the quality of the clinker or the cement. In particular, high phosphor content can be a limiting factor here [1].

When recycled in the brick-making industry, sewage sludge is usually mixed into the wet base product directly after dewatering. Limits here are set by its swelling effect caused by the high organic content [1].

The problem with direct utilization of the dewatering sludge is primarily the odor problem combined with the hygienic risk. Levels in the region of 5 % sewage sludge content in the base product are considered viable quantities [1].

Recycling in agriculture primarily makes use of the phosphates and other nutrients (nitrogen, potassium) contained in the sewage sludge. Furthermore, the organic content also improves the soil. It is often spread on the soil directly after being dewatering. The main disadvantage and the reason why this method is becoming less popular are the problems involved with also spreading harmful substances. The sludge may also contain heavy metals, as well as harmful organic substances (pharmaceuticals, etc.), and even bacteria and viruses that can cause a hygiene problem.

Recycling for agricultural uses is declining sharply throughout Europe. This is illustrated by the bans on spreading sludge for agricultural purposes in individual regions and countries (e.g. Switzerland) and by the greatly reduced tolerance limits [1] implemented throughout Europe compared to directive 86/278/EC.

2.2. Energetic utilization

Sewage sludge is put to energetic use in plants where only sewage sludge is treated (e.g. mono-incineration plants) or in plants where a different primary fuel (e.g. coal, solid waste) is to be replaced (co-incineration plants).

In terms of the physical process, a distinction is made between incineration (excess air: \( l > 1 \)), gasification (air excess: \( l < 1 \)), and pyrolysis (air excess: \( l \geq 0 \)).

Whereas incineration converts the bound thermal energy (organic part of the sewage sludge) in the plant itself into heat and makes use of it, gasification and pyrolysis target external use of this energy (gas engine, export of liquid fuel).

These processes, often also referred to as alternative processes, are still in the development phase in spite of some ambitious pilot plant projects. In many cases the potential advantages of these plant concepts (e.g. greater electrical efficiency) are eliminated again by the rising complexity of the plant and the process, and by the resulting overall costs.
In any event, the majority of the plants for energetic utilization of sewage sludge are incineration plants.

In addition to the possibilities already discussed, co-incineration of sewage sludge is used in combination with recycling (cement, bricks) in coal-fired power stations and waste power plants.

In coal-fired power stations, sewage sludge can be added as fuel in dried (granulate) or dewatered form. In addition to the fuel burning method used (dry-, smelting chamber, fluidized bed, etc.), the co-firing possibilities depend of course on the primary fuel used (hard coal or lignite). The critical and limiting factors in co-incineration of sewage sludge are the corrosion and slagging problems, as well as odor and hygiene aspects. Furthermore, the emission levels for co-incineration have been reduced to the level of mono-incineration in European standard 2000/76/EC by applying mixing-rules.

MSW plants are usually designed with grate or fluidized bed firing. Sewage sludge used for co-incineration can be added either in dry or dewatered form because the range of calorific values that can be covered in the processes used is sufficiently large. Usually the material is added through a separate feed inlet, but as an alternative the sludge can also be mixed into the waste in the storage bunker. As the same emission tolerances as for sewage sludge incineration apply to waste incineration, and waste fractions sometimes have higher contaminant loads, there are no fundamental problems generally in flue gas cleaning. Nevertheless, the changes in the ratio of contaminants, which is altered by mixing in sewage sludge (e.g., high proportion of sulfur to chlorine in the sewage sludge) must be taken into consideration when considering emission tolerances.

3. Mono-incineration of sewage sludge

A trend towards mono-incineration of sewage sludge has emerged over the past few years. The following chapters will now present the basics, the plant options available, and then some concepts for efficient overall plants.

3.1. Basics

3.1.1. Material properties

Sewage sludge consists of granular, flaky, and colloidal solids with water in between. The water, is bounded in different fractions: free water, capillary water, intracellular water and chemically bounded water.

There are several approaches and possibilities for categorizing sewage sludge. Sludge can be split into the following types according to where it arises.

- Primary sludge: Sludge from the primary settling tank,
- Secondary sludge: Sludge (activated sludge) from the biological stage,
- Tertiary sludge: Sludge from a tertiary stage (physical-chemical, e.g. phosphorus precipitation),
- Floating sludge: solids floating on the surface (grease, oil).

In terms of pre-treatment, the sludge can be divided into raw (non-stabilized) sludge and digested sludge (sludge after anaerobic stabilizing).

The following table shows typical values for material parameters that are important in incineration of various sludge types [some taken from 7].
Mono-Incineration of Sewage Sludge

Table 1: Differences raw/digested sludge

<table>
<thead>
<tr>
<th>Sludge type</th>
<th>Organic content % by mass</th>
<th>Calorific value Hu MJ/kg DS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw sludge</td>
<td>60 – 90</td>
<td>13 – 18</td>
</tr>
<tr>
<td>Digested sludge</td>
<td>40 – 60</td>
<td>8 – 13</td>
</tr>
</tbody>
</table>

The table shows that the fuel properties can vary a great deal. If a sludge incineration plant processing sludges from various sources is to operate continuously, the most important sludge parameters must be controlled within certain ranges.

Organic portion

The organic portion in sewage sludge typically comprises the following elements (Table 2).

Here it is important to consider that – unlike biomass or fossil fuels – sewage sludge contains a relative large proportion of nitrogen compounds (urea, protein, etc.). The high proportion of fuel nitrogen thus causes nitrogen oxides to form in spite of optimized temperature control in fuel burning, which is why equipment to remove NOx is needed.

The sulfur content in the sewage sludge can reach fairly high levels, and these levels require particular attention when sizing the flue gas cleaning plant that follows sewage sludge incineration. Due to the high sulfur content, SO2 levels of up to 1,500 mg/Nm3 are possible. As a result, the H2SO4 condensation temperatures of the flue gas can also be correspondingly high. This fact must be considered when sizing the boiler equipment and heat exchangers.

Compared with sulfur, the chlorine content tends to be low. Thus there is a high S/Cl ratio, unlike in most waste incineration plants.

Table 2: Typical elementary analysis of the organic portion

<table>
<thead>
<tr>
<th>Elements</th>
<th>Value %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>50 – 55</td>
</tr>
<tr>
<td>O</td>
<td>31 – 35</td>
</tr>
<tr>
<td>H</td>
<td>5 – 7.5</td>
</tr>
<tr>
<td>N</td>
<td>3 – 7</td>
</tr>
<tr>
<td>S</td>
<td>0.5 – 3</td>
</tr>
<tr>
<td>Cl</td>
<td>&lt; 0.2</td>
</tr>
</tbody>
</table>


Table 3: Typical analysis of ash

<table>
<thead>
<tr>
<th>Elements</th>
<th>Value %</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO2</td>
<td>40</td>
</tr>
<tr>
<td>Al2O3</td>
<td>14 – 1</td>
</tr>
<tr>
<td>CaO</td>
<td>8 – 10</td>
</tr>
<tr>
<td>MgO</td>
<td>2 – 3</td>
</tr>
<tr>
<td>Fe2O3</td>
<td>7 – 10</td>
</tr>
<tr>
<td>P2O5</td>
<td>10 – 15</td>
</tr>
</tbody>
</table>


A characteristic of sewage sludge is its high proportion of ash (30 – 60 %), which accounts for a substantial share of the fuel mass flow compared to other fuels (cf. biomass: approx. 2 %, coal: 5 – 20 %). This circumstance must be taken into account when sizing the ash discharge system.

Sewage sludge ash typically comprises the following main components (Table 3).

An important parameter is the ash softening temperature. This parameter is crucial in estimating the process temperature at which problems may occur in the ash removal area (ash fusion, ash deposits, slagging). In general, we can assume that alkali metals (Na, K) lower the ash softening point and alkaline earth metals (Ca, Mg) increase the ash softening point.
3.1.2. General process conditions

In order for the sub-processes occurring during incineration to proceed, the correct process conditions (temperature, pressure, concentration) and adequate retention time under these conditions must be available.

The retention time required depends primarily on the particle size of the fuel and determines the plant geometry.

These general requirements for incineration, described here in a simplified form, can be implemented in various ways due to the specific properties of the sewage sludge (burnout properties, particle size). Also, the process designs available on the market differ accordingly.

The energy balance is the crucial factor in cost-efficient operation of a sewage sludge incineration plant. In drawing up this balance, all preliminary and subsequent treatment stages, such as drying, heat utilization, and flue gas treatment, must also be considered.

Sewage sludge can be incinerated without auxiliary fuel if sufficient thermal energy can be recovered from oxidative combustion of the organic components to heat the flue gas.

**Figure 2:** Typical configuration of a sewage sludge mono-incineration plant
produced during incineration to the required minimum temperature (> 850 °C). Thus, the organic content (calorific value) and the DS-content of the sludge used in the plant are decisive in achieving this goal.

If dewatered sludge is incinerated directly, the drying process takes place in the combustion chamber. This is why flue gas energy usually has to be recycled to the combustion chamber. The combustion air is pre-heated for this purpose.

When partially or fully dried sludge is incinerated, the energy released is usually sufficient to obtain the required flue gas temperatures. Particularly when incinerating fully dried sludge, it is normally necessary to place an upper limit on the combustion chamber temperatures. This is generally achieved with flue gas recirculation. With targeted recycling of flue gas, the combustion chamber temperature can be reduced without increasing the amount of flue gas and the oxygen content as a result.

Due to flue gas recirculation and supplying of air at several levels (combustion in stages), the formation of nitric oxides can be substantially reduced without also jeopardizing the burnout properties (CO and TOC emissions).

3.1.3. Legal framework conditions in the EU

Incineration of waste (waste includes sewage sludge in this case) is governed by directive 2000/76/EC in the European Union.

This directive deals with both sewage sludge mono-incineration and co-incineration.

In addition to emission levels (see table in section 5.3.1) for gaseous, liquid, and solid emissions (flue gas, sewage, and ash), it also contains requirements relating to operation and measuring methods.

The directive specifies a flue gas temperature of > 850 °C after the final air input for operation of the firing plant, and this temperature must be maintained for at least two seconds. Furthermore, the directive requires the use of initial and auxiliary burners, as well as specifying the approval requirements for feeding waste to the plant.

Of course, there are also other directives and standards from various different sectors in addition to this guideline.

3.2. Incineration Technologies

Sewage sludge mono-incineration plants can be categorized in terms of sludge pre-treatment (dewatered, partially or fully dried), process control or equipment design, and in terms of location (centralized or decentralized plants).

In the following table, the main plant concepts that are relevant on the market are described, mentioning a selection of plant suppliers.

3.3. Large-scale plants: Andritz Bubbling Fluidized Bed (BFB)

Bubbling fluidized bed technology has won recognition in centralized sewage sludge incineration plants. Following its acquisition of Austrian Energy & Environment, Andritz AG can now draw upon decades of experience in this technology.

In sewage sludge incineration plants with a combustion capacity of more than 10 MW\textsubscript{th}, it is generally most economical to make use of the thermal energy generated in a steam boiler plant in order to produce electricity and process steam (e.g. for district heating networks).
Table 4: Overview available sludge incineration technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Sludge</th>
<th>Typical Power MW</th>
<th>Supplier (selection)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bubbling Fluidized Bed Incineration</td>
<td>dewatered, partial dried, or fully dried</td>
<td>1 to 50</td>
<td>Andritz AG, (A): BFB Reactor, Ecofluid AC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Infilco Degremont, (F): Thermlys Reactor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Krüger Veolia, (F): Pyrofluid</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kaloge, (A)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ES+S, (D)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hansol, (KOR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Circulating Fluidized Bed Incineration</td>
<td>dewatered, partial dried, or fully dried</td>
<td>&gt; 50</td>
<td>Andritz AG, (A): Powerfluid Hybrid</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>AE&amp;E Lentjes GmbH, (D)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Grate-fired Furnace</td>
<td>partial dried, or fully dried</td>
<td>1 to 10</td>
<td>Krüger Veolia, (F): Biocon</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Huber AG, (D): sludge2energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Cyclone-Furnace</td>
<td>fully dried</td>
<td>1 to 10</td>
<td>Andritz AG, (A): ECODRY</td>
</tr>
<tr>
<td>Multiple-hearth Incinerator</td>
<td>dewatered</td>
<td>up to 20</td>
<td>Bayer Industry Service, (D)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NESA, (BE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Rotary Kiln</td>
<td>fully dried</td>
<td>1 – 5</td>
<td>Eisenmann, (D): Pyrobustor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>...</td>
</tr>
</tbody>
</table>


Figure 3: Typical fluidized bed boiler plant

The above diagram shows a typical fluidized bed boiler plant, as is also used for sewage sludge.

Data on the plant in Hong Kong

- Customer: Veolia/OTV SA, Hong Kong
- Throughput: 2,000 t/d
Mono-Incineration of Sewage Sludge

- Sludge quality: dewatered, calorific value = 3.0-5.8 MJ/kg
- Steam quantity: 4 x 31.5 t/h
- Steam parameter: 43 bar; 383 °C

Andritz supplied 4 (bubbling) fluidized bed boiler lines for incineration of sewage sludge delivered from a total of 11 different sewage treatment plants.

Every day, 2,000 t of dewatered sludge are incinerated. This makes it the world’s largest sludge incineration plant. The plant is scheduled to go into operation in 2013.

3.4. Decentralized plants: Andritz Ecodry

A decentralized mono-incineration plant for sewage sludge as a disposal method for smaller and medium-sized municipalities has been widely discussed recently [6].

The advantages from technical and ecological viewpoints certainly originate from the following aspects, which can be achieved in most plant concepts.

- largest possible reduction in sludge volume,
- safe and full hygienization,
- safe and controlled reduction in emissions (Hg),
- no transport costs.

The advantages from the point of view of the operating company, in addition to the points mentioned above, include independence from the sludge and disposal market, as well as providing the operating companies with plant management that is calculable and assures a sound future.
The general advantage of sewage sludge mono-incineration arises from the fact that the ash, containing the much discussed phosphor as potential recyclable, is not mixed with other substances and is thus suitable for (future?) use.

In many cases the poor cost-efficiency, particularly due to the high investment costs of decentralized incineration plants, is considered to be problematical and disadvantageous. Of course, economies of scale do have some effect with greater sludge throughputs, and specific costs are reduced.

Many simplified plant concepts have been presented recently that can safely meet the prescribed legal and normative requirements, and where the investment also involves overall costs within a reasonable economic framework.

By way of example, the Ecodry technology of Andritz AG is described below in more detail.

### 3.4.1. Andritz Ecodry: process basics

The Ecodry process is characterized by two essential features:

- full drying before incineration,
- incineration in a cyclone furnace (cycloid combustion chamber).

**Why use a cyclone furnace?**

The cyclone furnace is a very simple and low-cost solution for incineration of fully dried sludge.

In the cyclone (primary) combustion chamber, the fuel, primary- and secondary air, and also the recycled flue gas are tangentially blown in. The sludge particles burn out in the cyclone flow. Most of the ash (> 90 %) is discharged through the conical, lower section. In the secondary combustion chamber, the gas phase can be fully oxidized.

As this technology does not require any mechanical moving parts, nor any complex internals, it provides a subsequent investment cost advantage. Furthermore, cyclone firing requires very little space.

**Why use full drying?**

Full drying before sewage sludge incineration has the advantage of compensating any fluctuations in sludge quality as best as possible and thus minimizing the use of auxiliary firing. In addition, the drying process before incineration provides some kind of redundancy, since in most plant concepts it is also possible to continue drying operations while maintenance work is being performed at the incineration part. This drastically reduce the required sludge storage volume. A further advantage results, of course, from the substantial reduction in the amount of flue gas as a result of full drying, cutting the investment and operating costs for flue gas cleaning.

Substantial advantages result from the use of (low-temperature) waste heat in the drying section, thus sharply diminishing thermal losses.

Over the past decades, Andritz AG has built up a broad experience in dealing with the three main drying technologies used for full drying of sewage sludge.

- **Drum drying**: Andritz DDS,
- **Belt drying**: Andritz BDS,
- **Fluidized bed drying**: Andritz FDS.
Depending on the project framework conditions, all three drying technologies can be used in combination with the Ecodry process in order to obtain the best solution for the customer.

3.4.2. Andritz Ecodry: choice of concept

In the choice of Ecodry concept, the energy balance, opportunities of using waste heat, and the space available are all fundamental decision criteria.

- The energy balance is positive if the organic portion or the degree of dewatering enables sludge incineration to release more energy than is needed to dry the sludge. As a result, the surplus energy can be used externally.

- The energy balance is negative if the organic portion or the degree of dewatering cause sludge incineration to release less energy than is needed to dry the sludge. This energy shortfall must be supplemented by additional energy from external sources (co-incineration).

- The energy balance is balanced or fluctuating if the organic portion or the degree of dewatering is such that sludge incineration releases at times less and at times more energy than is needed to dry the sludge. These fluctuations can be compensated with an appropriately sized granulate storage.

This configuration is mainly found when additional sludge is supplied from small external sewage treatment plants in spite of the decentralized concept.

Table 5: Comparison Ecodry concepts

<table>
<thead>
<tr>
<th>Ecodry concept</th>
<th>Heat transfer medium</th>
<th>Space requirement</th>
<th>Potential for utilizing waste heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDS</td>
<td>Thermal oil, steam</td>
<td>Small</td>
<td>Good</td>
</tr>
<tr>
<td>DDS</td>
<td>Hot gas</td>
<td>Medium</td>
<td>More complex</td>
</tr>
<tr>
<td>BDS</td>
<td>Thermal oil, steam, hot water, hot gas</td>
<td>Larger</td>
<td>Good</td>
</tr>
</tbody>
</table>
3.4.3. Andritz Ecodry: process description for Ecodry BDS

Sludge drying: Belt drying BDS

Sewage sludge that has been dewatered mechanically is fed to the drying plant. The Andritz BDS technology uses back-mixing in order to overcome the problematic, sticky phase (45 – 55 % DS) of the sludge. In back-mixing, sludge granulate that has already been dried is mixed into the dewatered sludge. A paddle mixer is used to mix and granulate the sludge. This pre-granulated mix is then applied evenly with a defined layer thickness to the slowly moving dryer belt.

Inside the dryer, warm drying air flows through the material on the belt, heating and drying it. The dryer operates with circulating air, with the heat required coming from heat exchangers.

The heat exchanger can be designed to use thermal oil, steam, or hot water. These act as heat transfer media for transferring the flue gas energy to the drying loop. In addition, it is also possible to transfer the heat from the flue gas directly via a gas/gas heat exchanger from the flue gas to the drying loop. This design is used if the heat balance is negative or leveled, and if the circumstances on site permit short distances between the drying and the incinerating equipment.

The exhaust air from the drying plant is cooled and condensed, and can then be disposed of thermally in the incineration section. Depending on the design of the overall plant, special odor treatment may be needed for the aspiration air from the sludge bunker and granulate silo plants.

At the end of the belt, the dried material drops into a discharge screw that transports it over a conveying system to a combined back-mix and discharge silo. The dry product is cooled to < 50 °C by a belt cooler and then transported through a discharge screw and on appropriate conveying equipment to an intermediate storage silo.

Incineration part: cyclone furnace

The fuel granulate is taken from the intermediate storage silo by a dosing screw. Before incineration, the grain size of the fuel must be reduced to a uniform size. This process stage is performed with a roller crusher followed by a screen. The target grain size for incineration in a cyclone furnace is about 1 mm. The fraction remaining on the screen (oversized) is returned to the intermediate storage silo.

The fuel granulate is blown pneumatically into the primary chamber of the cyclone furnace.

The granulate carried into the primary chamber ignites there as a result of the prevailing temperature and is supported by the rotating gas-flow inside the cyclone furnace. When the organic material is incinerated, porous ash particles are produced that are discharged through the cone. The ash from the furnace is cooled in a cooling screw and stored in an ash container or ash silo.

The comparatively low temperatures in the combustion chamber (800 – 850 °C) prevent slagging or sintering of inert material onto the primary chamber.

In the secondary chamber, gaseous, organic compounds and carbon monoxide that have formed in the primary chamber are completely oxidized.

In order to guarantee this, the retention time is at least two seconds, at a temperature of at least 850 °C and an oxygen content of at least 6 %. The optimum ratio of temperature to
oxygen content is set injection of fresh air or recycled flue gas. Air and flue gas are blown into through tangentially mounted nozzles at different levels in the primary chamber and in the transition to the secondary chamber.

For NO\textsubscript{x} reduction, a selective non-catalytic reduction (SNCR) process using urea as reducing agent is applied. The urea is injected through nozzles in the high-turbulence transition section between the primary and secondary chambers in order to guarantee best possible mixing. In this section of the furnace, the temperatures are well above 900 °C, providing optimum reaction conditions for NO\textsubscript{x} reduction.

**Heat utilization**

The flue gas leaves the secondary chamber and passes through a brickwork channel to the heat utilization section. Depending on the Ecodry concept used, a thermal oil-, steam- or hot water boiler is included. It is also possible to transfer the heat from the flue gas directly to the drying air by means of gas/gas heat exchangers.

When designing the heat utilization section it is essential to ensure that any problems with deposits on the heat exchanger surfaces are avoided as far as possible. It is also important to prevent temperature peaks in the heat exchanger so that ash deposits do not sinter firmly onto the heat exchanger. Temperature peaks are avoided by back-feeding the hot flue gas to flue gas that has already cooled down in a static mixer.

**Flue gas cleaning**

As an effluent-free process and particularly in view of its defined pollutant sink, dry sorbent injection has been proven successful as a flue gas cleaning process. In dry sorbent injection, a sorbent (or a mixture of various sorbents) is fed to the flue gas flow and removed finally at a bag filter.

In general, two different processes are commonly used.

- dry sorbent injection with Ca(OH)\textsubscript{2} + lignite coke (lime hydrate process),
- dry sorbent injection with NaHCO\textsubscript{3} + lignite coke (sodium bicarbonate process).

In the lime hydrate process (e.g. Andritz Turbosorb), acid gas components (SO\textsubscript{x}, HCl, HF) are converted chemically on moistened Ca(OH)\textsubscript{2} and bonded. This process takes place in a reaction chamber (e.g. circulating fluidized bed reactor) and on the filter layer. The additional activated coke added adsorbs heavy metals (Hg, Cd, etc.), dioxins, and furans. In the Turbosorb process, the sorbent is largely recirculated in order to optimize loading as much as possible. Exact temperature control is needed in the reaction chamber in order to achieve optimum separation.

The high reactivity of the sodium bicarbonate is used in the bicarbonate process, which is why there is no need for a separate reactor chamber. The reaction takes place entirely on the filter layer. It can also take
place at much higher temperatures, meaning that the water quench to cool the flue gas can be omitted.

A disadvantage is the considerable effort required to mill the bicarbonate immediately before adding it because the bicarbonate can only be stored in tablet form. This process stage has to be performed in special mills, which often have to designed duty/standby.

The fly ash is removed at the bag filter together with the loaded sorbent and stored in a container or sorbent silo.

The flue gas cleaning section is followed by the ID-fan, which controls the vacuum in the furnace and ultimately discharges the cleaned flue gas through a stack into the open air.

4. Operating experience with the EKT plant

The EKT Ecodry plant went into operation at the end of 2004. It remained in operation until the middle of 2007 and was then decommissioned when the operating company became insolvent. At the moment, the entire plant is being installed at a different location. Re-commissioning is scheduled to take place before the end of 2011.

The EKT plant was designed as a combined DDS and cyclone furnace.

Figure 7: EKT process flow diagram

**Plant specifications:**
- Location: Eferding, Austria,
- Throughput: 4.6 t/h,
- Sludge: digested sludge, 32 %,
- Water evaporation from drying: 3,000 kg/h.
The quality and origin extends from digested and limed sludges from chamber filter presses, to undigested municipal sludges with high organic content and little dewatering, to industrial sludges with extremely high organic content.

Thanks to full drying, the fluctuations in DS content before incineration could be balanced out effectively. The changes in organic content and thus, in the calorific value of the dried granulate, were overcome by the well-engineered automation concept in the incineration part.

4.1. Initial operating problems and solutions

The very different sludge quality caused some operating problems in the early days, some of which were resolved by modifying the operating mode and some by making changes to the plant.

4.1.1. Sludge conveying

The sludges, some of which were dewatered to high dry content levels in chamber filter presses with lime added and were highly compacted, could only be conveyed at the expense of considerable wear and tear on the pumps and by adding water. In addition, there were problems initially with extraneous material in the sludge (tree branches, bricks, etc.).

These problems were largely resolved by logistic measures or minor modifications to the conveying equipment.

4.1.2. Heat exchanger

The gas/gas heat exchanger originally installed had a design fault in the expansion compensation device. Furthermore, operation with sludges containing a large amount of lime proved problematical because the heating surface suffered severe fouling in the very hot area.

Ultimately, the heat exchanger design had to be modified and the existing heat exchanger replaced. The temperature control was altered by back-feeding of cooled flue gas ahead of the heat exchanger to the extent required to substantially reduce the maximum temperatures, thus solving the problem with deposits.

4.1.3. Deposits at the ignition burner

At the ignition burner, ash deposits formed which melted when the burner was in operation and ultimately blocked the burner.

The business model for the EKT plant was based on a gate fee for sewage sludge delivered by truck.

The spectrum of sludges supplied proved to be very wide in practice. Very different sludge qualities were treated.

The range of DS contents after dewatering and the organic content of the sludges delivered covered the following ranges:

- DS content: 15 % to > 40 %,
- Organic content: 25 % (!) to > 80 %.
These problems were investigated thoroughly using CFD simulation and could finally be resolved by retrofitting a controlled cooling and flushing air dosing system.

4.1.4. Biofilter

It became evident that the biofilter provided to treat the dryer exhaust air (in spite of the pre-scrubber) could not break down the very high ammonia loads originating from some of the sludges. In order to bring the odor emissions down to the required level (500 OU/m³), a further scrubber had to be retrofitted. In addition, the possibility of recycling the dryer exhaust air to the incineration plant was investigated in order to save chemicals. The investigations showed that the dryer exhaust air could normally be treated in the incinerator without causing any operating difficulties. The ammonia introduced even resulted in savings in consumption of SNCR agent.

4.2. Regular operation

After the initial operating problems had been resolved, the plant then achieved regular industrial operation with high availability and compliance with official requirements.

The plant processed an average of approximately 100 t of sludge per day.

Figure 9: EKT cyclone furnace

Emissions

Table 6 provides some examples of the emission values measured (TÜV measurements taken on December 13, 2006).

5. Overall plant concepts

There are very different concepts for planning sludge treatment and sludge utilization in a sewage treatment plant. The question is whether it is worthwhile investing in a digester plant if it is to be followed by a mono-incineration plant to make thermal use of the sludge.

This question has already been widely discussed [2].

It can be illustrated that the combination of digestion with subsequent mono-incineration may certainly yield some interesting prospects.
Particularly if the digestion process is very thorough, or if it is combined with mechanical, thermal or enzymatic disintegration (advanced digestion), it is possible to achieve high degradation rates and thus, high biogas production rates. The residual sludge has a lower calorific value, but this disadvantage is offset by the higher dry substance values obtained in mechanical dewatering. It would make sense, however, to include a full drying stage before the incineration plant.

The advantage of thermal utilization over the biogas variant is certainly the substantially higher efficiency when generating power from biogas compared to power generation from solids incineration. In addition, gas motors produce roughly the same amount of thermal energy, which then can best be utilized in a low-temperature drying plant.

In all, it is evident that it is well worth while conducting an exact investigation of the energy and material flows if this leads to best possible use of the resources available and thus takes a large step forward towards the goal of an energy self-sufficient sewage treatment plant.

Andritz AG is able to offer the main process stages in sludge treatment and is pleased to contribute its experience and know-how in designing concepts for new plants or optimizing existing equipment.

### Table 6: EKT-Emissions

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<th>Daily average</th>
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**Biofilter-Emissions**

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Source: TÜV measurements taken on December 13, 2006
6. Abstract

Mono-incineration of sewage sludge is one of the most promising methods for future utilization of sewage sludge. Sewage sludge differs substantially from other fuels, which is why there are special incineration processes available on the market. Andritz AG can offer a process concept with a bubbling fluidized bed for large-scale plants, while the Andritz Ecodry process, combining full drying with incineration in a cyclone furnace, is more suitable for decentralized plants. Depending on the requirements of the project concerned, the Ecodry process can be implemented with one of the three drying technologies available (drum drying, belt drying, fluidized bed drying). Operating experience with the EKT Ecodry plant in Austria showed that the Ecodry process works reliably and in compliance with official regulations after initial difficulties have been eliminated.

Using a low-temperature belt dryer in combination incineration of digested sludge in the cyclone furnace opens up new possibilities for energetic sewage sludge utilization with highest yields, placing the goal of energy self-sufficient sewage treatment plants within reach.

7. Literature