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Solar Sludge Drying Technology and Dried Sludge as Renewable Energy—Closing the Loop

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Abstract: The biggest problem in wastewater treatment is what can be done with the sewage sludge. Generally, there are few possibilities to manage it such as landfill, incineration or use it as a fertiliser in agriculture with limited amount. Nowadays, there is a simple technology that allows a very costly effective transformation from dewatered sewage sludge into a renewable energy resource. Sewage sludge contains water mostly which can be reduced by common dewatering processes until a DS (dry solids) concentration to about 25%. In this condition, the sludge can be incinerated, but the energy that can be obtained from the burning may be equal to the required one to evaporate the accompanying water. So, another reduction on water content is required until the mass contains 90% DS under which the calorific value will be increased to about 10 MJ/kg. Then, the sewage sludge can be considered as a clear substitute for coal with the advantage of a renewable and carbon dioxide neutral CO_2 emissions.

Key words: Sewage sludge, sludge thermal drying, renewable energy, neutral carbon dioxide, alternative fuels, saturated steam cycle.

1. Introduction

Nowadays, a problem that needs to be considered carefully is the efficient and environmentally sound management of the sludge generated by the waste water treatment plants [1]. Several sludge treatment solutions are available, such as landfill disposal, agricultural application, composting or thermal drying (Fig. 1).

The sludge has been used as fertilizer in agriculture for decades depending on whether its composition is suitable or not. If it is not, then it is sent to a landfill as solid waste.

When in certain areas, there was a choice of several wastes that could be applied on the soil, composting was the solution resulting in a stabilized product which could be packed and marketed.

As a result of this overuse of agricultural land, there are lots of areas where the sludge application on the soil is no longer allowed.

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In such scenario, it is compulsory to improve new technical solutions which have to be cost-effective, getting an overall cost optimization, easy management and low cost of operation and maintenance as well as safety for operators and environmentally friendly. Passavant's Solar Sludge Drying System has been developed to provide this solution.

2. Solar Sludge Drying System

Sewage sludge as withdrawn from the treatment process contains water mostly. Common dewatering processes reduce the water content, increasing the DS (dry solids) concentration up to 25%.

At 25% DS (75% water), the energy content of dewatered sludge is roughly balanced, that is to say, if sludge with this water content is incinerated, the energy that can be obtained from burning the organics is about the same as it is required to evaporate the accompanying water [2].

A further reduction of the water content is only possible through sludge drying. The advantage of sludge drying is, that not only is the mass reduced significantly, but also at 90% dry solids, the calorific

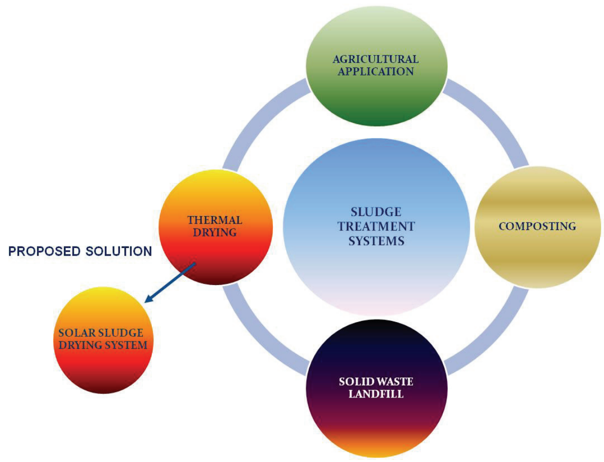

Fig. 1 Solar Sludge Drying System. A new solution for sludge management.

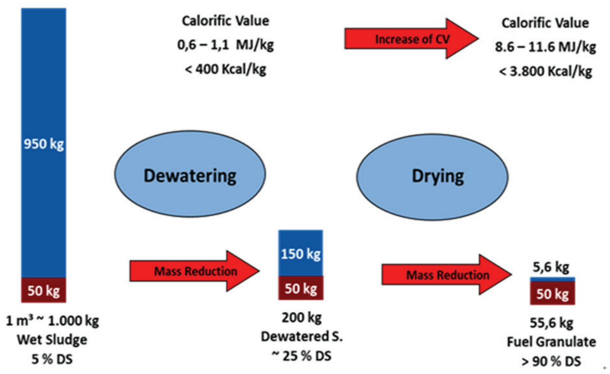

Fig. 2 The change of mass and calorific value [2].

Table 1 Dried sewage sludge as fuel [2-4].

Fuel	Lower calorific value (MJ/Kg)
Sludge 85%~92% DS	8.9~12.5~15.8
Dry wood	15.5 ~19
Mineral coal	~29
Brown coal	8.4~16.8

value is increased to about 12.5 MJ/kg (Fig. 2).

When comparing the calorific value of dried sewage sludge with other energy resources, it shows that dried sewage sludge can be an attractive alternative energy.

This means sewage sludge, if dried to 90% DS, is not waste, but an attractive alternative energy as shown in Table 1.

As sewage sludge has its source in food products, it is also a renewable and carbon dioxide neutral energy. That means that using dried sludge as a substitute fuel not only reduces the primary energy consumption but also avoids CO_2 emissions from fossil fuels.

According to Table 1, there are some additional conclusions to take into consideration:

(1) 2 t of dried sewage sludge equalizes 1 t of mineral coal in calorific value;

(2) 1 t of sewage sludge used as fuel avoids 0.48 t of CO_2 emissions from fossil fuels;

(3) Cement and power plants can reduce their demand of primary energy and also reduce CO_2 Emissions [5, 6]. In Spain, at Alicante's cement factory, it was substituted part of the coal used as primary fuel by dried sewage sludge. Based on a heat content of the substituted coal of 26 GJ/t and a ratio of 93 kg CO_2/t of coal, the following environmental indicators were achieved:

- The waste energy from the cement factory used for thermal drying implied 46 million therms gained annually, equivalent to around 18,000 t/CO_2;
- The energy supplied by the sludge combusted in the kiln (average value of 12.5 MJ/kg) implied 53 million therm gained annually, equivalent to 20,500 t of CO_2.

3. Process Description

The following flow chart (Fig. 3) will help to describe the process, as well as, show some data of one project designed by Pesa Medioambiente Sau (formerly named Passavant España SA) which will be used as an example. At the same time, Fig.4 describes the whole system for a better understanding.

The dewatered sludge between 20% and 30% dry solids content obtained in the WWT (waste water treatment) Plant is fed into containers or trucks and brought to the solar sludge drying plant, where is stored in a reception tank which has enough capacity to overcome long weekends (5 to 10 days) as minimum, as well as, to balance the difference that there is between the plant average treatment capacity and the sludge production.

Considering a sludge production of 25,454 t/year with a dry solids content of 22% DS, It is required a

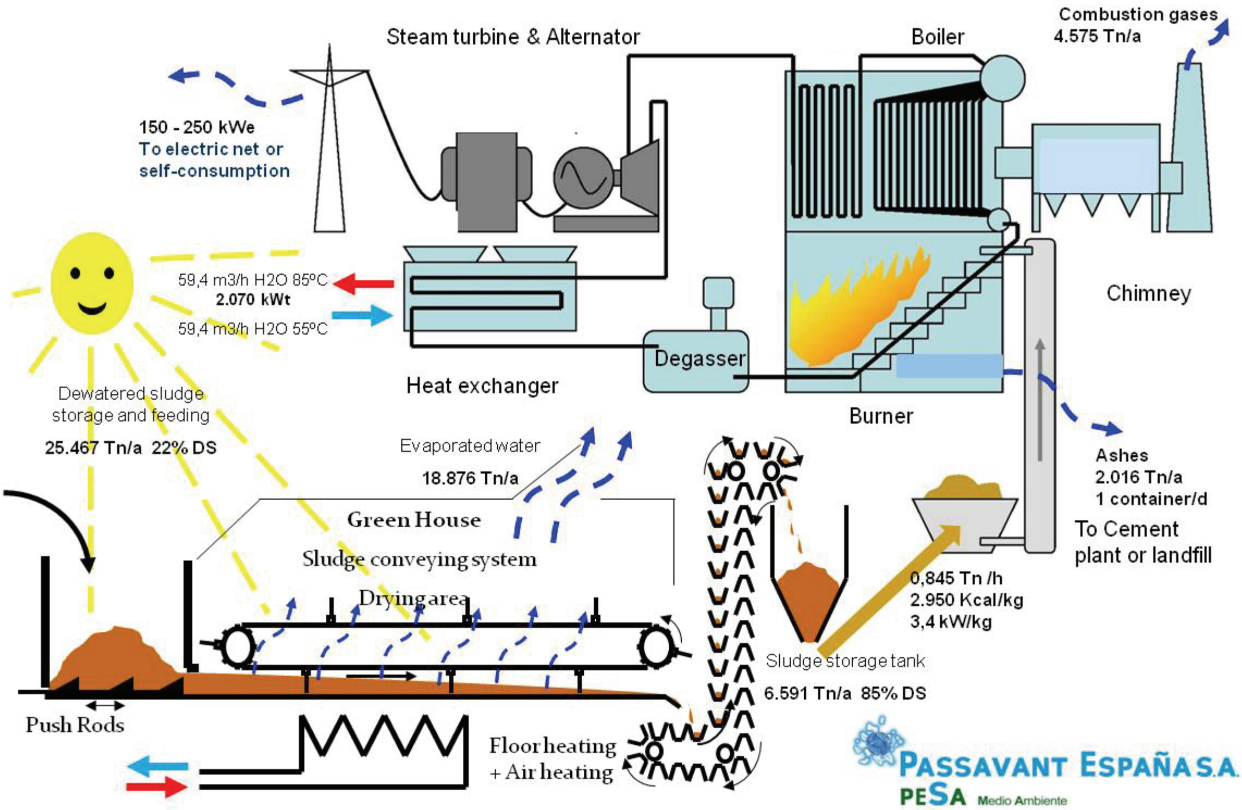

Fig. 3 Flow chart.

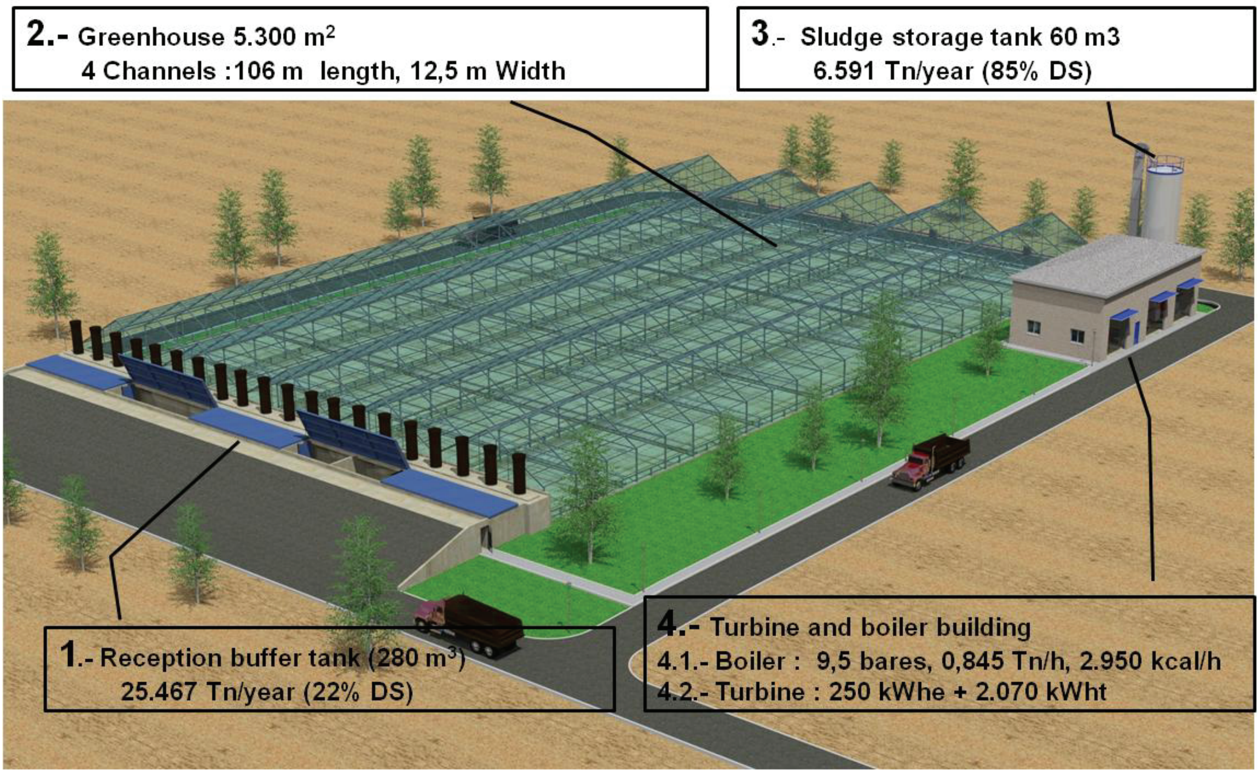

Fig. 4 Solar sludge drying plant (25,467 t/year) with energy recovery using sewage sludge as fuel granulate.

concrete buffer tank with a total volume of 210 m^3, divided in three parts of 70 m^3 each.

This buffer tank is provided with a push rood bottom system which makes some backwards and forwards movements in order to push the sludge located at the bottom of the tank into the drying area (Fig. 5).

The drying area or system itself consists of a greenhouse, equipped with a turning and conveying automatic device of sludge that conveys it from one side to the other one. Constant movement of the sludge prevents formation of clusters and ensures frequent renewing of the surface in order to increase the evaporation.

Solar radiation is used to evaporate water. In addition, there is also the possibility to install a floor and air heating system that will use the cooling water at 90 ºC from a CHP (combined heat and power) unit, whenever the latter exists or it is available.

In the project mentioned before like an example, it was foreseen to recover the thermal energy obtained from the water used to condensate the saturated steam at the outlet of a steam turbine.

The water evaporated from the sludge during the drying process leaves the greenhouse through the roof openings or vents provided to do this.

It takes some days to dry the sludge, depending on the weather conditions and the amount of residual thermal energy available from the CHP unit, whenever this is available.

The required area for drying 25,454 t/year from 22% DS to 85% DS is 5,300 m^2 (Fig. 6), divided in three different channels of 12.5 m in width and 96 m in length, and equipped with a floor heating system which will use recovered cooling water at 85 ºC (Fig. 7) obtained from the cooling system to condensate the low pressure saturated steam at the outlet of a turbine.

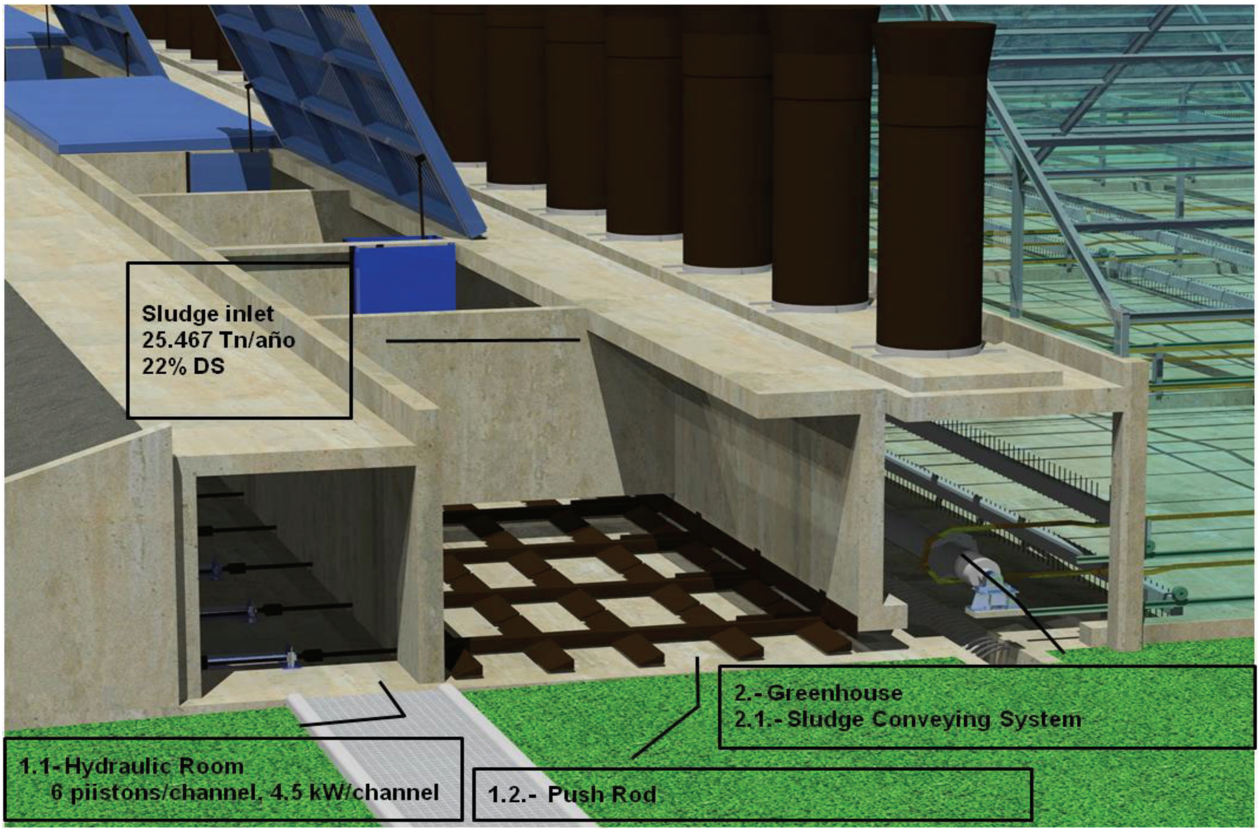

Fig. 5 Reception buffer tank.

Fig. 6 Greenhouse. Conveying and turning automatic device of sludge.

Fig. 7 Floor heating system: 1 Ut Pipe ½”/10 cm with hot running water from 55 ºC to 90 ºC.

The amount of dried sludge at 85% DS will be 6,591 t/year, whose calorific value will be around 2,950 kcal/kg. At the end of the drying area, it drops into a bucket conveyor and is stored in a silo (Fig. 8).

In order to recover the calorific power of the dried sludge, the system will be equipped with a boiler which will use this dried sludge as fuel, capable of burning 0.85 t/h of dried sludge, obtaining 3.6 t/h of saturated steam at 9.5 barg and 178 ºC (Fig. 9).

The high pressure saturated steam will be used in a turbine, where the pressure will be reduced from 9.5 barg to 1.25 barg (105 ºC), obtaining as a result both, electric power production from 150 to 250 kWh (Fig. 10) which will be used in the plant or sent to the electrical net, and low pressure steam.

The low pressure saturated steam at the outlet of the turbine, enters to an exchanger where it will be condensate into water. At the same time, the 59.5 m^3/h at 2.5 barg of cooling water used to condensate the steam is going to increase its temperature from 55 ºC to 85 ºC. The condensate at 105 ºC returns to the boiler.

The hot water obtained in the exchanger at 85 ºC is sent to the floor heating system which helps to the sludge water evaporation and reduces the required area for drying the sludge.

4. Technical and Economical Comparison among Several Sludge Thermal Drying Systems

According to both technical and economical, ratios shown in Tables 2 and 3 [6, 7] as well as the performances obtained in Passavant’s plants, it may be stated that the systems based on a low temperature thermal drying, those where operation temperature is lower than 80 ºC (Table 2), are more cost-effective,

Fig. 8 Final product: > 80% DS. Granulate from 0 to 8 mm in diameter.

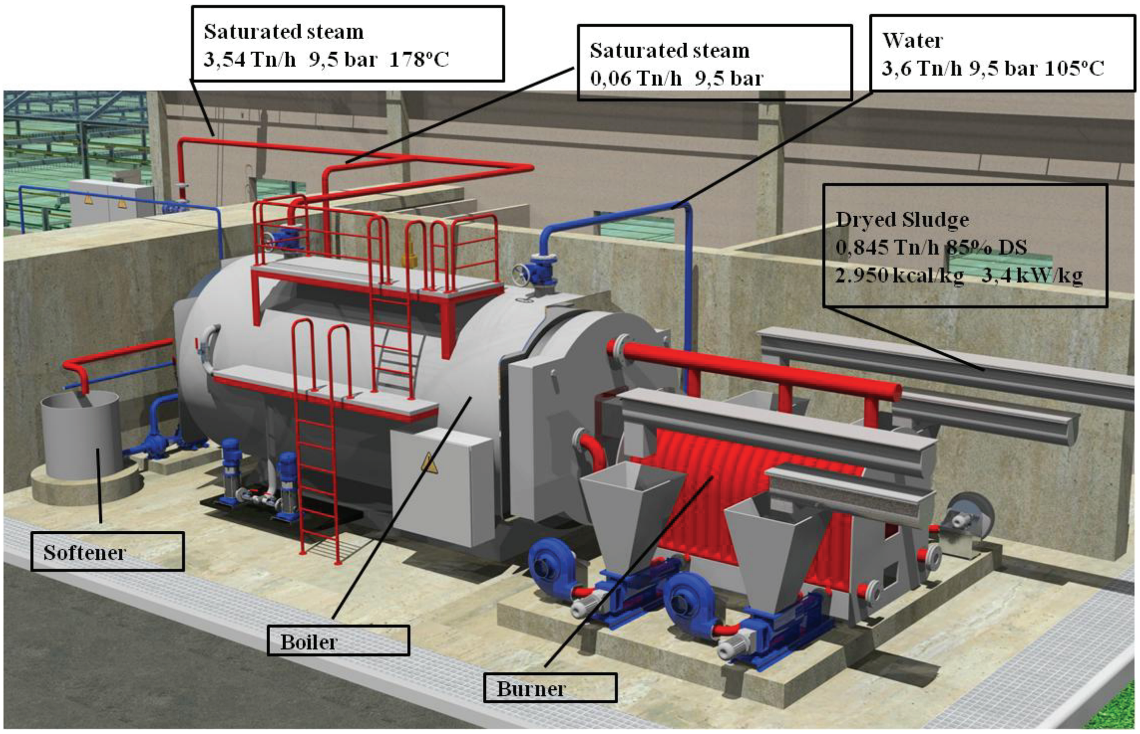

Fig. 9 Boiler and burner.

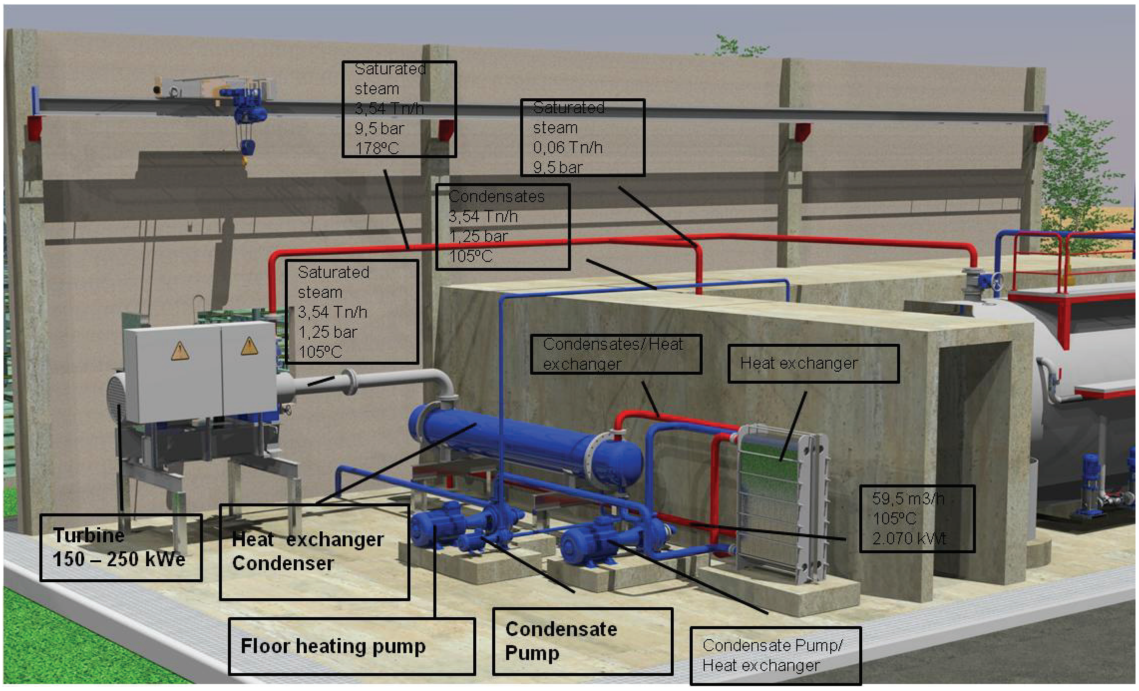

Fig. 10 Turbine.

getting an overall cost optimization, easy management and low cost of operation and maintenance, as well as they are safer for operators and more environmentally friendly than the ones which require high operation temperature.

Moreover, taking in consideration that the sludge disposal in a waste landfill may have a management cost between 70 and 160 €/t which depends on its

Table 2 Technical comparison among several sludge thermal drying systems [7].

	Convection drum dryer	Conduction rotary dryer	Vertical dryer trays	Belt dryer	Thin layer dryer	Incinerator/ /fluid bed dryer	Passavant
Tª (ºC)	300~500	100~130	100~130	55~70	200~270	80~100/900	Weather conditions
DS in (%)	> 20	> 20	> 20	> 20	> 5	> 25/< 40	> 20
DS out (%)	90-95	85~95	90~95	85~95	90~95	> 95	> 95
Energy:							
kcal/kg	750~900	750	750	774~860	750~1,000	800~900	860~1,000
kWh/t	900~1,050	900	900	900~1,000	900~1,200	900~1,000	1,000~1,160
Power :							
kWh/t	60-400	80~150	-	130~300	-	130~150	30~60
Life (y)	12~15	12~15	12~15	12~15	12~15	25	30
Operation (h/y)	7,200~8,000			8,000		24 h/d 7 d/w	8,000

a: both, energy and power, are referred to tones of evaporated water**.**

Table 3 Economical comparison among several sludge thermal drying systems [8].

System	Material	capacity 10^3 t/y	capacity 10^3 t DS/y	Investment million €	Investment €/(t·DS/y)	Operation (€/t·DS)
Thermal drying + burner	Dewatered sludge	50~200	11.5~46	4.8~13.8	290~410	105~130
Thermal drying + CHP	Dewatered sludge	50~200	11.5~46	9.6~27.0	590~830	40~110
Passavant' solar drying + burner + steam turbine	Dewatered sludge	10~50	2.3~11.5	2.4~9.0	780~1,050	60~105
Passavant' solar drying + burner + steam turbine	Dewatered sludge	50~200	11.5~46	9.0~30.0	660~1,050	60~105
STC's thermal drying (belt DRYER) + CHP	Dewatered sludge	10~47	2.3~10.8	2.6~7.8	730~1,120	60~140
Electric drying with heating pump	Dewatered sludge	10~33	2.3~7.6	1.4~2.8	360~610	150~220
Thermal drying + CHP + gasification	Dewatered sludge	50~200	11.5–46	14.4~39.1	850~1,250	30~110
Supercritic oxidation (SCWO)	Thickened sludge	90	20.7	4.3	210	200
Vertech's oxidation system	Thickened sludge	622	28	36.1	1,290	250
Biomethanisation + CHP	FORSU/sludge 80/20	35~140	8.1~32	12.0~28.8	890~1,500	70~140
Preliminary drying + incinerator + steam turbine	Dewatered sludge	50~200	11.5~46	25.2~72.7	1,590~2,180	220~320
Preliminary drying + incinerator (Dordrecht)	Dewatered sludge	240	55.2	77.5	1,400	250
Incinerator + steam turbine	Dewatered sludge	50~200	11.5~46	29.4~85.3	1,850~2,570	250~350
Windrow composting	Dewatered sludge	10~150	2.3~34.5	0.5~3.1	90~240	40~85
Tunnel composting	Dewatered sludge	10~150	2.3~34.5	2.5~18.3	530~1,080	90~170
Channel composting	Dewatered sludge	10~150	2.3~34.5	1.2~7.8	220~510	60~140

Note: FORSU means organic fraction of municipal wastes.

composition, distance to the landfill, yearly production or even if there are available or no other possible solutions such as agricultural use in the same area, the low temperature thermal drying systems provide the cheapest operation and investment cost for plants whose treatment capacity is from 50,000 to 200,000 t/y.

On the other hand, this kind of treatment is also an effective one when there is no possibility or there is a strong regulation in the area about the number of tons of sludge that can be used in agriculture.

The low thermal energy required for Passavant's system (1,000 to 1,160 kWh/t) to evaporate sludge's water, together with the lowest power consumption 30 to 60 kWh/t, makes it to provide the best cost-effective solution whenever the space is not limited.

5. Conclusions

Having been described before technically and economically the sludge solar drying system of Passavat, the following features are the most important ones:

- System fully automatic and continuous process. The sludge is fed on one side of a greenhouse and is moved during the drying process to the other side;
- Sludge is dried from 18 % DS to > 95% DS;
- Sludge is dried using solar radiation and, if available, additional heat, e.g., from CHP units or steam turbines;
- The sludge thickness is reduced by drying from ~0.15 m (6 in.) at feed side to ~0.038 m (1.5 in.) at outlet side;
- Distribution/turning inside greenhouse is done using chain scraper and harrows;
- No dirt or dust problems due to smooth conveying system;
- No odor problems due to thin sludge layer and continuous turning (aerobic conditions);
- Low and easy maintenance;
- Very low investment 660~1,050 €/t DS cost and very low operational cost 60~105 €/t DS;
- Width ~10 m to 12.5 m, length 50~120 m per channel;
- No pollution and no contact with sludge;
- Use of additional heat can reduce required surface by 75%;
- Use of additional heat, e.g., hot water at 85 ºC, enables high DS concentration (> 90%) and reduce the required surface;
- High evaporation rate and efficiency due to thin sludge layers;
- No sticking of sludge, as sludge is constantly moved;
- 19% higher surface area due to conveying and turning automatic device;
- Very low electric energy consumption (30~60 kWh/t evaporated water);
- Passavant's drying system is the most economical system on the market.

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