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Reducing the cost of sludge treatment and disposal by implementing thermal hydrolysis for a large wastewater treatment plant.

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Conventional Mesophilic anaerobic digestion (MAD) is an established technology for sludge stabilisation prior to dewatering and disposal. The drawback of MAD is that it requires large digestion volumes and achieves a relatively low efficiency in terms of biogas production, pathogen removal and dewatering. As a result, many utilities are considering an additional thermal drying step for digested and dewatered sludge in order to achieve the minimum product volume with low pathogen levels. This is however, at the cost of substantial capital and operational expenditure. Pre-treatment of raw sludge with the Thermal Hydrolysis Process (THP) prior to MAD alleviates most of the challenges of conventional digestion, dewatering and drying and reduces operational expenses. THP treatment consists of exposing sludge to temperatures of 150 – 165°C at pressures of 5 to 6 bar under saturated steam conditions. At these conditions, sludge viscosity is reduced, complex organic compounds are hydrolysed, cell walls are destroyed, and dewaterability is improved as a result of the destruction of extracellular polymeric substances (EPS). As a result, MAD digesters can be fed at high dry solids concentrations of 10 to 12% DS with reduced HRT (15 days) resulting in a strong reduction of the required digester volume. In addition, biogas production is increased. As dewaterability is improved, there are lower residual sludge amounts and a strong reduction or even avoidance of drying needs. The THP process is typically applied in one of two configurations:

Full THP: This setup treats both primary and secondary/waste activated sludge with THP followed by compact digestion. This configuration achieves a high level of pathogen removal and is commonly applied when the final product (called "biosolids") is directly land applied. This typically leads to the lowest overall cost for sludge management.

WAS-only THP: This configuration treats only waste activated sludge (WAS) with THP, with primary sludge being fed directly to MAD. This configuration also achieves higher biogas production and improved dewatering; however, it requires somewhat bigger digesters and does not achieve full pathogen removal. The THP system, as it's treating only the WAS, will be smaller and requires less energy. Dryer size and the energy balance of the overall process are also optimised.

This paper describes the business case for a typical, large- scale wastewater treatment plant (approx. 400,000 PE) producing 30 ton of dry Solids (DS)/day of raw sludge and compares three scenarios: conventional MAD followed by thermal drying, Cambi Full THP, and Cambi WAS-only THP followed by thermal drying. OPEX estimates are provided for the 3 cases. Table 1 shows the design basis of the study.

Table 1. Design basis considered in the study

Description	Unit	Value
Primary Sludge (PS)	tDS/d	12
	%VS	75
	COD/VS (g/g)	1.7
Waste Activated Sludge (WAS)	tDS/d	18
	%VS	70
	COD/VS (g/g)	1.45
Specific thermal energy during thermal drying	MWh/tH_2O evaporated	0.95
Specific electrical power consumption for thermal drying	MWh/tH_2O evaporated	75

As this study shows, THP significantly impacts the required digester volume, the digested and dewatered sludge cake volumes and quality, and the plant's energy balance (in both configurations). In the case of thermal drying, the dryer size, as defined by the water evaporation capacity (tH20/hour), is greatly impacted by THP. Full THP with land application avoids the need for thermal drying altogether but relies on an accepted and regulated outlet for high-quality biosolids (this framework does not exist in all countries). The main overview of key design numbers for the three scenarios is shown in Table 2.

Table 2. Main results of the compared configurations

Description	Units	MAD + drying Value	WAS-Only THP + drying Value	Δ	Full THP (no drying) Value	Δ
Digester volume	m³	15,000	6,394	-57.4%	4,091	-72.7%
Biogas production	Nm³/day	7,720	9,750	+26.3%	10,005	+29.6%
Electricity generation with CHP	kW	-	180	-	858	-
Cake dry solids	% DS	24%	30%	+29.2%	31%	+25.0%
Dewatered Sludge	t/year	29,113	20,531	-29.5%	19,583	-32.7%
Electrical energy for dryer	MWh/year	1,601	1,027	-35.9%	-	-
Total Thermal energy for dryer	MWh/year	20,282	13,003	-35.9%	-	-
Cake volume after drying	ton/year	7,764	6,844	-11.8%	-	-
Final sludge to be disposed	ton/year	7,476	6,844	-11.8%	19,583*	+152.2%

In addition, an OPEX evaluation is made comparing operational costs for the three scenarios. Based on unit costs as presented in Table 3, the OPEX is evaluated in Table 4.

Table 3. Operational Expense values

Description	Units	Value
Cost of electricity	€/MWh	150
Sludge disposal cost – Dried cake	€/ton	40
Sludge –transport cost for hygienised cake	€/ton	10
Polymer cost	€/kg active	4,0
Potable water	€/m³	2,0
NH_4-N removal cost	€/kgNH_4-N	0,4
External fuel for thermal drying	€/MWh	50
Chemical cost for boiler	€/ton of water	1

Table 4. OPEX Comparison

		MAD + drying	WAS-Only THP + drying	Full THP (no drying)
Electricity from CHP	Eur/y	-	-236,578	-1,126,981
Polymer (total)	Eur/y	441,942	457,710	488,808
Cake disposal	Eur/y	310,542	273,750	195,828
Electricity for THP, digestion, pre/post dewatering	Eur/y	143,193	116,768	132,124
Potable water + chemicals for steam	Eur/y	-	23,482	39,031
External fuel for dryer	Eur/y	130,057	-	-
Electricity for dryer	Eur/y	240,185	153,984	-
NH4 aeration (WAS tank)	Eur/y	51,226	72,988	70,081
Total OPEX	**Eur/y**	**1,317,145**	**862,105**	**-201,108**
Delta (- means savings)	***EUR/y***		**-455,041**	**-1,518253**

Conclusion: By applying THP to biological sludge, the operational cost of sludge treatment with thermal drying can be substantially reduced. By using Full THP, drying can be avoided altogether, resulting in the lowest sludge treatment cost.

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