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THERMAL HYDROLYSIS OF MUNICIPAL SLUDGE: FINDING THE TEMPERATURE SWEET SPOT - A REVIEW

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1. Keywords

Anaerobic digestion, dewaterability, refractory compounds, digester effluent quality

2. Highlights

- THP impacts AD performance, sludge dewaterability and digester effluent quality
- THP parameters with the highest impact: Sludge type and thermal hydrolysis temperature.
- THP temperature within the 140-160°C range is recommended for optimal performances

3. Purpose

Thermal hydrolysis used as pretreatment of anaerobic digestion of sewage sludge was initially implemented to improve sludge dewaterability. This allowed a decrease of the volume of sludge produced while increasing biogas production [1]. Thermal hydrolysis process (THP) has been largely applied in municipal WWTPs since the first full-scale plant in HIAS, Norway in 1995. Today, more than 82 THP full scale references exist. By allowing sanitation of the produced sludge in addition to decreasing its residual amount, THP is getting renewed interest to fit into new sludge management routes [2]. Quite abundant literature exists on the combination of sludge thermal hydrolysis and anaerobic digestion. Thermal hydrolysis operating parameters are usually optimized towards the reduction of the amount of sludge and/or the maximisation of biogas production. Nevertheless, side effects of the pretreatment, such as the increase in soluble COD in the final effluent are rarely considered. Indeed, the latter is usually returned to headworks of the WWTP for the removal of carbonaceous and nitrogen-rich compounds. Consequently, additional costs can be incurred if the quality of the effluent is degraded by thermal hydrolysis [3].

The aim of the study was to collect and analyse published data in order to determine optimum parameters of thermal hydrolysis, considering its impact on methane production, volatile solids reduction, dewaterability of the digested sludge and quality of the anaerobic digestion effluent.

4. Materials and methods

The scope of the study was limited to TH temperatures above 100°C. The following process performance indicators were extracted from 44 published papers: Methane production, expressed as methane yield ($\text{Nm}^3/\text{tVS}_{\text{in}}$); dewaterability (DW), expressed as %TS of dewatered digested cake; AD effluent quality, which includes soluble Chemical Oxygen Demand (sCOD), UV Absorbance at 254 nm (UVA), ammonium content (N-NH_4^+) and dissolved organic nitrogen content (DON). Statistical analysis was carried out using the Kruskal Wallis test. An initial analysis was used to determine which operating parameters had the highest impact on THP performances. This involved assessing the influence of (1) THP duration, (2) the presence of a flash system, (3) the AD HRT and (4) the AD operating mode (batch or continuous, lab- or full-scale) on each process performance indicator. Then, temperature impact on dewatering and AD performances was assessed for each type of sludge (waste activated and mixed sludge) independently.

5. Results and discussion

Sludge type and thermal hydrolysis temperature were shown to have the highest impacts on all studied parameters (Table 1). Further analysis was thus performed separately for both waste activated sludge and mixed sludge to assess the impact of THP temperature.

Table 1: p-values obtained with the Kruskal Wallis test when assessing the the impact of AD HRT, THP duration, AD operating mode, the presence of a flash system, THP temperature range and sludge type on AD, dewatering and AD effluent quality performance indicators.

Parameters	Process performances indicators						
	VSR	VSR increase	CH ₄ prod	CH ₄ prod increase	Cake dryness	Soluble COD	UVA
AD HRT	0.20	0.93	0.0013	0.06839	0.58	0.092	-
THP duration	0.078	0.049	0.13	0.1101	0.71	0.027	-
AD mode	0.034	0.85	0.015	0.1894	0.85	0.25	-
Flash system	0.014	0.18	0.035	0.08308	0.89	0.14	-
THP temperature range	0.0054	0.0020	0.0034	0.007691	0.033	0.0074	0.050
Sludge type	0.0072	0.027	1.9E-08	0.00034	-	-	-

Results showed that a temperature above 140°C allowed increasing both VS removal and methane production. No significant difference was observed between the 140-160°C and 160-200°C ranges within the dataset. Nevertheless, some papers described a decrease in biodegradability at high temperature [4-5]. The best digested sludge cake dewaterability results were obtained for THP temperatures higher than 160°C. However, such high temperatures also lead to a significant increase in soluble COD content and colour of the liquid effluent downstream digested sludge dewatering (Table 2).

Table 2: THP temperature weighted optimisation (white = optimum. grey = acceptable. black = unfavourable)

Parameters	THP operating temperature ranges		
	100-140°C	140-160°C	160-200°C
Volatile solids removal			
Methane production			
Dewatering			
Filtrate quality			

6. Conclusions and perspectives

The added value of a THP pretreatment is mostly limited to waste activated sludge that is inherently less biodegradable than primary sludge. Such a thermal pretreatment was shown to increase methane production, VS removal and digested sludge cake dryness. Nevertheless, the higher the THP operating temperature, the lower the dewatering effluent quality (soluble COD content and colour), which is returned to the WWTP headworks. A THP operating temperature within the 140-160 °C range was shown to be a good compromise in regards to the selected performance indicators.

7. References

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