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Second generation THP optimizes energy integration

A second-generation thermal hydrolysis technology offers an improved, continuous, and steady-state process that optimizes biogas production, energy efficiency, and operational savings, according to Professor of Chemical Engineering **Fernando Fdz-Polanco** at the University of Valladolid, Spain.

Thermal hydrolysis processes (THPs) offer significant economic, energy, and environmental benefits, as demonstrated by the increasing number of THP installations at sludge treatment facilities across Asia, Europe, and the United States.

THP is used to pre-treat sludge and improve anaerobic digestion, with benefits that include higher biogas yields, production of EPA Class A biosolids, and reduced carbon dioxide emissions.

Anaerobic digestion, a well-established technology used to generate biogas from sewage sludge, is constrained by the hydrolysis, or solubilization, stage. Several pre-treatments are used to overcome this limitation, with thermal hydrolysis emerging as the preferred technology due to its technical and economic advantages.

Understanding THP developments and limitations

All THP technologies share similar characteristics in terms of biogas production, digested sludge (biosolid), and anaerobic process. First, by keeping digestion Hydraulic Retention Time (HRT) constant, THP increases biogas yield for Waste Activated Sludge (WAS) by 40 to 60 percent, 10 to 25 percent for mixed sludge, and 10 to 60 percent for other organic substrates such as Municipal Solid Waste (MSW), algae, and manure.

Second, THPs reduce the volume of biosolids produced, proportionally to biogas yield increase, with lower viscosity; they also improve dewaterability, with total solids greater than 30 percent, reduce odors, and provide pasteurization of biosolids to achieve EPA Class A standards with no pathogen regrowth.

Third, the following characteristics are shared by all anaerobic digesters operating with a THP pretreatment:

- Reduced energy consumption in mixing
- Higher dissolved solids (DS) concentration in feed (10 percent DS)
- Higher organic loading rates (4 kilograms volatile solids per cubic meter per day)
- No foam formation
- Increased elimination yield of emergent compounds
- Higher chemical oxygen demand and nitrogen concentration in dewatering recycle.

THP parameters

An understanding of the key design and operating parameters of industrial-scale thermal hydrolysis processes (Table 1) helps to follow the evolution of this technology into the emerging second generation of THPs.

Mechanisms: The first hydrolysis mechanism is thermal, whereby the physical structure of the solids is transformed by means of high temperatures and chemical reactions. At moderate temperatures (100°C), reaction times are necessarily long, i.e., greater than an hour, while at temperatures above a certain limit (greater than 180°C), secondary reactions appear.

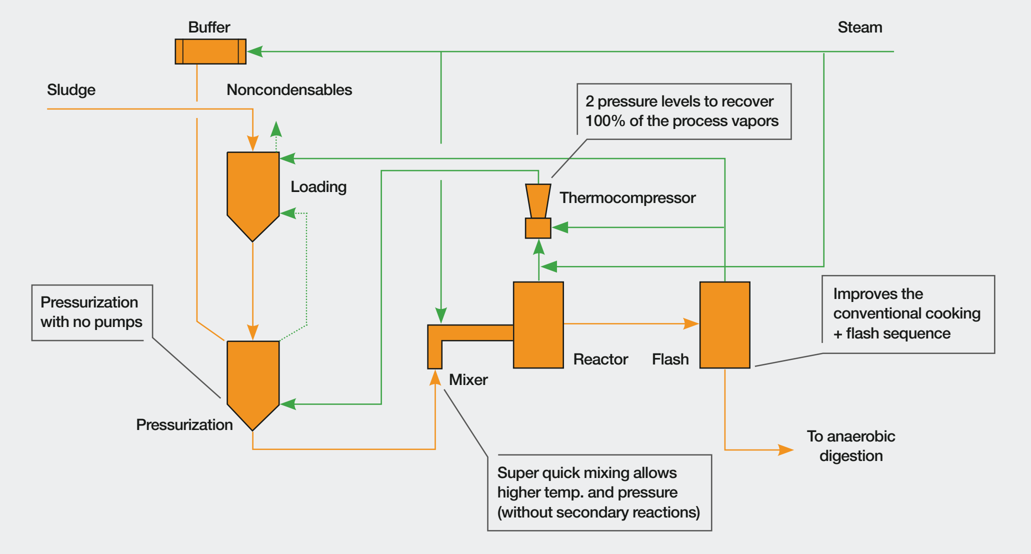
The second hydrolysis mechanism is steam explosion, or the flash boiling that occurs when a hot, pressurized liquid is suddenly decompressed. In the case of sludge, the water contained in the external polymer structure and inside the cells partially vaporizes, resulting in a cell structure fracture, both internally and externally. For temperatures of 170°C and times in the 0- to 30-minute range, the impact of steam explosion is much more significant than the thermal effect.[1]

Heat exchange: Regarding the heat transfer, some technologies use heat exchangers to preheat the feed and recover the energy in the hydrolyzed sludge. Different thermal fluids – such as water, steam, and hot oil – are used, and the main drawback is that heat exchangers require intensive maintenance since recalcitrant scaling occurs during low-temperature operation. Other processes use live steam injection to heat both the feed and the reactor. When steam explosion is used, heat recovery is achieved by recycling the flashed vapors. In typical commercial processes, less than 66 percent of the process vapors are recovered. The heat transfer choice will affect heat integration and the opportunities to recover energy from the hot, hydrolyzed sludge.

Sludge flow: In considering sludge flow, the third parameter, most commercial systems use pumps to pressurize sludge. Due to the high viscosity, high temperature, and the likely presence of abrasive solids, pumps are delicate parts of the installation and require much attention and maintenance. An alternative, widely used option in the chemical and food sectors for feeds with high solid contents is the use of pressurized vessels to transfer the required pressure and temperature to the sludge.

Operating regime: In batch

Figure 1. Simplified diagram of the teCH4+ process.



processes the preheated sludge is loaded to the hydrolysis reactor and pressurized up to the pressure setpoint using live steam injection. After a predetermined reaction time, the reactor is flashed through a valve or nozzle in the so-called steam explosion and splits into hydrolyzed sludge and vapor phases. It is possible to approach nearly continuous flow by operating several parallel reactors in cycles.

In contrast, in continuous hydrolysis processes preheated sludge is fed in a continuous, controlled manner to the hydrolysis reactor, with no loading and unloading cycles. This operating mode is directly related to the possibility of operating in a steady state regime. When operating in steady conditions, and as a consequence of a continuous regime, all process variables are constant within the narrow range imposed by the control system.

In the case of thermal hydrolysis, it is very relevant that the reactor temperature, pressure, and levels are maintained steady at all times. In non-steady state operation, process variables are not constant and fluctuate along the operation. In the batch processes with steam explosion, once the hydrolyzed material starts flashing, the reactor pressure will gradually decrease. The result is diminishing steam explosion efficiency, as it is governed by the differential pressure between the reactor and flash vessel. From a technical standpoint, the operating regime is directly related to the process stability and controllability as well as to its energy integration.

In the chemical industry, for example, the original batch, non-steady state processes rapidly evolved into their improved, continuous, and steady-state second-generation versions.

Second generation tH4+

Recently, tH4+ technology has emerged as the first milestone of second-generation thermal hydrolysis, as it presents conceptual, technical, and economic advantages over the existing commercial processes. This novel technology is based on the knowledge and experience accumulated by members of the Spanish company teCH4+ during a project financed by Aqualogy that engaged the University of Valladolid to design, build, start-up, and operate a continuous TH process treating the sludge of a 200,000-population equivalent water resource recovery facility. This project received the 2014 International Water Association´s Honour Award in the Design Projects category and served as a stepping stone for teCH4+ to develop the new, patented tH4+ process that overcomes the limitations of the first-generation THP technologies.

The key differentiators of the teCH4+ process are presented in the simplified diagram of Figure 1.

Overcoming limitations

The tH4+ technology has been designed from first principles and is based on in-depth knowledge of the scientific and technological process foundations. From the conceptual design, the objective was to overcome the limitations observed in existing commercial technologies. Specifically, and following the previous structure, the key innovations are discussed below.

Mechanisms

The best commercial processes, limited to temperatures below 180°C, integrate the two hydrolysis mechanisms in sequences where the thermal mechanism is followed by steam explosion. The tH4+ process goes one step beyond by operating at higher temperatures in short enough time for the secondary reactions not to occur. This higher temperature and pressure enables a first steam explosion before the thermal mechanism is applied, followed by a second steam

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Table 1 – THP parameters

Mechanisms	Heat exchange	Sludge flow	Operating regime
Thermal (cooking)	Heat exchangers	Pumps	Batch
			Continuous
Steam explosion (flash)	Live steam	Pressurization	Steady state
			No steady state

>> The tH4+ process goes one step beyond by operating at higher temperatures in short enough time for the secondary reactions not to occur. >>

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to the massive inconvenience not just to us but to the airport and local road network, would not have been feasible at all. The Aqua-Swirl's versatility meant that we could design the devices for the specific requirements of this site, without the need for any bends in piping, whilst their inherent strength allowed us to save on time and cost through not requiring a concrete surround. Their compact size and small footprint, together with the lifting supports and straps provided, meant installation was very quick and simple, and final placement could be done manually; we needed only a single day in which to dig,

Due to its light weight and robust build, the SDS Aqua-Swirl™ hydrodynamic separator could be lifted and maneuvered easily into position using the excavation equipment already on site. Photo by SDS Ltd.

Sufficient capacity exists within the underground storage facility landside to accommodate excess airside surface water runoff.

position, connect up, and back fill."

An additional benefit of the SuDS system has been the reduction in the frequency and volume of the flooding that occurred in the neighboring Airport Way under-pass. While the flooding hazard for both carriageways continues to remain categorized as "significant" for a 100-year storm event, the severity of flooding across the access route in a 30-year event has been reduced to the category of "moderate" for one carriageway, and the second carriageway is deemed entirely clear for a 10-year event. Furthermore, for all return periods the hazard remains in place for a maximum of only 2 hours, thereby significantly reducing the duration of restricted access, while the installation of a pump, which is able to transfer flows to the SDS GEOlight® tanks, ensures that emergency access can still be gained.

Future developments

Sufficient capacity exists within the underground storage facility landside to accommodate excess airside surface water runoff, the first flush of which will be highly contaminated with substances such as de-icing chemicals and will be diverted to the Thames Water foul system for treatment. While airside and landside runoff have more typically been considered two entirely separate wastewater streams, LLAOL is developing plans to manage holistically all sources of surface water, including the control of their dispersal.

Author's Note

Mark Manning is the business development manager of SDS Ltd., a leading UK manufacturer and supplier of sustainable drainage systems, based in Biddisham, Axbridge, England.

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explosion. This improvement over the conventional sequence results in shorter residence times, and thus smaller and less expensive equipment, with better biogas yields.

Heat integration

The easier-to-maintain THP designs use live steam in preference to heat exchangers, and so does the tH4+ process. The critical difference is that the two steam explosions create two different pressure levels of process vapors. Optimizing those by applying pinch technology heat integration techniques rarely used in the water industry, 100 percent of the flashed vapors can be recovered, minimizing the specific energy consumption of the process.

Sludge flow

While the majority of the commercial processes pump the viscous, abrasive sludge, the tH4+ design avoids the associated pumps' maintenance problems and costs by using pressurized vessels for the same purpose.

Operating regime

Most of the original batch THP designs have been superseded by their continuous counterparts. The tH4+ process extends this improvement path by also ensuring a steady-state regime, which improves the controllability and results in an easier-to-operate, more robust design.

All of these technical advancements represent a milestone in the THP design evolution and will contribute to strengthening THP as the technology of choice in advanced anaerobic digestion.

Author's Note

Professor Fernando Fdz-Polanco is a Fellow of the Institution of Chemical Engineers and Professor of Chemical Engineering at the University of Valladolid, Spain. With more than 40 years of research experience in environmental technology, he is a recognized authority in wastewater treatment, particularly in anaerobic digestion and thermal hydrolysis. He is also a senior advisor to teCH4, a company based in Madrid, Spain, with offices in Miami, Florida, USA, and the Republic of Singapore.

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2. Fernández-Polanco, D., & Tatsumi, H. (2016). "Optimum energy integration of thermal hydrolysis through pinch analysis." *Renewable Energy.* Special Issue: Biogas as a Renewable Fuel. 96(B), 1093-1102.

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Online THM analyzer accredited for Barcelona

The leading water utility in Spain, Aigües de Barcelona, received accreditation to the ISO/IEC 17025:2005 Standard for the use of Aqua Metrology Systems' (AMS) online THM-100™ analyzer to continuously monitor trihalomethanes (THMs) in their drinking water supply network servicing 3 million inhabitants in metropolitan Barcelona. In addition to providing the utility with contract compliance and process optimization data, THM readings can now be used to submit regulatory compliance data. AMS is based in the United Kingdom but maintains operations in Silicon Valley, California, United States.

The THM-100 analyzers are an integral part of the utility's THM mitigation strategy, and as such, the utility sought to have them recognized as part of their accreditation.

Aigües de Barcelona's Water Quality Director & Laboratory Manager, Miquel Paraira Faus, says, "The THM-100 is unique in its self-calibration, remote monitoring diagnostic feedback, and online or offline analysis. These features are critical to its ability to provide us with accurate and repeatable results required to meet the ISO accreditation."

Aqua Metrology Systems' CEO Rick Bacon explained that this is the first ISO 17025 accreditation obtained with the THM-100, facilitating the use of the instrument in certified laboratories and representing a significant breakthrough in the application of online field-based instruments for regulatory control of water quality. Bacon says, "We foresee a far wider uptake of advanced online monitoring technology as anticipated by the US Environmental Protection Agency in its Next Generation Compliance strategic initiative for improving regulatory control, efficiency, transparency, and consumer access to compliance data.

Pentair showcases Helix flux innovations at WEFTEC 2016

Pentair plc presented several breakthrough innovations, including the Airlift® and Crossflow MBR technologies with X-Flow membranes and Helix flux enhancement, at WEFTEC 2016,