THE APV INATURE SLUDGE TREATMENT PROCESS

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ABSTRACT

An important component in the operation of large wastewater treatment plants is the Anaerobic Sludge Digestion process. The main aims are to improve the biological conversion rates, maximize gas generation volumes as an energy resource, and minimize sludge disposal volumes that represent a cost to plant operations.

This paper will show that through the innovative use of proven process technologies, a significant improvement in the biological conversion process can be realized utilizing an external recirculation system incorporating a low-pressure homogenizer for digester sludge treatment. We shall show how higher organic conversion rates, increases in energy production (biogas yields), and reduction in sludge volumes can be achieved, and how a net positive financial benefit may be realized after a relatively short payback period.

KEY WORDS
Anaerobic Digestion, Homogenizer, Biogas Production Enhancement, Solids Reduction

1.0 INTRODUCTION

Digestion is a widely used process for anaerobic sludge stabilization at municipal waste water treatment plants (MWWTP's). Typical conversion rates for the organics are 45 - 55%. Due to high investment and operational costs this process can consume up to 30% of total MWWTP running costs.

Increasing cost of sludge disposal and uncertainty of future disposal scenarios are also major issues. Sludge reduction by increasing organic conversion rates is a key consideration in reducing solids disposal volumes and subsequent MWWTP operating costs. Higher conversion rates will improve energy production and reduce energy costs for the MWWTP.

Large sludge particles and flakes do not encourage high conversion rates: they are not conducive to biodegradation processes. Floating sludge, inflated sludge (binding water/air), and digester foaming are all unwelcome upsets. Methods to introduce uniformity in particle size distribution and increase sludge reaction surface area are encouraged.

Adaptation of an effective liquids/solids conditioning process (homogenization), to digester sludge treatment and by incorporating a reliable process design, we can realize improvement in all of these areas.

2.0 DISCUSSION

2.1 The INature – Process System Design

The Inature System is a side-stream recirculation facility. It effects an improvement in the biological conversion process within the digester by conditioning sludge mechanically using a Macerator (for undesirably large upstream solids) and – at the heart of the system - a Low Pressure Homogenizer.

2.2 Low-Pressure-Homogenizer (LPH)

Mechanical homogenizers consist of a high-pressure piston pump and a homogenizing valve (Figure 1). The pressurized liquid has to pass a gap within the valve and hits upon the impact ring. The pressure energy will be released to kinetic energy while creating high shear and impact forces. This process results in intense mechanical homogenization. According to the pressure applied this is called either low-pressure (50-200 bar), or high-pressure-homogenization (200-1200 bar). This technology is widely used in various industries to produce stable dispersions or emulsions. With this system, agglomerates, particles, and droplets are disrupted with high efficiency. At higher pressures (>400 bar) undesirable cell disruption can take place. A negative impact would occur on the digestion process by disrupting anaerobic bacteria species. Higher pressures also demand much higher energy inputs, which make homogenization uneconomical. The highest economy for treating digester-sludge is achieved with a low-pressure-homogenizer at 150 bar. The energy input at this pressure is only 5.5 kWh/m^3 (19.800 kj/m^3). In view of the preceding considerations, the INature system uses a low pressure homogenizer.

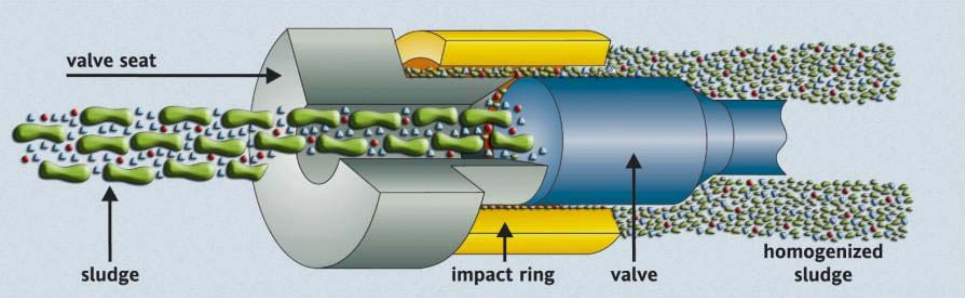

Figure 1: ***Low Pressure Homogenizer***

2.3 Effect of low-pressure-homogenizer (LPH) on digestion-process:

The biological conversion of organic material into biogas takes place within the liquid phase. Particulates are converted by transferring components from the surface into the liquid phase (enzymatic reactions). This process is limited by the surface area available. Sludge agglomerates are separated by air/liquid space cavities and surface-water. These physical barriers hinder the biological reaction process. Effective improvement of the digestion process is achieved by continuous transfer of convertible biomass into the liquid phase, resulting in higher particulate surface area and disruption of agglomerates releasing entrained air or water.

2.4 Effect of low-pressure-homogenizer (LPH) on digester-sludge:

Figure 2 shows typical microscopic structure of untreated and homogenized digester-sludge. Agglomerates, big particles and long-chain bacteria are disrupted after passing through the homogenizer.

Improved particle size distribution of untreated and homogenized digester sludge has been compared; results have been obtained by laser-diffraction-spectroscopy. Figure 3 shows a typical particle size distribution-shift through homogenization.

Note at X_{50} particle size is reduced from 30 microns to 15 microns; at X_{90} particle size is reduced from 80 microns to 32 microns. The surface area now available for reaction has increased by more than 100%.

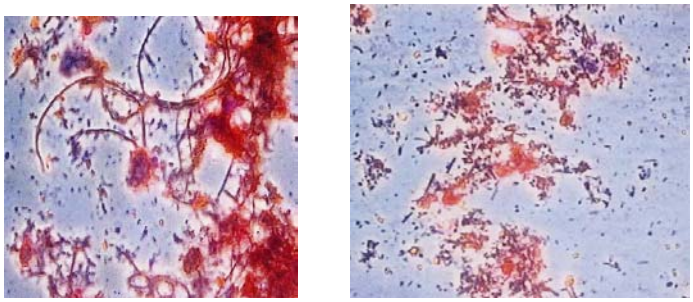

Figure 2: ***Typical microscopic structure of untreated and homogenized digester-sludge.***

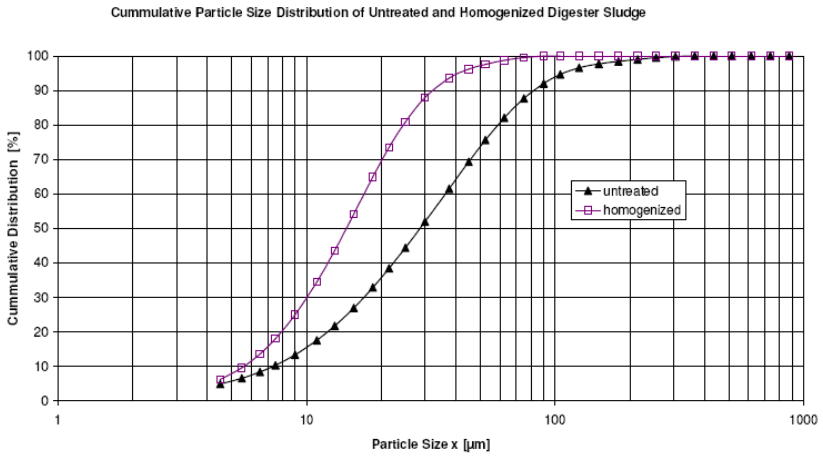

Figure 3: ***Typical particle size distribution-shift through homogenization***

Homogenizer conditioning provides a high input energy conversion rate into sludge disruption. Sludge treatment using low-pressure-homogenizers pre-conditions sludge to optimize the biological conversion process, and continuous operation within the recirculation loop provides a consistent supply of convertible substrate to the digestion process.

2.5 Effect of low-pressure-homogenizer (LPH) on biogas-yield:

For digester-sludge that has been treated with the INature low pressure homogenizer, results have returned 25 - 35% increases in biogas production from untreated samples. Figure 4 shows comparative gas-production over a typical 30 day retention period. Please note, that samples used for this investigation were already highly stabilized. Note especially that the improvement in biogas-yield is stable over the full 30 day period. For other processes such improvements have typically only been reported for the starting phase and short digestion periods.

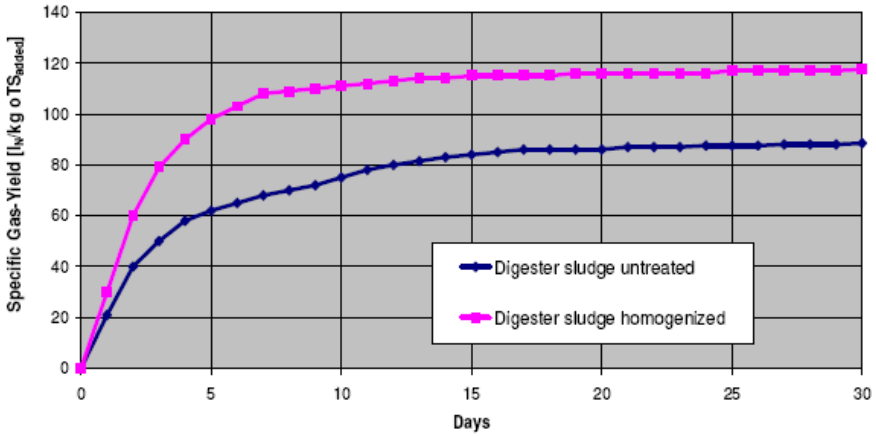

Figure 4: ***Comparative gas-production over a typical 30 day retention period***

2.6 Effects Of Sludge On Process Equipment – Design Considerations

Standard mechanical homogenizers are designed to process clean fluids. Reliable operation on digester-sludge requires adaptation of the critical machine components. Particulates and their resulting wear characteristics are key issues.

The INature homogenizer unit employs a revolutionary homogenizer-valve which is designed around the needs of treating digester-sludge. The free-floating-valve [patent pending] allows big particles to pass, recognizes contaminants, and has a self-cleaning mode. These features combined with a high homogenizing efficiency allow reliable and effective treatment of digester-sludge.

Upstream of the homogenizer, an optimized macerator prevents passage of particles too big to be handled by the equipment – cotton .

The high Pressure feed pump employs piston packing and ball valves specifically designed for the application.

Tailored valves, feed pump, and optimized piping and automation technology complete the containerized process-equipment package. See figure 5.

Figure 5: ***Tailored valves, feed pump, and optimized piping technology***

2.7 Demonstration Plants – Operation & Results

Plant A: MWWTP Scharzfeld, Germany (20,000 PE)

Plant operates 2 mesophile digesters joined in series. Digester 1 (1000 m^3) is heated, stirred and equipped with an external recirculation. Digester 2 (750 m^3) has an external recirculation only.

Average feed-flow to the digester process is (44-60)m^3 sludge per day, made up by (35-50)m^3 primary sludge and (9-20)m^3 thickened excess sludge. Hydraulic retention time is (29-37) days. From time to time some fat is added to the feed-flow.

The INature low-pressure-homogenizer was in operation without a thickening-unit The digester-sludge was taken out from the recirculation loop of the second digester, homogenized, then added to the feed-flow of first digester.

The specific flow-rate of the homogenizer was 2.3 m^3/h. Maximum daily throughput of 55.2 m^3 equals 32 days retention time at design flow.

During the operation period 13,326 m^3 digester-sludge has been treated by the homogenizer within 5,815 running hours.

Plant A – Results, Specific Biogas Yields

During the reference period the specific biogas-yield was **450 l_N/kg** oTS_{added}
This increased to **548 l_N/kg** oTS_{added}, an increase of **+22 % with Inature Process**.
The amount of treated digester sludge during this period was 61 % of design flow.

Conversion Rates

Were reported as 53% rising to 65% **with Inature Process**, an increase of 23%.

2.8 Cost/Benefit Example – MWWTP Size 100,000 PE

As an example a cost/benefit calculation for the INature technology is shown using typical plant data for a MWWTP sized for 100,000 PE.

Assumptions:

- -digester feed 297 m3/day primary and excess-sludge
- -sludge has 3.0 % TS and 70 % VSS as an average
- -hydraulic retention time is 20 days, hence digester volume is 6.000 m^3
- -organic conversion rate is currently 55 %
- -specific biogas-yield 452 l_N/kg oTS_{added}
- -sludge disposal costs € 200/ t TS, equals € 11.00 - € 67.00 per ton dewatered sludge
- -biogas used as fuel for combined heat and power unit (CHP), efficiency 35 % ($P_{e|ectr}j_c$)
- -biogas energy content 6.4 kWh/m^3_N
- -costs for electrical power 0.07 €/kWh, sold for 0.09 €/kWh (green tariff)
- -60 % of sludge to be homogenized for 25 % higher conversion rate

2.9 Cost/Benefit - Additional Biogas-Less Sludge

Using INature technology gives significant higher organic conversion rate.
Biogas-yield will increase by 25 %. Specific biogas-yield increases to 565 l_N/kg oTS_{added}.
Total biogas production per year will rise by 257.000 m^3_N.
Out of this additional biogas 575,000 kWh electrical power will be generated by CHP (combined heat & power unit) per year.

This equals a benefit of **€ 51,800 pa**

Because of higher organic conversion rate, sludge for disposal will be reduced.
Reduction of sludge mass is 313 t/year (conversion rate raised to 68.75 %).

This equals a benefit of **€ 62,600 pa**

3.0 SUMMARY

Benefit from additional electricity	+51,800 p.a.
Savings from disposal costs	+62,600 p.a.
Total Benefit	+114,400 p.a.
Less INature Running Costs	-44,499 p.a.
Net benefit	+69,901 p.a. – AN ENERGY POSITIVE PROCESS

4.0 CONCLUSIONS

The INature system incorporating customized Low-Pressure Homogenizer technology, is a reliable process that significantly improves anaerobic digester performance.

INature provides a continuous supply of 'conditioned' sludge optimized to maximize organic conversion rates, gas yields, sludge reduction, detention times, and reactor throughput.

INature is a side-stream process. It enhances Reactor performance, but the reactor may continue to operate at reduced efficiency if it is taken off line (for maintenance).

INature is an Energy Positive Process – it creates more energy and cost advantages than it uses.

INature is proven; it has already been shown to operate effectively on two MWWTP sites for over 7000 hours.