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Upscale and demonstration of an integrated novel microwave pre-treatment system for efficient production of biogas from anaerobic digestion of pig manure to create a sustainable waste management system

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Executive Summary

In this deliverable, Ashleigh Environmental have demonstrated the optimized complete system and the various works completed to streamline both the AD facility and the biowave system into one functional system by the addition of auxiliary equipment when and where necessary to optimize the complete system. Example of challenges and the innovative solutions are also given herein.

1 Deliverable 7.3 Optimized Complete System

PART 1 Anaerobic Digestion Plant Optimisation

1.1 Installation of sub-agitator

Figure 1. 3- initial blockages in pipework from buffer tank

After the first six week of commissioning the pipework (check valve and reducer) from the 3-day buffer tank to the mono pump began to block with accumulated solids that were settled in this buffer tank. This disrupted the feeding regime, biogas production and subsequent heating of the digester as a tractor drawn slurry spreader had to be borrowed and connected to the buffer tank to remedy the blockage on numerous occasions which took time to organize. No over-night feeding of slurry to the AD occurred during this period to offer protection to the progressive cavity pump running dry.

Figure 2. left image is compacted solids existing the pipework of the buffer tank, the right image is the sub-agitator ready for installation.

On the 3rd week of December 2017, the buffer tank was drained and Ashleigh Environmental removed the 90° bend inside the tank and in the same week inserted a 5kW submersible agitator to maintain a homogeneous mix of slurry and prevent solids settling in the bottom of the tank which were causing the blockages. The supplier of the agitator delivered the agitator without the star-delta control panel, thereby making the agitator inoperable until the 1st week of February 2018. Once operational a small noticeable increase in gas production occurred due to the feedstock being better homogenized and this section of the AD system has been trouble free since.

1.2 Installation of Timed Water-Jet System

Figure 3. left image is the water-jet system in place, the right image is the simple water-timer to operate the jet every four hours.

Other challenge that developed was that the outlet pipe to the digestate storage began to intermittently block with solids causing digestate spillages once released and a build-up of gas pressure (due to AD tank liquid volume increase) and subsequent pressure drop when liberated resulting in a distribution to the heating temperature of the digester. This problem resulted in hours of gas boiler down time, having an overall negative effect in system performance. This occurred intermittently over several months. The solution to this problem was to insert a water jet (from mains water supply) into the outlet pipe, using a timer to operate every four hours to assist in the flow of solids through the pipe into the digestate store. Thus far it is proved to be a great and inexpensive success.

1.3 Installation of 25kW Oil Boiler

Figure 4. 25 kW oil boiler to augment the thermal energy requirement during commissioning stages.

The methanogen auto commissioning mode was running over Christmas period into January, but this system began either to underfeed or overfeed the digester and the electrical costs were approx. €30/day to operate and was de-commissioned since the 18kW immersion heated was running since start up commissioning.

It was decided to install a small oil boiler (25kW) at the end of January thereby replacing the electrical immersion heater. This boiler continued to assist in heating the digester as the AD system could still not sustain itself at this stage with the inferior quality of slurry arriving from the farm coupled with the commissioning occurring over the colder winter months.

1.4 Optimisation of Slurry Quality from The Farm

A pig slurry quality review was performed initially by LJMU to discern which was the best pig house to receive slurry from. Also, the general management of slurry from each of the six houses was undertaken to improve the flow to the biowave-AD system. It was decided to receive slurry only from the fattening houses where possible and as fresh as possible with minimal disruption to the daily operation of the commercial pig farm.

1.5 Hydrogen Sulphide Abatement

Hydrogen sulfide (H2S) occurs in all biogas regardless of feedstock used. It can be especially high in biogas if the substrate is mainly from animal slurrys. The average H2S ppm in Ashleigh Environment's biogas is approx. 3657ppm which is very high considering that a typical CHP unit upper recommended limit of H2S is somewhere between 200 to 300ppm. Dosing with ferric hydroxide occurred in April to attempt to reduce the H2S but proved very expensive to sustain long term. Currently the gas analyzer is offline as it will not log any biogas composition data with H2S levels above 5000 ppm. As time goes on the average H2S will increase to unknown levels >5000 ppm. The economics of scrubbing the biogas with this level of H2S and having to make very frequent oil changes to any potential CHP biogas engine currently do not make the economics very viable.

It was decided to install an 80 Liter/minute air pump on a timed cycle to attempt to abate the H2S level in the biogas. By injection air (oxygen) into the gas collecting head space thereby creating a biological environmental for Sulphur eating bacteria to reduce the H2S in the biogas. Currently this is being trailed.

PART 2 Biowave System Optimisation

2.1 Biowave Slurry Throughput Optimisation

Pig slurry settles very quickly in the system with the liquid fraction continuing to flow while the solid fraction remains and builds up in pipework until complete failure occurs. The biowave system is very stable once the process is running and the correct flow rates are obtained. Two check valves were modified to further prevent blockages and any system fatigue.

Figure 5. left is caked solids blocking the check valve with swing-flap removed, right is a modulation valve caked with solids.

2.2 Development of Maintenance Regime.

Ashleigh Environmental, LJMU and SAIREM have reviewed the process and produced a cleaning regime to keep the system clean.

2.3 Process Optimisation

The trailing and validation of the Biowave AD system since March 2018 has provided the opportunity to identify any areas of the overall system design that would need to be re-evaluated, and modified to further optimise the Biowave AD system. The main areas under review is the pumping system and power requirements of the system.

2.6 Optimisation of Heating Philosophy

Figure 6. Shows the pipework and valves arrangements of the Biowave AD system.

The average temperature of the pig slurry over the summer period is approx. 20˚C. Over the winter period slurry temperatures can drop to 5 to 10˚C depending on how long it resides in the pig slurry holding buffer tank.

Throughout the installation and commissioning phases efforts were made to continuously optimise the heating systems associated with the system. These process optimisations are now being implemented and trials continue.

2.7 Optimisation of Flushing Sequence to the Biowave Process

When running the essential flushing sequence to clean the biowave system after batch processing the flushing pump was initially connected to the farm mains water supply. It was observed that the pressure in the spray jets to wash the hopper was low and slurry residue was left on the sides. It was decided by Ashleigh Environmental and recommendation by EMCA to install a 1m³ IBC water container as close to the flushing pump as possible. This provided a reservoir to satisfy the demand of the flushing pump. The delivery of water and the volume of water used into the flushing line has improved and the biowave system now automatically cleans itself more efficiently. The volume of water required to flush the system has significantly reduced since the installation of the IBC.

Figure 9. IBC plumbed with a ballcock to main water supply and outlet connected directly to flushing pump in biowave container.

2.8 Conclusion

The fully integrated Biowave AD system have been successfully completed, thereby creating the first of its kind microwave pre-treatment system of pig slurry. The optimization of the complete system resulted in a holistic approach where various system challenges were analysed and subsequently engineering solutions were introduced at this bespoke biowave-AD pilot facility to further optimise the complete system. Further technical information on the optimised system is described in the periodic report.