Project Summary and Key Takeaways

Evaluation of the potential for improvement of the Residual Biogas Potential test and investigation of alternative test procedures for 'End of Waste' biofertilisers

Project Summary

The Residual Biogas Potential (RBP) test is used to evaluate the stability of digestate samples in anaerobic conditions. The RBP test is a component of PAS 110:2014, which sets the compliance requirement for stability of digestate derived from the anaerobic digestion of source-segregated biodegradable materials. Operators who wish to achieve quality assured- and end-of-waste status digestate under the Biofertiliser Certification Scheme (BCS) must comply with PAS 110 standards.

BCS Participants who experience difficulties with the RBP test (i.e., test failures or invalid results) may face considerable operational challenges as material that does not pass the test must be held on-site until a passing result is achieved—a minimum of 28 days (the duration of the RBP test).

This project aimed to understand the cause of test-related failures and invalid results, explore potential improvements to the method, and/or identify suitable alternatives. The four research objectives and key findings for each are outlined below.

Objective 1: ***Identify any patterns with respect to test failures and non-responses***

Under PAS 110, an RBP test failure occurs when the final result exceeds 0.45 litres of biogas/gram of volatile solids. Invalid results, reported in the REAL database as non-responses (NR), can be caused by three things. NR (1) indicates an anomalous result, NR (2) indicates equipment failure, and NR (3) occurs when negative biogas production is recorded after the first five days of the test.

Analysis of historical RBP data found a very low failure rate (0.7% in 2020 and 1.3% in 2021). In practice, NR (1) and NR (2) also cause very few issues. Rather, the majority of troublesome results are NR (3) as these most often prevent a site achieving a valid result for certification purposes.

This project built on previous work to support the finding that NR (3), can be attributed to a phenomenon called ammonia inhibition, which occurs when digestate samples high in ammonia are treated with standardised sewage sludge inoculum (as specified in PAS110), comparatively low in ammonia. The contrast in conditions effectively 'shocks' the microbial community, resulting in a precipitous (but temporary) decline in biogas production.

BCS approved labs do not routinely report final RBP values after an NR (3) is flagged, as the sample would not be valid for certification purposes. However, for this project, testing continued for the full 28 days. In all cases where NR (3) was reported, the biogas curves eventually returned to a normal level as the microbes acclimated to the new conditions over time. Therefore, to minimise issues caused by NR (3) results, one option could be to consider abandoning the requirement for positive gas production after five days as the test may ultimately be completed successfully. Moreover, to facilitate future analysis, final RBP values and daily biogas production curves could be reported to the REAL database.

Objective 2: ***Investigate whether it is possible to predict the 28-day test result by analysis earlier in the RBP test procedure***

This portion of the study involved conducting 30 RBP tests on various digestate samples. This investigation aimed to explore the possibility of predicting the 28-day test results by analysing data

collected in the first 10-15 days of the test. The predictive accuracy of three models (first-order kinetic, Gompertz, and Chen and Hashimoto) were assessed, with mixed results.

While the data show potential to develop predictive curves, each curve is site specific, as RBP is largely dependent upon digester retention time and the total achievable biogas production from the feedstock (which vary between sites). Further, the models performed inconsistently (e.g., the first-order kinetic model performed well for separated fibre but had limitations in accounting for changes in the biogas curve, whereas the Chen and Hashimoto model exhibited good performance for whole digestate and separated liquor but faced challenges with separated fibre.)

The unique characteristics of different feedstocks and the complexities of AD processes require a tailored approach for each test, making a 'one-fits-all' model to replace the RBP test impractical. Therefore, applying early predictive models to RBP tests is not currently recommended as a suitable alternative for quality control within the PAS 110 specification.

Objective 3: ***Investigate the efficacy of using different inocula to achieve greater reliability***

Building on section 1, digestate samples taken from a single site were treated with four different inocula: sewage-fed, food waste-fed, farm crop-fed (from the sampled site), and farm crop-fed (from another site) and tested to clarify the impact on RBP results from using different inocula.

In all cases, digestate samples using municipal wastewater inoculum (currently the required inoculum under PAS 110 for standardisation purposes) produced more gas than those using inoculum from the food waste or crop-fed digesters.

The data suggests that the specific inoculum used impacts the rate and quantity of gas generated by the test sample. As the wastewater inoculum routinely produced a greater volume of gas, it may not be the most suitable material for this test. Further research could be conducted to find a more suitable standard inoculum. Alternatively, another option is to allow each facility to use inoculum that matches what is already in their digester. This is currently permitted to BCS sites in limited circumstances under the parallel testing procedure. However, if this were adopted more broadly, standardisations would be needed to ensure the inoculum is prepared uniformly across sites.

Objective 4: ***Consider alternative procedures to the standard RBP test (NIRS & Aerobic Tests)***

Novel NIRS tests were conducted to assess its suitability, followed by desk-based research into the applicability of NIRS and several Aerobic tests to the stability determination of digestate.

While NIRS shows promise for rapid, cost-effective, and non-destructive assessments, its application to digestate for determination of residual biogas requires further research and development to establish an applicable procedure (e.g., to process wet samples), database, and model. At this stage, it is not a suitable alternative to the RBP and there are significant concerns over its future potential. Until such a point in time the methodology to process ‘wet’ samples is proven, it is recommended that NIRS is not further investigated as an alternative to RBP.

Aerobic tests offer rapid results but require careful consideration of the inoculum sources. These alternative tests show potential but require further validation and refinement before they can effectively evaluate biogas production and digestate stability as they quantify different processes than anaerobic digestion. Practical challenges also make these tests unsuitable. For instance, the Oxygen Uptake Rate test, included in the EU FPR, can only be applied to samples with a particle size <10mm. Further, a commercial laboratory offering this method in the UK has not been found. However, laboratories using similar standards such as D6691 and ISO7827 have been found in the UK, with a price of £5,000 per sample processed.

Key Takeaways and Next Steps

- BCS sites have a very low failure rate in terms of surpassing the PAS 110-specified threshold for biogas production (0.7% in 2020 and 1.3% in 2021). The majority of results that prevent a site from achieving a valid result for certification are invalid test results which occur when negative biogas production is recorded after the first five days of the test (abbreviated NR (3)).
- NR (3) results are most common for digestate samples high in ammonia due to an inhibitory reaction that occurs when standardised sewage sludge inoculum is introduced. This affect appears to be temporary, with biogas production becoming positive again over time. Therefore, the occurrence of NR (3) results may be resolved by removing the requirement for tests to show positive gas production after day five of the test.
- To enable future analysis, all final RBP values and daily biogas production curves could be reported to the REAL database (even samples that are invalid for certification).
- This project intended to explore whether altering the inoculum to substrate ratio, (effectively diluting the sewage sludge inoculum) has any impact on the frequency of NR (3) results in samples high in ammonium. This was side-lined due to time constraints but may be worth researching in future.
- The unique characteristics of different feedstocks and the complexities of AD processes make a 'one-fits-all' model to replace the RBP test impractical. Therefore, applying early predictive models to RBP tests is not currently recommended as a suitable alternative for quality control within the PAS 110 specification.
- Further research into modelling should focus on improving accuracy using larger datasets and exploring different modelling techniques. It may be beneficial to develop sample-specific models tailored to different feedstock types and/or process specifications rather than pursuing a universal model.
- Digestate samples treated with municipal wastewater inoculum (per PAS 110) consistently produced more gas than those treated with sewage-fed, food waste-fed, and two types of crop-fed inocula. Therefore, wastewater inoculum may not be the most suitable material for this test. Further R&D could identify a more suitable standard inoculum. Alternatively, operators could be permitted to use inoculum that matches what is already in their digester (subject to guidance to ensure inoculum is prepared uniformly across sites).
- Continued research, collaboration between labs, and sharing of microbiological analysis of sludges could facilitate optimisation of the RBP inoculum and greater test accuracy.
- The application of NIRS to digestate for determination of residual biogas requires further research and development to establish an applicable procedure, database, and model (e.g., expand spectral libraries, inter-laboratory validation studies on biosolids, combine with machine learning algorithms). At this stage, it is not a suitable alternative to the RBP and there are significant concerns over its future potential.
- Aerobic tests are not currently a suitable alternative for the RBP test and would require further validation and refinement before they can effectively evaluate biogas production and digestate stability. Aerobic tests also present practical challenges. For instance, the Oxygen Uptake Rate test, an aerobic test included in the EU FPR, can only be applied to samples with a particle size <10mm. Further, a commercial laboratory offering this method in the UK has not been found. Laboratories using similar standards such as D6691 and ISO7827 have been found in the UK, with a price of £5,000 per sample.