Validation of a predictive AD performance model on full scale assets

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Introduction

Anaerobic digestion (AD) is the principal process applied for the treatment of sewage sludge. However, there is a lack of practically applicable and reliable models and support tools to assist in optimisation. An AD process model was developed during an earlier STREAM project (Giacalone, 2017). The aim of this project is to validate, implement and develop the model for process management at full operational scale.

Model Development

The model was developed from a series of bench-scale (50L) AD experiments following a Box-Behnken design incorporating temperature, Primary:SAS ratio and organic loading rate.

The model has three interrelated components to predict different AD outcomes (Fig. 1).

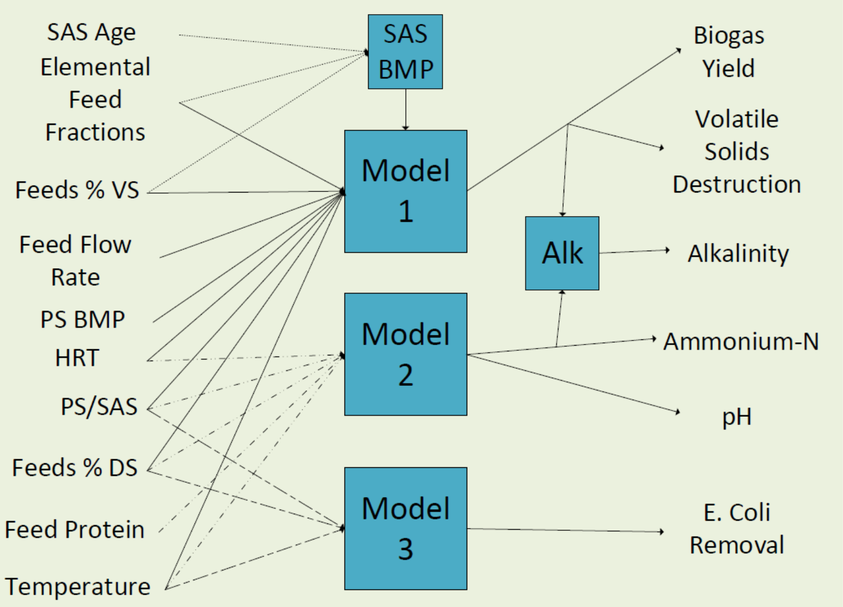

Figure 1 - Model structure

The model(s) were developed using unconstrained multivariate linear regression. The models use specific input data for each sludge feed stream which is combined & fed into the reaction models, to determine biogas yield and digestate ammonium-N, amongst other information.

The model was designed to minimise the data inputs and to use routinely collected samples, thus it has significantly less complexity than other models describing similar systems.

Validation Strategy

The model was developed and validated at bench scale, therefore, full scale validation was required to confirm that the difference in geometry and scale does not effect model performance.

The initial sites chosen for validation operated at a wide range of digestion operating conditions.

A specific data set was developed for this exercise; importantly flow meters calibration was confirmed and data was checked for accuracy before used for model validation.

Biogas Model

Biogas yield is one of the main indicators of AD performance. The model predicts this parameter based on a multivariate regression model providing a rate constant and a corresponding rate equation.

Biogas yield data was collected from three operational AD sites for validation (Fig. 2). The model predicted accurately at low and high biogas yields, without significant skew and therefore provided a reliable prediction of biogas yield.

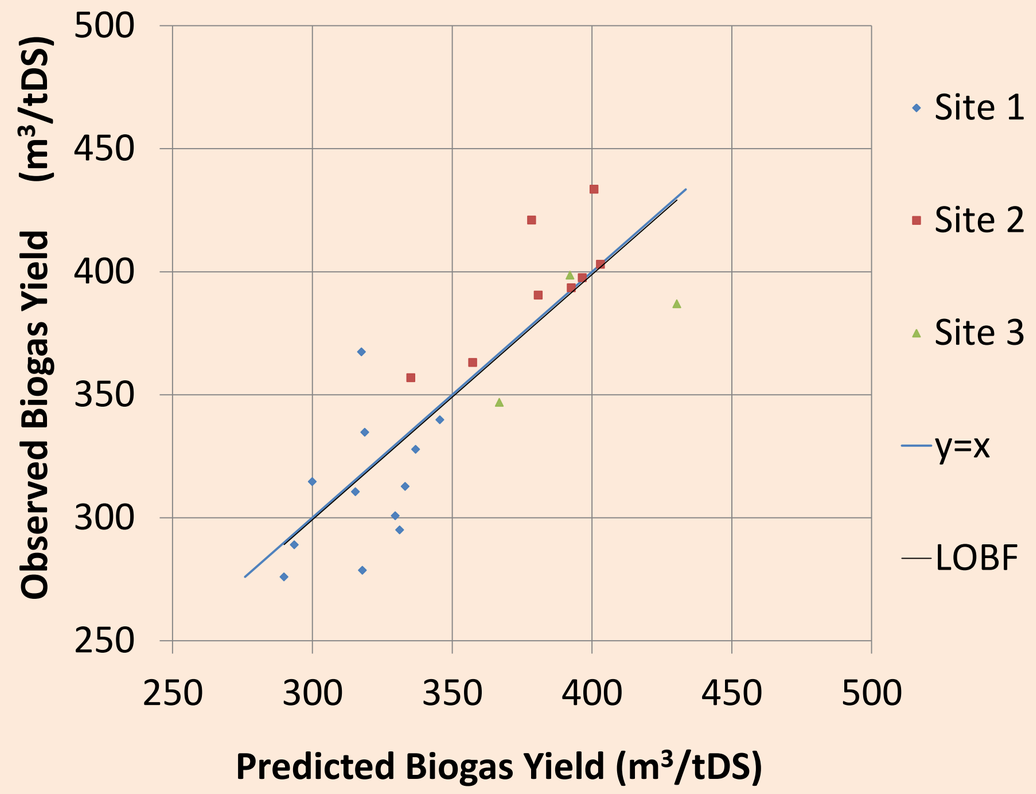

Figure 2 - Comparison of model predictions of biogas yield with measured values for three sites.

Ammonium–N model

Ammonium inhibition can significantly reduce digester performance. Typically operators do not monitor ammonium, so the model could be used to identify sites with potential ammonium inhibition risks.

The model predicted ammonium-N concentrations relatively successfully (Fig. 3). The model is capable of assessing the potential for ammonium accumulation and can distinguish between high and moderate ammonium sites, although at high ammonium-N sites the model appears to overestimate observed values. The high r-squared value indicates the model follows this skewed trend well.

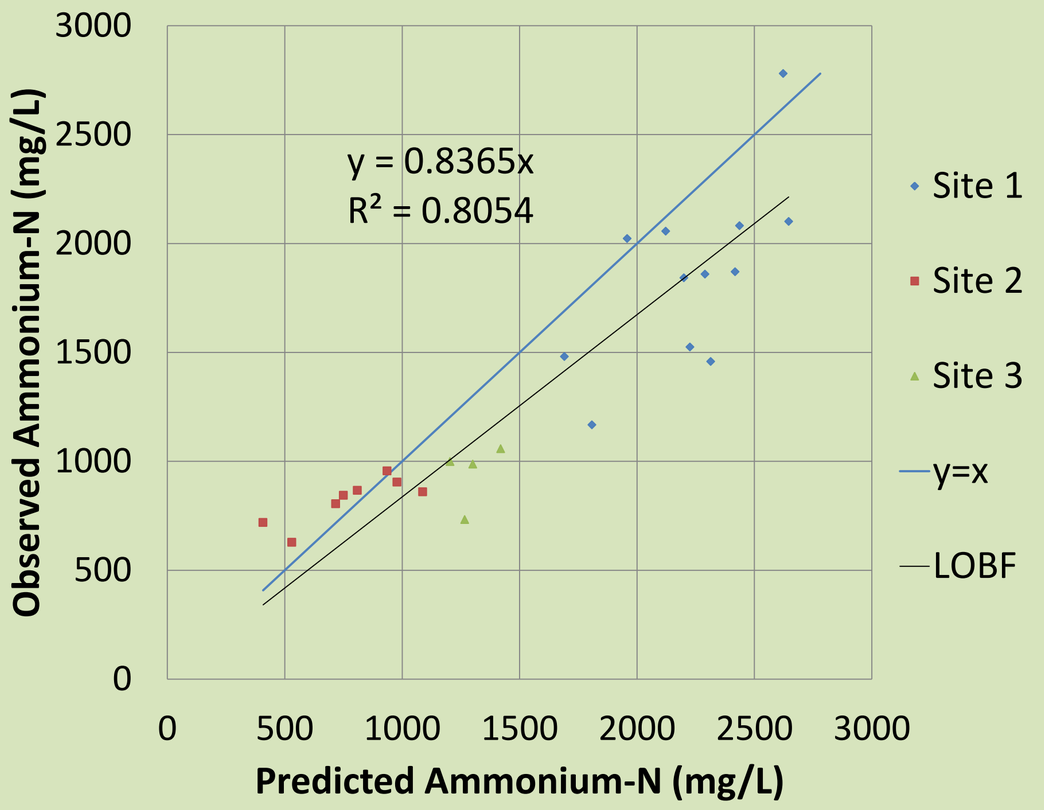

Figure 3 - Comparison of model predictions Ammonium-N with measured values for three sites.

Conclusions and Future Work

During validation at three UK sewage treatment works, a predictive model of conventional sewage sludge digestion showed good agreement with operational data. The data gathered so far shows that the model can predict biogas yield, and ammonium accumulation. The models predictive envelope will be extended to include advanced digestion. The model also has the capacity to predict *E. coli* removal, volatile solids destruction and pH.

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