Applications are invited for a studentship starting, ideally, on 16 September 2024, to be supervised by Dr Ian Bull (University of Bristol).

**Biogeochemical characterisation and impact of a sustainable smart fertiliser manufactured from agricultural waste streams**

UK animal-based agriculture involves hundreds of millions of animals producing many tens of millions of tonnes of faecal waste. Such waste is both a blessing and a curse. While we all would recognise the value of animal dung as a valuable fertiliser for food production, the basic problem is that animal production systems are extremely intensive and highly regionalised. Consequently, huge surpluses of faecal wastes exist, way in excess of what is required locally for arable agriculture. In this common scenario faecal matter presents a major waste disposal problem. Over-application of faecal wastes causes serious degradation of soil health, concomitant with leaching and runoff polluting water courses. The fundamental problem that exists is the insurmountable logistics of transporting millions of tonnes of liquid or semi-liquid faecal waste to locations where it is needed as an agricultural fertiliser. To overcome this CCm Technologies Ltd have developed a novel process that brings together a range of waste streams using innovative chemical engineering and circular economic principles to produce a pelleted smart fertiliser that can be conveniently bagged for transport and handled for field application. Crop trials have already demonstrated the effectiveness of this fertiliser in enhancing yields compared to standard NPK inorganic fertilisers. This revolutionary new fertiliser is high in plant fibre and microbial residues which raises possibilities for building stable organic carbon and nitrogen stocks in agricultural soils. Hence, this fertiliser holds the potential to aid the mitigation of climate change by increasing soil carbon sequestration and improving soil quality, while simultaneously limiting nitrogen loss through leaching and volatilisation.

The proposed PhD project will have two primary themes:

***Theme 1: Qualitative and quantitative biogeochemical characterisation of the pelleted fertiliser***
The need to undertake characterisation stems from uncertainties relating to the biochemical nature of anaerobic biodigester residues used to manufacture the fertiliser pellets. This work will be based on analytical protocols developed in previous studies of faecal materials and soil organic matter undertaken in the OGU. Analyses will be performed on the input streams to the anaerobic biodigester and the resulting residues used as the primary organic feedstock to manufacture the pellets. The pellets will be analysed to assess any changes in composition during production. Pellets formulated from different animal excreta (cattle, chicken and human) sources will be assessed. The analyses will use solvent extraction to determine free lipids and acid/base hydrolysis to determine complex lipids. Strong acid treatment of lipid-extracted residues will be used to determine protein and carbohydrate content, as amino acids and monosaccharides. Pyrolytic techniques with be used to characterise insoluble residues, e.g. lignin. All procedures will be underpinned by state-of-the-art (GC/HPLC) chromatographic-mass spectrometric methods to identify constituent organic components, with internal standards added to enable quantification of the different biogeochemical fractions.

***Theme 2: Biogeochemical impact of the pellet in terms building soil organic carbon and nitrogen***
This theme builds on the extensive experience the OGU has in determining the fate of farm wastes in soils at the molecular and isotopic level. The work will involve two aspects:

(i) *Assessing the amount and biochemical nature of soil organic carbon following pellet fertiliser application and cropping*. This can be assessed in the field using soils from crop trials compared to conventional fertiliser treatments and in the laboratory using crop plants grown in pots with and without pelleted fertiliser applied. The same analytical chemical techniques as used above will be applied to the pellet-treated soils. Ideally, the crop should be maize to enable the organic carbon contributions from the crop and pellets to be separated isotopically. In addition to the detailed molecular analyses, bulk soil %C and $\delta^{13}C$ values will be determined to provide baseline information on the overall soil organic carbon pool.

(ii) *Assessing the fate of pellet ammonium nitrogen in soils and plants*. Again, this aspect of the project builds on extensive experience built up in the OGU in tracing and quantifying the fate of applied ammonium using $^{15}N$-amino acid stable isotope probing. The experiments will use $^{15}N$-labelled pellets produced by CCm's pilot plant by adding $^{15}NH_4SO_4$ to the biodigester feedstock used to manufacture the pellets. Given the expense of producing the $^{15}N$-pellets the experiments will be restricted to maize grown in pots or metre square plots. The experiments will be run until the plants reach full maturity. Soils will be subsampled and

submitted to strong acid hydrolysis to yield proteinaceous amino acids. After derivatisation the $^{15}N$ content of the amino acids will be determined by gas chromatography-combustion-isotope ratio mass spectrometry. The analyses will yield important quantitative information on the production of organic N in soil following pelleted fertiliser application. As above, in addition to the detailed molecular analyses bulk soil %N and $\delta^{15}N$ values will be determined to provide baseline information on the overall soil organic N pool. Determination of $\delta^{15}N$ values for the plant tissues will allow nitrogen use efficiency to be determined for the pellets compared to conventional fertilisers.

***Deliverables***

The main deliverables will be:

(i) Novel knowledge of the biogeochemical composition of anaerobic biodigester waste.
(ii) Qualitative and quantitative assessments of the fate of pelleted biodigester waste in the soil at the biogeochemical level.
(iii) Development of a mechanistic understanding of how CCm fertilizers contribute to soil C sequestration.
(iv) Qualitative and quantitative knowledge of the fate of ammonium N from the pelleted biodigester waste routed to soil, crops and the atmosphere.
(v) A highly trained PhD analytical chemist with key skills in setting up agricultural experiments and analysing organic matrices at the molecular and isotopic levels

## Candidate Requirements

Applicants must have obtained, or be about to obtain, a First or Upper Second Class UK first degree, or the equivalent qualifications gained outside the UK, in chemistry or in a related discipline (biochemistry, biogeochemistry, environmental sciences).

## How to Apply

Please make an online application for this project at the following page How to apply | Study at Bristol | University of Bristol .

## Funding

A full studentship will cover UK tuition fees, a training support fee and a stipend (£18,622p.a. in 2023/24) , updated each year) for 4 years.

## Getting in Contact

To discuss this project in advance of making an application, please contact Dr Ian Bull (ian.d.bull@bristol.ac.uk).