Engineered Anammox Biofilms for Low-Energy Wastewater Remediation and Environmental Protection

Lead Supervisor: Joseph L. Keddie, University of Surrey, School of Maths and Physics

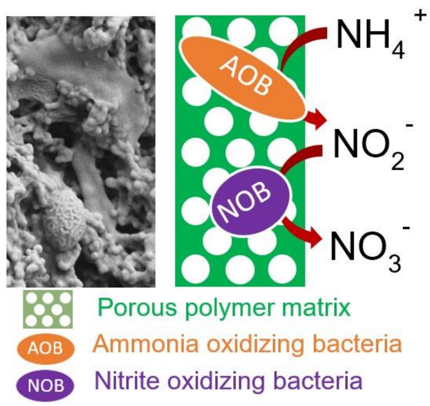
Email: j.keddie@surrey.ac.uk

Co-supervisors: Bing Guo, University of Surrey

Nitrogen, in the forms of ammonium and nitrates ions, is a serious problem in the UK and elsewhere in water being discharged into the environment because it can harm aquatic ecology and detrimentally affect human health. Run-off of water from agricultural land and effluent from sewage are both major sources of nitrogen in water. In this research project, an improved way to employ a biological process to remove nitrogen will be investigated and developed.

Combinations of nitrifying and denitrifying bacteria are already used to convert ammonium ions to nitrates and then to nitrogen gas. But the processes consume a large amount of energy and are expensive, making them less viable. An attractive alternative, consuming less energy and being less expensive, is to use anammox bacteria, which convert ammonium and nitrites directly to nitrogen gas. The name "anammox" is derived from the phrase "anaerobic ammonia oxidation".

Although anammox bacteria are a promising way to tackle an environmental problem, with 200 anammox facilities operating worldwide, they are not easy to work with. To perform their function, they need to be immobilized and remain active in biofilms across a range of temperatures. A biofilm is the natural habitat of bacteria in the form of a layer of organisms surrounded by natural molecules, such as saccharides and glycoproteins, to form a matrix. In this research, you will investigate ways to make a type of "synthetic biofilm" by encapsulating anammox bacteria into water-based paint coatings. These so-called "biocoatings" can be used in the future in bioreactors for agricultural or city wastewater. In natural systems, an anammox process relying on biocoatings could be employed in wetlands constructed by humans.



Already at the University of Surrey, our team has devised a biocoating containing metabolically-active *E. coli* bacteria as a model organism. More recently, we added nitrifying bacteria to a biocoating and successfully removed ammonium from water in a bioreactor.

In the first half of the project, you will focus mainly on developing ways to make a synthetic biofilm containing the anammox bacteria. You will use the facilities of the Soft Matter Group at Surrey, where there are several ongoing projects relating to colloidal coatings and biocoatings. Water-based coatings (such as emulsion paints) are normally made by allowing all of the water to evaporate. The polymer particles in the dispersions pack together and fuse to make a strong and robust material. Some species of bacteria cannot survive this type of drying process. In this project, you will make biocoatings by forming a wet gel layer on porous substrates. The bacteria will be kept alive as polymer particles in the wet gel fuse to make a strong biocoating. You will explore how to optimise the coatings through the selection of the polymer particles, the gelation methods, and the processing times and temperatures. You will add electrically-conducting nanomaterials to the biocoatings to assist extra-cellular electron transport. You will then investigate the metabolic activity of the bacteria using kinetic experiments, batch tests, fluorescence methods, and high-resolution electron microscopy. You will also study the growth of natural biofilms on the synthetic biocoatings, as it is hypothesized that biofilms will be seeded on the coatings.

In the second half of the project, you will use the biocoatings to treat samples of real wastewater and surface water. You will collect surface water in the field, such as on agricultural land. Compared to model systems of ammonium solutions, real wastewater is more complex because it contains a range of organisms and matter, which can interfere with the chemical reactions. Using the laboratories in Civil and Environmental Engineering at Surrey, you will characterize the properties and function of the biocoatings and measure their efficiency in removing nitrogen. The main outcome of the project is to have biocoatings that contain anammox bacteria that are able to remove ammonia from wastewater and surface water. Ultimately, the project will lead to an improved method for treating water using less energy and lower costs, which can help to address the pressing environmental concern of nitrogen.

Training opportunities:

The project includes a three-month placement at Advanced Material Development, where you will learn about technology transfer and scale-up in the environmental sector. There will be an opportunity for fieldwork (collection of surface water in wetlands). You will work in an interdisciplinary environment using laboratories in Civil and Environmental Engineering and in the Soft Matter Group. Important skills in environmental science, including water engineering, microbiology, and analytical chemistry will be developed.

Student profile:

This opportunity will be ideal for a candidate with interests in environmental science and with a relevant degree in biomaterials engineering, environmental/water engineering, physical chemistry or microbiology. Good practical laboratory skills, analytical skills, and teamworking skills are desirable.

Funding particulars:

Anammox bacteria will be provided by industrial collaborators at Thames Water. Nanomaterials will be provided by Advanced Material Development Ltd, who will also offer a three-month placement.

References:

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University of Surrey press release.

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