Modelling microbial immigration at critical interfaces of urban and natural water environments

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Anthropogenic activities have caused more and more ecological burdens and disturbances to natural environments. Besides the chemical pollutants, microbial pollutants are continuously discharged from urban environment to natural environment. For example, wastewater carries microorganisms from human waste (gut microbiome), sewer sediments, and land runoffs to wastewater treatment plants (WWTP, which use bioreactors), the bioreactor microbial mass is partially removed and enters the natural water bodies (e.g., rivers, lakes, ocean). At the interfaces of these compartments (sewer, WWTP, river), the microbial flux is hypothesized to influence the microbiome of the receiving compartment through Microbial Immigration process[1,2]. Continuous microbial immigration at these interfaces may affect the microbial community composition and functions to various extends. Some low abundance but highly important species are also affected by this process, for example, nitrogen cycle species (nitrification, denitrification) and pathogens and antimicrobial residence bacteria, which are crucial for the natural environment health and public health.

The importance of microbial immigration has been reported in literature, but contrasting conclusions were made. Through analysing the microbial community similarity of the connected compartments, some studies showed high or low similarity or numbers of shared species. A major challenge is the lack of quantification methods and models. Studies are looking into the effects of urban wastewater discharge to natural waters, either treated by wastewater treatment plants (WWTP) or untreated. Monitoring and surveillance are important aspects, while it is crucial to have ecological theories and models to understand the observed data and predict future status. The supervisory team's previous work has developed quantitative steady-state mass-flow immigration model[1,2] for the sewer-WWTP interface and monitored microbial communities in WWTP and river catchment in the UK. Based on the previous work, quantitative models of microbial immigration from WWTP to rivers at steady and non-steady states can be built.

This project aims to develop quantitative methods and models based on microbial immigration theory, to track and predict microbial pollutants from urban to natural water. The student will review the literature and develop mathematical models of microbial immigration, construct lab-scale experiments and quantitative measurements of microbial community, and test different scenarios of wastewater discharge to river.

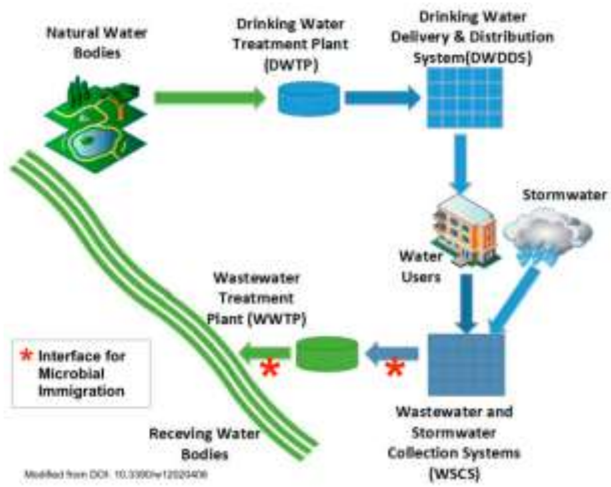

Figure 1. Urban-environmental water flow and critical interfaces for microbial immigration.

Training opportunities:
The student will receive guidance and training on mathematical modelling, wastewater engineering, reactor design and operation, and microbiology and mentorship from the supervisory team. The student will develop critical thinking, analytical skills, and new methodologies within the topic area with relevant support to ensure they can succeed and generate novel data which they will then be encouraged to present at institutional, national and international level conferences throughout the course of their PhD and that will form the basis of high-quality journal papers. The project aligns with cutting-edge research in the international research community and allows student to build up research profile in the microbial ecology area. The output could influence policymaking and industrial transformation to cope with climate change, net zero and sustainability.

The student will have access to expertise on environmental microbiology and modelling (Guo, Read), facilities to establish lab scale wastewater systems (Surrey), access to a state-of-the-art microbiology laboratory (CEH) and expertise in pathogen-related microbiology (Ritchie) to ensure that data generated fit for the purpose of quantitative modelling, environmental risk assessment and informing policy and industry. The supervisory team has existing links with water company (Thames Water) and access to sampling locations is readily available. International collaboration and exchange/placement are also available (McGill University, Canada).

Student profile:
This project would be suitable for students with a Masters' Degree in microbiology, environmental engineering, mathematics or a related topic with 2:1 or 1st class degree in the above subject areas. They will show an aptitude for understanding microbial ecology or mathematical modelling and working in a precise manner. They should be a self-starter with the confidence to interact with a wide range of contacts from academic to laboratory staff and industrial contacts and they must demonstrate enthusiasm and willingness to learn. Experience in microbiology, molecular biology, or mathematical modelling would be advantageous.

References:

1. Guo, B., Sheng, Z. & Liu, Y. Evaluation of influent microbial immigration to activated sludge is affected by different-sized community segregation. *npj Clean Water* **4**, 20 (2021). https://doi.org/10.1038/s41545-021-00112-7
2. Guo et al. Wastewater Influent Microbial Immigration and Contribution to Resource Consumption in Activated Sludge Using Taxon-Specific Mass-Flow Immigration Model (2022) https://doi.org/10.1101/2022.08.15.504022

https://research.reading.ac.uk/scenario/