Project Title	Modelling Pollution Transport in Vegetated Flow Environment
University (where student will register)	University of Warwick
Theme (Max. 2 selections)	Climate & Environmental Sustainability ☒ Organisms & Ecosystems ☐ Dynamic Earth ☐
Key words	Plastic recycling; Flash graphene; nanographene; density functional theory; Plastic waste; sustainability
Supervisory team (including institution & email address	**PI: Dr Soroush Abolfathi** Soroush.abolfathi@warwick.ac.uk **Co-I: Prof Gary Bending** G.Bending@Warwick.ac.uk **Dr Jonathan Pearson** J.M.Pearson@Warwick.ac.uk **Dr Petr Denissenko** P.Denissenko@Warwick.ac.uk

Flagship Criteria Intake 2023	**Score**	
CENTA2 L1/2 end-user co-development and supervision 2 for a L1/2 partner that have no prior CENTA collaborations: Jacobs, Marine Biological Association, AstraZeneca	**(2+2)**	**2**
CASE project, confirmed by a specific letter of support from the CASE partner, projects without such a letter clearly stating commitment will not be awarded a point.	**1**	**1**
Diversity of the supervisory team (diversity towards e.g., gender, ethnicity, disability, and cultural background)	**1**	**1**
Career development of the supervisory team: specifically targeted at projects led by an academic who is seeking their first PhD student as lead supervisor.	**1**	**1**
Collaboration project with one of our Research Centre Partners (BGS, CEH, NCEO, NCAS) led by an academic from an HEI partner	**2**	
Applicant co-development of the project	**1**	**1**
Sum	**10**	**6**

Project Highlights:

- Identifying and quantifying the key underlying mechanisms that govern the transport and fate of pollutants (solute and solid) in vegetated freshwater flow domains.
- Development of models capable of simulating pollutant transport processes, nutrient removal efficiency, and hydraulic efficiency in vegetated flow domains (e.g. river, pond, wetland).
- Undertaking scenario modelling to Investigate the effects of climate variability, seasonal and interannual variation in vegetation composition on the pollutants transport and fate in vegetated environmental flows.

Overview (including 1 high quality image or figure):

Vegetation is often present in environmental flow domains (e.g. streams, rivers, wetlands, and estuaries), playing an important role in maintaining the water quality by providing oxygen and reducing the suspended sediment concentration. The presence of vegetation enhances solute mixing and diffusion within the vegetation due to the effects of the plant stem wake and the resulting complex hydrodynamic structure. Hence, modeling the flow and pollutant transport in the presence of vegetation is vital for understanding solute mixing and the diffusion within a canopy, and environmental flows.

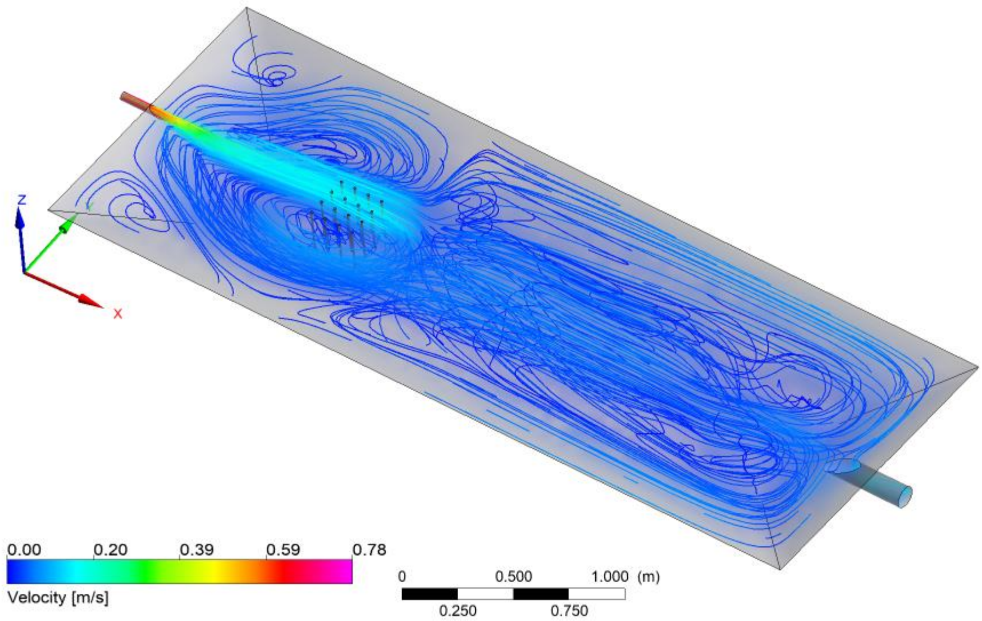

Figure 1: Numerical simulation of tracer concentration trajectory across a pond with flexible vegetation

Vegetated environmental flow systems are significantly important for freshwater ecology and biodiversity. The combination of soil, sediment bed, vegetation, and organisms in environmental flow systems can facilitate treatment of water and removal of solute and solid pollution. It is the interplay between water-vegetation-soil that governs the physical, chemical and biological processes influencing pollution transport and fate. Dynamics of water movement and the interactions with vegetation plays a key role in determining the mixing and dispersion of pollutants in environmental flow systems. Plant communities have a prominent effect on the hydrodynamics and performance of these flow systems, as they generate flow resistance, changes the velocity field, and affect mixing characteristics, enabling suspended material to fall to the bed of the flow domain. Seasonal variation in vegetation growth and die-back influences the performance of these systems. However, critical knowledge gaps remain in sources and fate of pollutants in vegetated environmental flow systems.

The main aim is to identify and quantify key mechanisms that govern the transport and fate of pollutants using laboratory studies and field-based data collected by our industry partner, Norfolk Rivers Trust. This project will also use the physical and field-based data to develop and validate numerical model to simulate the interaction of solute and microplastics with vegetated flows and sediment bed. The new insights offered by this project will enable understanding the dynamics of pollutant transport in vegetated freshwater flow systems. Hence this project will provide a step change in environmental protection and integrated catchment management by understanding and quantifying the pollution transport and fate in vegetated flows, and significantly, be influential at a time of considerable pollution stress on freshwater systems.

Methodology:

This project will undertake laboratory-based physical modelling measurements and fieldwork data collection to understand the dynamics of pollutant transport in rivers and wetlands. We will create an interacting mesocosm river and wetland environments using the world class experimental facility at Warwick Water Laboratory. Fluorometric tracing along with novel particle staining techniques will be applied, alongside planar laser-induces fluorescence (PLIF) with the aim of identifying and quantifying underlying physical transport mechanisms of pollutants and the impact of hydraulic conditions on the transport and fate of the pollutant.

The effects of vegetation on the flow (in rivers and wetlands) and pollutant characteristics will be modelled by developing numerical models based on the Reynolds averaged Navier–Stokes (RANS) and large eddy simulation (LES) method. We will develop particle model of scalar transport for both rigid and flexible vegetation. The numerical model will be validated against experimental data and scenario modelling will be performed.

Training and skills:

Students will be awarded CENTA2 Training Credits (CTCs) for participation in CENTA2-provided and ‘free choice’ external training. One CTC equates to 1⁄2 day session and students must accrue 100 CTCs across the three years of their PhD.

Training will be provided in a wide range of numerical tools to process and analyse experimental fluid dynamics data. Training on particle staining technique will be provided for microplastics tracer measurement. The student will be trained in cutting-edge hydrodynamic and fluorometric measurement techniques including, Particle-Image-Velocimetry and Laser-Induced-Fluorescence. Through our industrial partners a range of training will be provided on catchment planning and management, and pollution risk management. In addition, the researcher will be trained for using the world-class High-Performance Computing facility at Warwick.

Partners and collaboration (including CASE):

Name of L1/L2 Partner (where applicable)	
Name of CASE partner (where applicable – project proposal **must** be accompanied by a letter of support from the CASE partner)	*Norfolk Rivers Trust*

Further information on partners and collaboration (including CASE):

This PhD project benefits from supervision by two internationally leading groups at University of Warwick including, Warwick Water (Engineering) and Microbial Diversity and Functioning (Life Sciences). The research team are internationally recognized for their research into fate and transport of contaminants in aquatic and ecologically sensitive systems. Besides the standard NERC PhDfunding, the project is supported by Norfolk Rivers Trust (NRT) and Anglian Water. The Student will have the opportunity of data collection in wetlands operated by NRT and Anglian Water. Furthermore, there will be internship and placement opportunity for the student at NRT to engage with projects in pollution risk-management, catchment planning and management.

Respiratory and Contact Infection Resilience of the Project:

Given that this PhD will have combination of laboratory and numerical modelling investigations, potential COVID19 disruptions are considered on the project and the student progress. The supervisory meetings will when necessary be hold online and access to all computational resources (PC, HPC, etc.) will be given through VPN secure connections. The laboratories in the School of Engineering and Life Sciences are both COVID secure, and upon appropriate health and safety assessment, the student should be able to continue work during the potential period of COVID disruptions in the future.

Possible timeline:

Year 1: Basic research skill training; literature review and familiarisation with atomistic simulation methods and analysis techniques and development of computational methodology for simulation of pollution transport in vegetated flow environments.

Year 2: Comprehensive laboratory hydrodynamic and fluorometric measurements for solute and microplastic transport under various hydraulic conditions in interacting mesocosm river and wetland environment. Calibration and validation of numerical model for simulating pollution transport in vegetated flows.

Year 3: Detailed analyses of laboratory data, scenario modelling using the developed numerical tool. Writing the thesis will take place during the final year.

Further reading:

Journal:

Rillig, M.C. (2012) 'Microplastic in terrestrial ecosystems and the soil?', Environmental Science and Technology 46, 6453-6454.

Ballent, A., Pando, S., Purser, A., Juliano, M.F. and Thomsen, L. (2013) 'Modelled transport of benthic marine microplastic pollution in the Nazaré Canyon', Biogeosciences 10(12), 7957-7970.

Besseling, E., Quik, J.T.K., Sun, M. and Koelmans, A.A. (2017) 'Fate of nano- and microplastic in freshwater systems: A modeling study', Environmental Pollution 220, 540-548.

V. Nikora (2010) 'Hydrodynamics of aquatic ecosystems: an interface between ecology, biomechanics and environmental fluid mechanics', River Res. Appl.

H.M. Nepf (2012) 'Hydrodynamics of vegetated channels', J. Hydraul. Res.

Further details:

Further details about the supervisory team of this project can be find here:

Dr Soroush Abolfathi: https://warwick.ac.uk/fac/sci/eng/staff/sa/

For any inquiry related to this project please contact Soroush.Abolfathi@Warwick.ac.uk