CENTA Project Proposal Form – 2025 entry

Project Title	FATE AND TRANSPORT OF MICRO-AND NANOPLASTICS IN GROUNDWATER
University (where DR will register)	University of Birmingham
Supervisory team (including institution & email address	**PI: Prof. Stefan Krause, University of Birmingham (s.krause@bham.ac.uk)** **Co-I: Dr Sophie Comer Warner, University of Birmingham (s.comer-warner@bham.ac.uk.)** **Dr Dan Lapworth, BGS (djla@bgs.ac.uk)** **Dr Bentje Brauns, BGS (benaun@bgs.ac.uk)** **Dr Tim Besien, Environment Agency (tim.besien@environment-agency.gov.uk)**
Is the PhD suitable for part time study?	Yes ☒ This is a requirement of NERC

Project Highlights:

- Unique opportunity to work side by side with the researchers and practitioners and create transformative research that creates direct impact
- Innovative methodologies based on the integration of next generation microplastic analysis, experimental and modelling techniques
- An interdisciplinary cross-sectoral supervisory team with exciting opportunities for close involvement in international research and training networks (PlasticUnderground network of >20 international partner institutions)

Overview

Microplastics (synthetic polymers <5mm) and nanoplastics (<1mm) are now known to be omnipresent in the environment and have been detected in the world's water bodies, sediments, soils and atmosphere. Recent evidence of micro- and nanoplastics (MnP) in soils and groundwater raises severe concerns for agricultural and water industries, food manufacturers, regulators, environmental interest groups and citizens. Private and public sectors require detailed understanding of environmental and public health risks posed by MnP in soils and groundwater. This includes the assessment of MnP impacts on crucial ecosystem functions, such as soil fertility or the natural attenuation potential of pollutants in groundwater, as well as the development of effective solutions to reduce public health risks due to exposure from groundwater resources or food uptake of MnP and leaching contaminants.

This PhD project will analyse the fate, transport and impacts of MnP from soils to groundwater to develop solutions to reduce the environmental and public health risks posed by MnP in groundwater. The PhD will therefore investigate potential risks of MnP, their additives and adsorbed pollutants that can impact the soil and groundwater microbiome with potentially

drastic consequences for water quality and the natural attenuation capacity of groundwater aquifers.

Following an interdisciplinary multi-method approach, this PhD project will develop and integrate eld and laboratory experimental capacity with numerical modelling tools to provide detailed understanding of the transport mechanisms and time scales of soil and groundwater MnP fluxes and interactions due to properties of MnP coronas. It will quantify aquifer type and land use specific MnP transit and peak arrival times for a wide range of currently circulating synthetic polymers, characterise MnP properties encountered in the eld as well as novel biodegradable polymers. The quantification of travel and transit time dependent leaching of selected plastic additives and adsorbed pollutants will enable identification of material property and context dependent risk profiles that will assist private and public sectors in understanding environmental and public health risks posed by MnP.

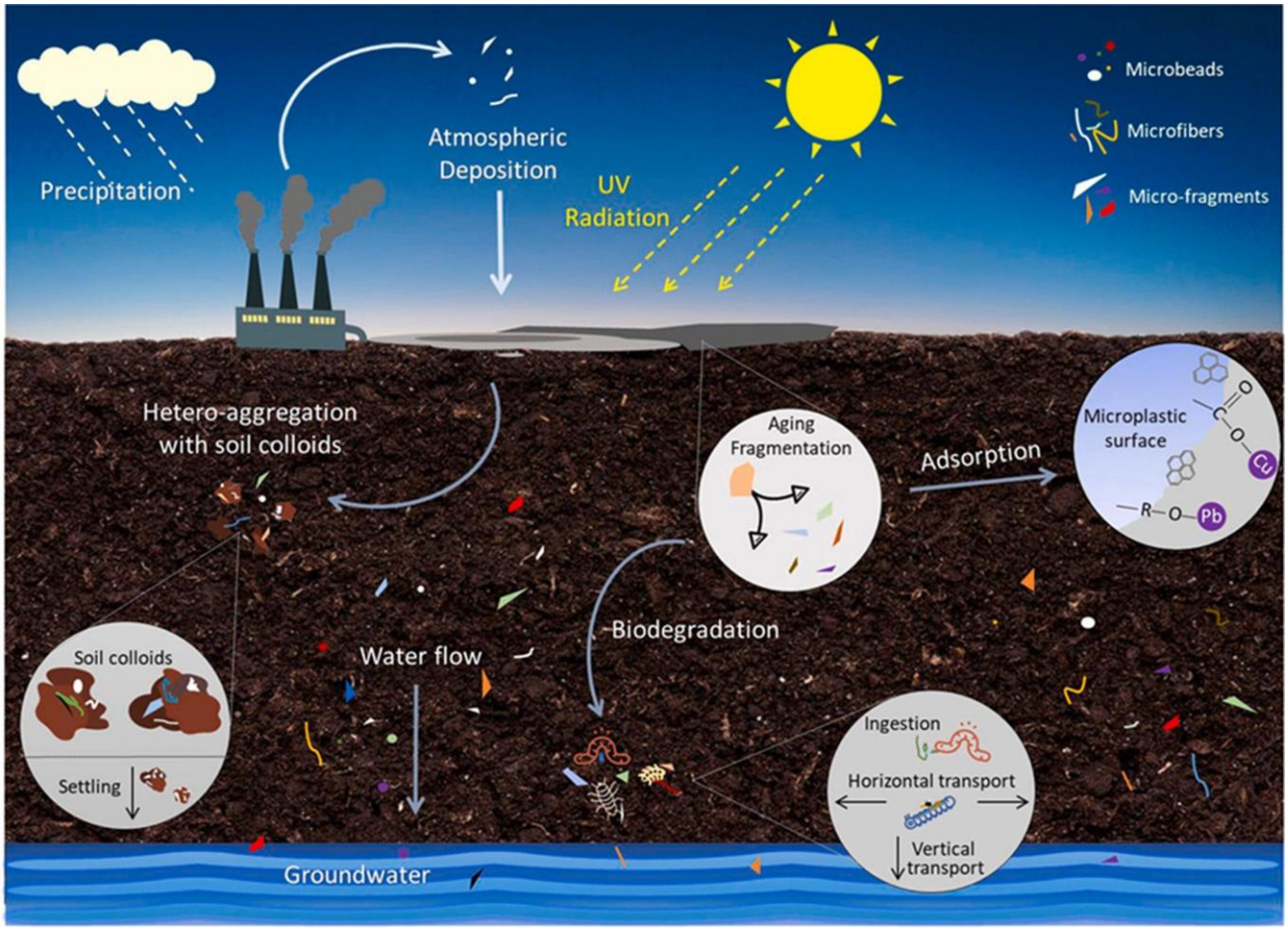

Figure 1: Processes controlling the transport and transformation of MnP along their transport across the soil – groundwater interface (from Ren et al., 2021)

Methodology:

The project will combine cutting-edge analytical skills ranging from novel MnP sampling, extraction and separation techniques, advanced MnP identification tools such as fluorescent staining (Nile Red), digital imaging (fluorescent, confocal scanning and transmission electron microscopy fourier-transform infrared spectroscopy), to technologies for MnP characterisation of MnP degradation (including hyphenated technology ThermoGravimetric-InfraRed-Gas Chromatography/Mass

Spectrometry (TG-IR-GC/MS)) and single particle/single cell ICPMS. Particle property-dependent MnP transport and transformation, including leaching of additives and co-pollutants will be tested in column experiments using the unique experimental infrastructure of the Birmingham EcoLaboratory (https://www.birmingham.ac.uk/research/activity/ecolaboratory/index.aspx). Interpretation, generalisation and upscaling of results will be grounded in process based particle tracking and reactive transport models, advancing mechanistic understanding of the transport, fate and impact of MnP in soils and groundwater and enabling predictions that support subsurface risk assessments.

Training and skills:

DRs will be awarded CENTA Training Credits (CTCs) for participation in CENTA-provided and 'free choice' external training. One CTC can be earned per 3 hours training, and DRs must accrue 100 CTCs across the three and a half years of their PhD.

The PhD project encourages applications from individuals with an appetite for interdisciplinary research. Benefitting from the diverse background of the supervisory team at UoB, BGS and EA, the Doctoral Researcher will receive tailored training in laboratory analytical skills for MnP identification and characterisation, particle tracking and tracer analysis, MnP reactive transport modelling as well as in the effective communication of research outputs with diverse end-user communities. The close alignment of the PhD project with international training initiatives such as the PlasticUnderground Training Network, with its Summer School and training courses, will provide additional international experience and networking opportunities.

Partners and collaboration (including CASE):

Name of External partner (where applicable)	Environment Agency
Name of CASE partner (where applicable – project proposal **must** be accompanied by a letter of support from the CASE partner)	BGS
Letter of support from CASE partner attached (where applicable)	Yes ☒

BGS collaborative partner funding through the BUFI programme (£9k) is available to fund fieldwork, travel and laboratory analysis. This is spread equally over the duration of the PhD.

Possible timeline:
Year 1: Development of soil and aquifer column experiments for MnP fate and transport studies and training in particle identification and characterisation methods.

Year 2: Conduction of particle breakthrough experiments and analysis of contaminant leaching for

variable MnP and soil/aquifer properties and management scenarios.

Year 3: Data analysis and modelling of MnP particle transport for providing predictions of property dependent risk profiles.

Further reading:

Journal:

- Drummond J.D., Schneidewind U., Li A., Hoellein T.J., Krause S., Packman A.I. 2022. Microplastic accumulation in riverbed sediment via hyporheic exchange from headwaters to mainstems. Science Advances. DOI:10.1126/sciadv.abi9305

- Margenat H., Drummond J., Nel H.A., Stonedahl S., Sabater F., Krause S. 2022. Hydrologic controls on the accumulation of different sized microplastics in the streambed sediments downstream of a wastewater treatment plant (Catalonia, Spain). Environmental Research Letters. In print

- Nel H.A, Chetwynd A., Kelly C., Stark C., Valsami-Jones E., Krause S., Lynch I. 2021. An untargeted TGA-FTIR-GC-MS approach for plastic polymer identi cation. Environmental Science and Technology.

- Kukkola, A., Lynch, I., Sambrook-Smith, G., Nel, H.A., Krause, S. 2021. Microplastic uptake and propagation in freshwater food-webs – current knowledge and key gaps. Environment International. 152, 106504. https://doi.org/10.1016/j.envint.2021.106504

- Krause S., Baranov V., Nel A. H., Drummond J. D., Kukkola A., Hoellein T., Sambrook Smith G. J., Lewandowski J., Bonnet B., Packman A. I., Sadler J.P., Inshyna V., Allen S., Allen D., Simon L., Mermillod-Blondin F., Lynch I. 2021. Gathering at the top? Environmental controls of microplastic uptake and biomagni cation in aquatic food webs. Environmental Pollution. 268 (A), 115750. https://doi.org/10.1016/j.envpol.2020.115750

- Nel A.H., Naidoo T.; Akindele E.; Nhiwatiwa T.; FADARE O.; Krause S. 2021.

Collaboration and infrastructure are needed to develop an African perspective on micro(nano)plastic pollution. Environmental Research Letters. 16 (2). 021002

- Drummond J.D., Nel H.A., Packman A.I., Krause S. 2020. Signi cance of Hyporheic Exchange for Predicting Microplastic Fate in Rivers. Environmental Science & Technology Letters. 7(10), 727-732. DOI:10.1021/acs.estlett.0c00595

- Krause S. 2020. Science based solutions to plastic pollution. One Earth. 2 (1), 5-7. DOI:https://doi.org/10.1016/j.oneear.2020.01.004

- Nel H.A., Chetwynd A.J., Kelleher L., Lynch I., Mans eld I., Margenat H., Onoja S., Goldberg Oppenheimer P., Sambrook Smith G.H., Krause S. 2020. Detection limits are central to improve reporting standards when using Nile Red for microplastic quanti cation. Chemosphere. https://doi.org/10.1016/j.chemosphere.2020.127953.

- Nel, H. A.; Sambrook Smith G.H., Harmer R., Sykes R. Lynch I., Krause S. 2020. Citizen science reveals microplastic hotspots within tidal estuaries and the remote Scilly Islands, United Kingdom. Marine Pollution Bulletin. 161(Part

  B). 111776. 10.1016/j.marpolbul.2020.111776

- Nel H., Krause S., Sambrook Smith G.H., Lynch I., 2019. Simple yet e ective modi cations to the operation of the Sediment Isolation Microplastic unit to avoid polyvinyl chloride (PVC) contamination. MethodsX, 6, 2656-2661, https://doi.org/10.1016/j.mex.2019.11.007.

- Tibbets J., Krause S., Lynch I., Sambrook Smith G. (2018). Microplastic patterns in a UK urban headwater river. Water, 10, 1597.