



Human pharmaceuticals in the aquatic environment

Pharmaceuticals are extensively used in everyday life. According to the NHS, more than 100 million prescription items were issued in 2016/2017 in Scotland. Many pharmaceutical compounds are not fully metabolised in the human body and are excreted in partially metabolised or un-metabolised forms. This activity, along with washing off of topically applied medical creams and improper disposal of drugs (by flushing down the toilet), results in these compounds entering our sewers.

Pharmaceuticals enter wastewater treatment plants in raw influent but many of these compounds are recalcitrant to removal. Conventional, less advanced treatment plants such as those in rural areas, are unable to fully remove these pollutants from wastewater effluent.

With the release of effluent into surface waters (rivers, lochs), pharmaceuticals have a direct pathway into the environment, where their impacts are not fully understood. Potential impacts are wide ranging and may include contamination of potable drinking water supplies, behavioural changes in fish and accelerating the spread of antimicrobial resistant bacteria.

Over the past 12 months, the ERI has monitored the River

Dee in Aberdeenshire to assess the fate and transport of pharmaceuticals. The fieldwork included sampling from the river's source upstream of Braemar, to its end in Aberdeen city. Compounds including ibuprofen (anti-inflammatory), paracetamol (analgesic), trimethoprim (antibiotic) and carbamazepine (anti-epileptic) have been detected in the mid nanogram per litre concentration range, with sharp spikes in concentrations observed directly downstream of wastewater treatment plants.

Using novel passive sampling techniques, time weighted average concentrations of pharmaceuticals in the River Dee have been captured to identify temporal and spatial trends. This data will be mapped and used to illustrate seasonal, and flow, variations, as well as to identify 'hot spots' for compounds of eco-toxicological concern.

The ERI is also working through a unique partnership with Glasgow Caledonian University and the James Hutton Institute in collaboration with stakeholders such as NHS Highland, the Scottish Environment Protection Agency (SEPA) and Scottish Water, to investigate this multifaceted issue. Research includes analysing pharmaceutical pollution in hospital wastewaters and preparing a national database on pharmaceuticals detected in the Scottish

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environment. Currently, pharmaceuticals do not have environmental quality standards in the UK, or Europe, for maximum allowable concentrations in wastewater effluent and surface waters. One of the aims of the current work at ERI is to provide evidence-based research which will support policy changes allowing inclusion of pharmaceuticals in environmental quality standards.

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University for the Common Good



Making waves in water innovation

Water is of central importance to the economy of Scotland. Our water sector generates a turnover of £3.7bn and provides 16,600 jobs across the country. Water resources are critical to key sectors in the Scottish economy including agriculture, food and drink, tourism and energy. However, with growing pressure on resources, a changing climate and increasing legislative requirements there are many emerging challenges associated with drinking water provision, wastewater treatment and resource management.

The University of the Highlands and Islands' Water Quality Innovation Group (WQIG), chaired by the ERI's Professor Stuart Gibb, seeks to help address these challenges, particularly those faced in rural and sparsely populated regions of Scotland, and in similar areas around the world. It draws on expertise from locations around the Highlands and Islands in the areas of water analysis; monitoring and assessment; water treatment and remediation and in integrated catchment management.

A recent event held at An Lochran in Inverness promoted engagement between UHI researchers, businesses and national stakeholders with interests in water quality. This included producers, users, regulators and funders. The event helped to identify common challenges and opportunities for collaborative working, with the ultimate aim of developing innovative new products and services. Such collaborations help to meet policy and regulatory challenges and to advance responsible stewardship of water resources and the low carbon economy.

Further events are already planned, including one focussed on the distilling and brewing industries.

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The University of the Highlands and Islands' Water Quality Innovation Group (WQIG) and stakeholders

Oceans as carbon 'sinks'

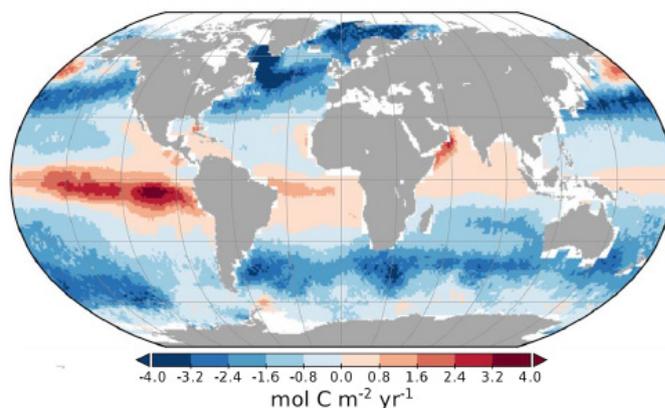
Oceans help slow down global warming by absorbing carbon dioxide, but exactly how much is not yet clear. In some areas the ocean absorbs, while in others it emits carbon dioxide depending on local conditions. Over the whole globe, the net flow is into the ocean. A previous estimate shows around a quarter of the carbon dioxide emissions caused by human activity end up in the ocean.

A new, and more accurate, estimate resulting from the OceanFlux Greenhouse Gases (GHG) project, is that the oceans take up about a third of carbon dioxide produced by human activity. In terms of helping to reduce climate change, this new discovery may sound positive, but the more carbon dioxide that dissolves into the oceans, the more it leads to ocean acidification – a serious environmental problem that makes it difficult for some marine life to survive.

Researchers (including ERI's Dr. Lonneke Goddijn-Murphy) used new knowledge of gas transfer processes at the sea surface to better calculate the carbon dioxide flow from the air into the sea. They used the latest sea surface data obtained by the international marine carbon research community (Surface Ocean Carbon Dioxide Atlas), as well as measurements from satellites. Funded through the

European Space Agency's Science for Society programme, results of the study have recently been published in Global Biogeochemical Cycles.

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Illustrative map of annual CO₂ flux in global oceans in 2010; upwards fluxes are defined as positive.



oceanflux evolution
support to science element



Satellite monitoring of peatlands



ERI's Dr. Chris Marshall, Henk Pieter Sterk and Iain Detrey visited researchers at Yugra State University, Khanty-Mansiysk, Western Siberia, continuing a relationship between the two institutions which first began in 2014 with the team led by Dr. Elena Lapshina.

Western Siberia is home to some of the largest and most remote peatlands in the world, which presents unique challenges in surveying their health and response to global climate change. A satellite monitoring technique known as 'InSAR' can be used to overcome many of these challenges. Using radar, InSAR is able to track the natural movement of a peatland surface (bog breathing), throughout the year which can then be used to map their condition.

The purpose of this visit was to apply the validation techniques developed in the Flow Country peatlands of Caithness and Sutherland to rather different continental peatlands which include areas of natural tree cover and larger seasonal variation.

The trip was not without its hitches but was an overall success with over 70 sites surveyed across an area of 150km. This included visits to the remote Mukrhino field station in the east and the large crude oil extraction sites to the west.

The trip was funded through the EU International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT) trans-national access programme. In addition to fieldwork, time was taken to explore the city of Khanty-Mansiysk and its museums, providing excellent language practice for some of Yuga state university's translation students.

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Peatlands “Fire Blanket” project

In good condition, peatlands are the most efficient soil carbon store; they regulate freshwater and climate, and maintain biodiversity. However, management interventions and disturbances can jeopardise the delivery of all these services by destabilising the vast peat carbon store that has been locked away over thousands of years. Damaged peatlands can release carbon back to the atmosphere as greenhouse gases like carbon dioxide and methane, which amplify climate change in the same way fossil fuels do. Degradation of peatlands can also have negative effects on peatland-derived drinking water supplies and freshwater habitats. Importantly, disturbed peatlands may also become more vulnerable to stress, including climate-change induced increases in drought frequency and severity, and incidence of wildfires.

Evidence on how land use and climate extremes interact in peatlands is vital in informing best management practice. However, it is also challenging to gather because of the ephemeral nature of these threats and the usual paucity of high-quality ground-based observations within an area of interest, capable of providing the necessary pre-impact and control data.

Following a dry and warm spell, a large wildfire burnt approximately 6500 ha of blanket bog in May 2019 within the Flow Country peatlands of Caithness and Sutherland. Unlike other wildfires in the UK, the May 2019 fire covered an exceptionally large area that includes peatlands in a range of conditions: drained, drained and afforested, under restoration (through forestry removal and drain blocking) and near-natural. All those areas were actively being used by previous projects involving the ERI’s “Carbon, Water and Climate” theme researchers.

In the aftermath of the fire, Dr. Roxane Andersen led a team of researchers and secured Urgency funding from NERC (Natural Environment Research Council) for the “Fire

Blanket” project, which aims to seize this unprecedented opportunity to understand how blanket bog management influences soil organic carbon response to wildfire events. The project will achieve that by:

- (1) Estimating the immediate carbon losses through combustion for each of the land uses
- (2) Assessing fire resistance and severity in blanket bogs under different management regimes, including afforestation
- (3) Determining how the interplay between management and burning severity alters the post-fire fate of dissolved organic matter, and the aquatic exports from land to sea
- (4) Understanding legacies of fire on the fate of the vast carbon store held in the peat
- (5) Developing future-proof management strategies for drained and afforested blanket bogs.

This 12 month project started in September 2019 with the appointment of ERI-based field and lab technician Paula Fernandez-Garcia and is now in full swing, with water sampling and vegetation monitoring underway. As well as the ERI/UHI team, the project includes researchers from the Centre for Ecology and Hydrology (CEH), the National Oceanographic Centre (NOC), the University of Nottingham and the Royal Society for the Protection of Birds (RSPB). Scottish Natural Heritage, the James Hutton Institute, the Flow Country Rivers Trust and Scottish Water are also key partners.

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Building links with Tokyo Nodai University



Back row: Dr Elizabeth Masden, Yudai Hirai, Midoriko Ito, and Assistant Professor Koji Asakuma.
Front row: Dr Nina O' Hanlon, PhD students James Slingsby, Melissa Costagliola-Ray and Nicola Largey.

Students from Tokyo University of Agriculture (Tokyo Nodai) recently embarked on a visit to the University of the Highlands and Islands, focussed around Forestry (Inverness) and Marine Science (ERI). This 'pilot' Scottish Experience was set up by UHI International Development Executive following a visit from UHI to Tokyo Nodai in 2018, with a Memorandum of Understanding signed between the two institutes.

Based initially at Inverness College, the seven students spent their first days taking ESOL language classes, visiting Culloden Battlefield, being introduced to Nessie and sampling highland hospitality. At the start of the second week, forestry students headed to the Scottish School of Forestry, and two students, Midoriko Ito and Yudai Hirai, together with Assistant Professor Koji Asakuma, Department of Ocean and Fisheries Sciences, headed to Thurso.

During their visit, Mido, Yudai and Koji learned about ERI's renewable energy and environment research from staff and PhD students, visited sites along the Caithness coastline to undertake seabird surveys, and discussed the use of UAV (drones) for terrestrial and marine monitoring. Unfortunately, stormy weather resulted in the boat trip to Stroma being cancelled but the group enjoyed a tour of the Castle of Mey instead. On the way south, we visited a wind farm and explored the Peatland trail at Forsinard.

Back in Inverness, all the students presented the highlights of their visit and introduced UHI staff to Japanese culture. A Scottish-themed farewell dinner with Highland dancers and a piper provided a fitting end to a very successful international collaboration.

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EURORUN project



The ERI has been taking part in Europe-wide studies around fresh water biogeochemistry (EuroRun), cooperating with groups of early career researchers from more than 20 partner universities. This project involved a coordinated sampling and analysis campaign to produce a wide spatial and temporal investigation with Dr. Peter Gilbert leading the ERI component. The results showed the significance of diurnal variation in carbon dioxide fluxes from rivers, which are much larger during the day.

own research on water quality and carbon cycling in Flow Country rivers. Providing a good networking opportunity, new fresh-water science collaborations are now in the making.

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ERASMUS+ international collaboration

With the support of ERASMUS + International Credit Mobility, ERI, North Highland College and the Faculty of Technical Sciences, University of Novi Sad (UNS) in the Republic of Serbia have embarked on a series of exciting mobility exchanges.

Earlier this year Professors Maja Turk Sekulić and Jelena Radonić from Department of Environmental Engineering and Occupational Safety and Health (UNS) visited ERI. Their visit coincided with an ERASMUS+ visit by Rúnar Gunnarsson and Stefan Gudnason from the University of Akureyri in Iceland, placing Thurso at the heart of an Erasmus + crossroads.

Through a series of guest lectures and teaching, Maja and Jelena laid the foundation for two of their students (Miljana Lukic and Sanja Radovic) to take up mobility projects at ERI over the summer. Miljana's project with Lisa Shearer (PhD) and Dr. Szabolcs Pap looked at 'Distillery and Shellfish by-products as biosorbents for sustainable water treatment', whilst Sanja worked with Dr. Mark Taggart on 'New, more sustainable, approaches to remove challenging organic and inorganic pollutants from water'.

ERI's first teaching mobility was undertaken by Mark at the end of June, coinciding with some beautiful summer weather in Serbia. Mark gave a series of guest lectures and taught undergraduate and PhD students as well as being introduced to staff across the Faculty. A large music festival held within the ancient fortress in Novi Sad provided a cultural backdrop to Mark's visit.

Following on, Dr. Paul Gaffney and Dr. Szabolcs Pap recently completed their teaching mobility visits at University of Novi Sad. Paul introduced students to using water chemistry in ecological restoration whilst Szabolcs lectured on a range of topical issues from plastic pollution to cutting edge waste water treatment technologies. With more than 50,000 students and 5,000 employees, UNS is one of the largest educational and research centres in Central Europe. Both staff found the experience of teaching large classes quite different to the situation back home.

We are currently in the process of organising return visits from Dr. Dragan Adamović in February, followed by Professor Maja Turk Sekulić in March.

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At the heart of ERASMUS' – visitors from University Novi Sad, Serbia and University Akureyri, Iceland meet with staff from ERI and UHI in Thurso

NHC Research Student of the year

Congratulations to Dr. Yuan Li who has been awarded the NHC Research Student of the Year for 2018-19 for her PhD which evaluated the potential use of natural waste materials as low-cost biosorbents for the removal of pharmaceuticals from aqueous media.

Whilst most current biosorption studies consider the synthesis of functionalised sorbents, or look at compounds from certain therapeutic groups, Yuan's work examined how materials that are abundant in nature, or are by-product from industry can, with nominal processing, be applied to eliminate a wide range of compounds that may exert adverse eco-toxicological effects.

Yuan was out of the country when the Graduation Ceremony took place so was awarded her certificate earlier in November by ERI Director Stuart Gibb and North Highland College, UHI, Principal Donald MacBeath.

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New faces @ ERI

Paula Fernandez Garcia field and laboratory technician



Acquiring a BSc in biochemistry and a MSc in toxicology and diseases of wild birds from the University of Castilla-La Mancha (Spain) helped me to realise how much I enjoyed doing both field and lab work. This, alongside my interest in the problems that affect wildlife and the environment, propelled me to intern at different research organisations, including ERI.

I joined the NERC funded "FIRE BLANKET" research project in September

as technician. The overarching objective of this project is to understand how blanket bog management influences fire resilience and carbon fate. My main task is to undertake monthly water sampling and laboratory analyses at ERI. I also support the vegetation monitoring and other field campaigns associated with this project.

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Samuel Langlois Lopez PhD student



Hi! My name is Sam and I joined ERI in October 2019 to do my PhD. I graduated from Aberdeen University in 2018 and I've been working as a research assistant on the Isle of May for the last two summers. I am interested in all things related to seabird ecology and I am also a keen bird ringer.

My PhD aims to understand whether a population of great black-backed gulls has any effects on the puffin population of the Isle of May, as well as providing new insights into the foraging ecology of

the gulls themselves. My project involves a lot of time in the field every spring and summer, which means I get to live with 200,000 seabirds on an uninhabited island for over 2 months every year!

I am a big fan of wild, isolated places and Thurso is as good as it gets. I am very excited to explore the area and see what it has to offer.

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Liam Godwin PhD student



Hello, my name is Liam! I have just started my PhD in ERI. Previously I studied Biology at the University of York and spent an Erasmus year between Aarhus University, Denmark, and the Greenland Institute of Natural Resources.

My PhD is funded through the SUPER DTP and I will be working with Roxane Andersen, Paul Gaffney (ERI), Josie Geris (University of Aberdeen) and Mark

Hancock (RSPB). The main research theme will be understanding the effect of peatland restoration on aquatic ecology, specifically Atlantic Salmon, in the Flow Country.

I look forward to exploring the Highlands and meeting everyone else so far up north.

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Pia Tappe visiting student



Hi, my name is Pia Tappe and I am currently in my third year of undergraduate studies in Environmental Science in the beautiful city of Münster in Germany.

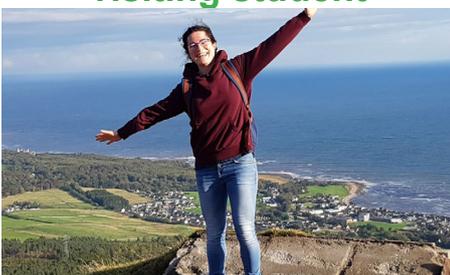
At the ERI, my project is supervised by Dr Roxane Andersen and Magnus Davidson. We aim to estimate the carbon footprint of a sporting estate in the Highlands. We want to account for the carbon emissions and savings both from their performance as a business and from the land use and land

cover. Our aim is to provide information to support future decisions of the estate management.

I am very excited to be in Scotland, gathering all these new experiences of working in science and meeting great people!

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Agathe Mery visiting student



Hello, I am Agathe and I joined the ERI for a four-month placement as part of my degree at EPF (Paris), a leading French engineering school. I am going into my fourth year of undergraduate studies, specialising in Environment and Renewable Energies.

I am helping to investigate pharmaceutical degradation in effluent-receiving surface waters with Dr Mark Taggart and PhD student Lydia Niemi. It involves a mix of field, lab and desk-based work, to increase understanding of the persistence and

behaviour of these contaminants in aquatic environments.

Eager to broaden my experience, I am excited for the new opportunities this placement will give me: meeting new people and exploring the beautiful surroundings, which will make my time here unforgettable.

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