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An Overview of Expertise in the area of EcoGeoChemistry at Plymouth University

KEY RESEARCH GROUPS in EcoGeoChemistry @ PLYMOUTH

Biogeochemistry Research Centre

The Biogeochemistry Research Centre (BGC) was formed in 2009 by the merger of the Biogeochemistry and Environmental Analytical Chemistry group (BEACh), and the Petroleum and Environmental Geochemistry Group (PEGG). This has brought together two of the strongest research groups in the University, with excellent reputations for the delivery of world-class research, teaching and enterprise activities. http://www1.plymouth.ac.uk/research/bgc/Pages/default.aspx

Centre for Research in Earth Sciences

The Centre for Research in Earth Sciences (CRES) at Plymouth University brings together an outstanding research team that spans the spectrum of Earth science disciplines. The complementary skills and knowledge of CRES researchers ensures an interdisciplinary approach to the scientific study and analysis of key Earth science issues that are of broad concern to society. http://www1.plymouth.ac.uk/research/cres/Pages/default.aspx

Centre for Research in Environment and Society

One of the most active research centres within the University, CeRES has a geographical focus on three linked fundamental elements, namely environment-society interactions, environmental processes and change, and their governance through regulation, management policies and stakeholder involvement. The centre blends the traditions of the natural sciences (physical

geography) and social sciences and humanities (human geography, politics). Much of the work that the centre does is interdisciplinary, and individual staff engage with a wide range of other departments in universities and research institutes from around the world. http://www1.plymouth.ac.uk/research/ceres/Pages/default.aspx

Environmental and Fluid Modelling

Current research areas and activities: The study of behaviour of pollutants and nutrients in soil; including the change of soil structuring under clover and its consequences for leaching, and the extent of migration of cable oil through soil. Modelling of high-performance filters for environmental, industrial and medical applications. Modelling of processes involved in the production of high-performance carbonate- based paper coatings. Development of environmentally benign catalysts. Production, sale and use of void structure and pore-fluid modelling software called Pore-Cor Research Suite. http://www.porexpert.com/

Ecotoxicology Research and Innovation Centre (ERIC)

The Ecotoxicology Research and Innovation Centre (ERIC) offers a range of internationally recognised expertise on environmental toxicology and chemistry. Ecotoxicology at Plymouth has a long history of world-class research that addresses fundamental questions about the mechanistic effects of substances on aquatic organisms (algae, invertebrates, fish) and other wildlife. Interests cover a range of pollutants (organic chemicals, metals, natural toxins, radiations) and their interactions with the natural geochemistry of the environment (metal speciation, colloid chemistry, salinity, temperature etc) as well as the presence of pathogens (bacterial populations, parasites). The research centre has a horizon scanning capability for new and emerging threats to the environment and the health of wildlife; and therefore has a range of very topical themes (e.g., nanotoxicology). The centre applies its practical expertise to a range of innovation activities including animal health diagnostics, biomarkers for environmental monitoring, the development of test methods for regulatory ecotoxicology and analytical methods for chemical detection, as well as a variety of practical expertise on hazard and risk assessment. http://www.plymouth.ac.uk/research/eric

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KEY RESEARCHERS in EcoGeoChemistry @ PLYMOUTH

Professor Steve Rowland https://www.plymouth.ac.uk/staff/steven-rowland

After more than 31 years in organic geochemistry research, Steve Rowland is currently Professor of Organic Geochemistry, Head of the Petroleum and Environmental Geochemistry Group and co-Director of the Biogeochemistry Research Centre. He was also Visiting Professor and Blaustein Fellow at Stanford University, USA and a Visiting Professor at the CSIRO in Australia. He has published over 200 papers including in the leading journals Science and Nature, supervised more than 35 Ph.D students and won research grants worth millions of pounds. In 2008 Steve was awarded a prestigious European Research Council Advanced Research Grant of 2 million euros, one of only 100 awards in science & engineering in the EU, one of 19 in the UK. Steve's major interests are in the areas of organic and environmental organic geochemistry, with particular emphasis in these areas:

- Origin and significance of highly branched acyclic isoprenoids (e.g. use as climate proxies, calibrants for molecular evolution etc).
- Nature of unresolved complex mixtures of hydrocarbons and naphthenic acids (e.g. effects as pollutants, corrosive chemicals, pipeline blockages etc)
- Fate and effects of organic pollutants especially oil pollution (e.g. effects of dispersants on toxicity and longevity of oil pollution)
- Fate and effects of plastics and other hydrophobic pollutants (e.g. transport of toxic pollutants into marine organisms).
- Origin and Significance of Highly Branched Acyclic Isoprenoids

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Professor Gregory Price https://www.plymouth.ac.uk/staff/gregory-price

Gregory Price is Professor of Environmental sedimentology and Head of the Centre of Research in Earth Sciences. Greg's current research involves the investigation of past climate and environmental change and more specifically understanding larger perturbations in the Earth's physical and biological systems; abrupt climate change during globally warm intervals, extreme events in polar environments and the timing of the onset of northern hemisphere glaciations. He is also interested in the preservation of climatic signals in marine fossils and how these data are used to reconstruct ancient ecosystems. A number of projects principally involving the integration of stratigraphy, sedimentology and the use of oxygen, carbon and strontium isotopes are currently being undertaken via the analysis of material from Deep Sea Drilling Project/Ocean Drilling Project sites; the eastern sub Urals, Siberia, Spitsbergen, Iran, the Volga River, Russia, the Atacama region, Chile, Argentina, the Crimea, and various locations within the UK.

Professor Will Blake https://www.plymouth.ac.uk/staff/will-blake

Will Blake is Professor of Catchment Science and Director of the Plymouth University Consolidated Radioisotope Facility (CoRiF). Will's research focuses on the impact of human activities and natural disturbances on catchment fine sediment dynamics from soil erosion and sediment transport through to siltation of river channels and estuaries. He is also interested in the fate of contaminants associated with fine sediment e.g. nutrients from agriculture and heavy metals from mining. He works in the UK and overseas (e.g. ; radioactive contamination in Fukushima, Japan; tropical rainforest logging in Malaysian Borneo; wildfire in Australia, Greece and Canada).He specializes in

the application of sediment tracing technology to examine fine sediment sources and budgets in catchments. This involves using natural and artificial sediment properties such as fallout radionuclides, mineral magnetics, geochemistry and biomarkers to explore catchment response to disturbance. My work in this area is strengthened by my involvement as an expert member of a joint International Atomic Energy Agency (IAEA) and UN FAO Coordinated Research Programme (CRP) concerning sediment tracing in aquatic systems. At Plymouth, I am the Director of the ISO9001:2008-certified Consolidated Radioisotope Facility and an ISO auditor for the Analytical Research Facility. The CoRiF laboratory is pleased to host international visiting research fellows in this area and we have recently undertaken training and knowledge exchange programs with colleagues from Belgium, Canada, Spain and Tunisia. We also undertake contract analyses for UK and overseas clients (e.g. gamma spectrometry for sediment and peat geochronology (fallout Pb-210 and Cs-137) and sediment fingerprinting).

Current research work includes: (i) development of fallout radionuclide and other sediment properties as sediment tracers in river basins, (ii) assessing catchment response to disturbance e.g. wildfire (Australia, Greece and Canada), logging (Malaysian Borneo), agriculture and the legacy of past industrial activity (UK), and (iii) geochronological applications of environmental radioactivity (peats, saltmarshes, lake sediments and floodplains).

Professor Peter Matthews https://www.plymouth.ac.uk/staff/peter-matthews

Peter Matthews is Professor in Applied Physical Chemistry and CEO and director of PoreXpert Ltd, the university's main spin-out company, selling consultancy services and the PoreXpert suite of software described below.

His Environmental and Fluid Modelling research interests are currently concerned with fluid flow in porous materials, particularly when this has environmental importance. His research group currently comprises three PhD students, and three internal and four external post-doctoral fellows. He has previously supervised 20 PhDs, 17 as P.I., to successful and timely completion. He has attracted over £4.5m of research funding to date, the sources of which have been research councils (NERC Environmental Diagnostics programme, NERC NE/K004212/1, EPSRC GR/K70489 and BBSRC BB/E001793/1, BB/E001793/1), industry (British Gas / Transco, Omya AG, EDF), and purchasers of the software described below. He has written 152 publications in research and pedagogy, including a 500 page textbook on Experimental Physical Chemistry (Oxford University Press, 1985), and over 35 consultancy reports.

Matthews' research group has pioneered a new way of modelling porous materials, by producing software (Pore-Cor succeeded by PoreXpert®) which generates three-dimensional void networks which closely match the full percolation characteristic and porosity of any meso- and macro-porous material. Matthews' approach contrasts with the otherwise almost universal approach which is simply to take the slope (1st derivative) of the percolation characteristic, in the form of a mercury porosimetry intrusion curve or a soil water retention curve, and equate it to the number of voids of that size. However this approach is only valid for the very small number of samples, such as track-etch membranes, which comprise aligned capillary tubes which do not connect with one another. In the new approach, the simulated structures are generated by means of Euler beta and gamma functions optimised by a Boltzmann-annealed amoeboid simplex. The simplex not only fits the entire percolation characteristic and porosity, but also builds in other characteristics, such as short range size auto-correlation functions, in a Bayesian type of approach (Matthews et al., 2006). Once the structure has been generated, a wide range of characteristics and properties of the void network can be examined, such as the absolute sizes and numbers of voids, connectivity of the network, absolute permeability, diffusion, tortuosity, thermal conductivity and filtration characteristics (Gribble et al.,

2011). PoreXpert can also be used to optimize the design of porous materials, or predict properties such as ageing and formation damage (outline patent submitted 2012).

Professor Richard Handy (ERIC) https://www.plymouth.ac.uk/staff/richard-handy

Richard is Professor of Environmental Toxicology, and Director of the Ecotoxicology Research and Innovation Centre. Richard has broad interests in comparative aspects of toxicology and the interface between biology and medicine. He is a member of the anaesthesiology research group at the Peninsula Medical School, and is keen to collaborate actively on clinical topics. He is an expert on the technical details of hazard assessment, and on risk assessment for the environment. He has had consultancy work in this area from government departments, the EU commission and chemical companies. He has current research interests the eco/toxicity of nanomaterials; dietary exposure to metals and other contaminants; the use of organ perfusion systems for metal research. Immunotoxicity of metals and pesticides (invertebrates, fish, rodents), Gastro-intestinal physiology and pathology of metals (fish, rats, humans); Cardiotoxicity of metals, and more recently, nanomaterials (rats, fish).

Professor Paul Worsfield https://www.plymouth.ac.uk/staff/paul-worsfold

As professor of Analytical Chemistry, Paul's research activities are at the interface of Analytical Chemistry with Environmental Chemistry. He is Head of the Biogeochemistry and Environmental Analytical Chemistry (BEACh) Group at the University of Plymouth and a member of the Biogeochemistry Research Centre. Particular areas of current interest are the development of field based and laboratory techniques for the determination of macronutrients (e.g. P, N species) and micronutrients (e.g. Fe species) in natural waters and their role in terrestrial, freshwater and marine biogeochemical processes. The technique of flow injection (FI) analysis provides an integrating theme for my research activities, with particular emphasis on the design, construction and deployment of automated FI instrumentation for laboratory and in situ applications. Current research projects include

- The effect of climate change on bioavailability of iron and rates of nitrogen fixation in Trichodesmium
- Impact of sea level rise on the fate of radionuclides at contaminated nuclear sites.
- Solubility of aerosol iron in open seawater.
- Measuring the effect of sedimentary nitrogen and phosphorus on water quality.
- Impact of wildfire on UK water resources
- Design and implementation of technical and management systems for the Langage farm anaerobic digester
- Uncertainty estimates for iron species in seawater.

Dr Sean Comber https://www.plymouth.ac.uk/staff/sean-comber

An Associate Professor in Environmental Science, Sean has diverse research interests, including the source apportionment of chemicals in the environment; metal speciation and toxicity, the fate and behaviour of chemicals in the environment; environmental legislation; and waste-water treatment.

Dr Charlotte Braungardt https://www.plymouth.ac.uk/staff/charlotte-braungardt

Charlotte is an Associate Professor in Environmental Science with research interests in the geochemistry and biogeochemistry of catchment systems, from headwaters to estuaries and into the coastal zone. Current research projects investigate point and diffuse sources of elements associated with metal mining activities and the impact of contamination on the aquatic environment, soils and the assessment of risk for humans from uptake of metals into agricultural products. The application of novel techniques to assess the impact of metal inputs into catchments have been the focus of recent activities. These integrate metal speciation measurements obtained with an in-situ voltammetric profiling system with speciation modelling and ecotoxicological studies on oyster embryo bioassays. The MARA bioassay (Microbial Assay for toxic Risk Assessment) is used to determine toxic effects of mixtures of metals and organic compounds.

Dr Andrew Turner https://www.plymouth.ac.uk/staff/andrew-turner

An Associate Professor in Environmental Science, Andy has research interests in the speciation, adsorption and fate of trace metals in natural waters; emerging pollutants; and bioaccessibility, bioavailability and toxicity of contaminants

Dr Rich Boden https://www.plymouth.ac.uk/staff/rich-boden

Rich is a lecturer in Environmental Microbiology & Biotechnology with expertise spaning physiology, ecology, biochemistry, taxonomy and environmental process, including soil and freshwater geochemistry. The main thrusts of his work concern the microbial transformations of metals, metalloids and sulfur in a range of environments. Active research projects can be split into pure and applied aspects. Pure research in theoretical biology include projects on inorganic sulfur metabolism in bacteria; the impacts of coastal inundation on nitrogen fixation in soils; impacts of bioenergy crop growth on soil microbiology and geochemistry; microbially mediated mobilisation of As(III) and As(IV) from arsenopyrite; and Pathogenicity in Euphydryas editha and Melitaea cinxia and their ethnobotanical responses. His applied research tackles issues of biotechnology and bioremediation, notably rare-earth element biorecovery (REECover) and bioextraction, and Coupled biosensors for measurement of organophosphate contamination of freshwater.

Facilities for EcoGeoChemistry @ Plymouth University

The **Analytical Research Facility (ARF)** is one of the analytical chemistry units of the University of Plymouth. It contains many state of the art analytical instruments for the determination of trace to ultra-trace elements. Examples of the instrumentation include: an inductively coupled plasma – optical emission spectrometer (ICP-OES; Varian 725-ES), inductively coupled plasma - mass spectrometers (ICP-MS instruments, ThermoFisher, X series 2), a simultaneous electrothermal

atomisation atomic absorption spectrometer (SIMAA 6000, Perkin Elmer), and numerous flame atomic absorption spectrometers. Between them, these instruments may be used to determine elements at concentration ranges of between 0.01 ng mL-1 up to > 1000 µg mL-1. If preconcentration techniques are used, the limits of detection may be improved further.

The ARF laboratories routinely assist 30 – 40 undergraduate project students from the School of Geography, Earth and Environmental Sciences (SoGEES) every year as well as lending support to postgraduate students from biology, marine science, geology, nutrition and even other faculties from the University of Plymouth. In addition, since ARF, along with the Consolidated Radioisotope Facility (CORiF) have become ISO 9001 accredited, they also undertake consultancy work which, over the last year, has brought in well over £20,000 to the university. The ARF also participates in certification exercises and inter-laboratory comparisons. Examples of such exercises include the analysis of Oyster tissue for the IAEA, work for the Laboratory of the Government Chemist (LGC), the determination of lead in bone for the New York State Department of Health and the speciation of arsenic in blood; also for the New York State Department of Health.

Through its support for both undergraduate and postgraduate students, the ARF routinely analyses samples as diverse as soils, sediments, waters, biological tissues (both plant and animal), plastics and oils. Over the years, ARF has also developed many analyte preconcentration techniques and has coupled many chromatographic systems to atomic spectrometric detectors enabling analyte speciation to be achieved. This facilitates elucidation of the overall toxicity of a sample with respect to a given analyte since each species of that analyte will have a different toxicity. Perhaps the most developed of the chromatographic techniques developed for speciation has been for arsenic, where a range of foodstuff materials as well as soils and sediments have been analysed using coupled HPLC-ICP-MS. Other broad areas of interest include standardised step-wise sequential extraction techniques and the bio-accessibility of analytes using PBET (physiologically based extraction test) and BARGE (Bi-Accessibility Research Group of Europe) methods.

The **Ecotoxicology laboratory suite** has extensive laboratory facilities for all aspects of ecotoxicology including molecular biology, biochemistry, physiology, and computer aided video tracking equipment to quantify animal behaviour. The laboratory suite is well equipped for cell imaging (confocal microscopes, single-cell electrophoresis such as the comet assay, real-time intracellular metal ion measurements etc.), equipment for biochemistry (various plate readers/spectrophotometers, bespoke equipment for working with small volumes), electrophysiology rigs, equipment for iono-regulation studies, respirometry, and metabolic studies. The group has extensive facilities for making animal feeds and to study the effects of oral exposures to chemicals in fish.

Commissioned in December 2006, the **Consolidated Radio-isotope Facility (CORiF)** is a dedicated laboratory for the manipulation and analysis of natural and enhanced radioactive materials. The radioanalytical instrumentation comprises three state-of-the-art gamma spectrometers and two liquid scintillation counters. It houses a wide range of equipment associated with the processing and preperation of any sample type. The CORiF has a license to hold and dispose of alpha, beta and gamma radionuclides which are used to support many applications in research and consultancy. The Laboratory acquired **ISO9001:2008 certification** in 2010 and is currently undertaking a range of analytical services related to internal and external research projects and contracts. It is committed to offering advanced postgraduate training and participating undergraduate teaching mainly for the School of Geography, Earth and Environmental Science and the School of Biomedical and Biological Sciences. Major areas of work include:

- studies of the eco- and geno-toxic effects of radio nuclides
- sediment geochronology
- soil erosion and sediment budget studies
- investigations of land contaminated with radionuclides
- geochemical tracer studies using radiochemicals
- complementary research involving non-radiometric analyses

These areas are of direct relevence to research into Climate Change, Catchment and Coastal Processes, Environmental Protection and Sustainability, many of which are funded by Research Councils. The facility also undertakes external contract work in these areas, and others, via an arrangement with UoPEL.

Existing MSc Courses at Plymouth University

MSc ENVIRONMENTAL CONSULTANCY

This course focuses on conserving our environment for future generations by working with industry and governments to reduce human impacts and provide solutions to environmental problems.

MSc SUSTAINABLE ENVIRONMENTAL MANAGEMENT

At the frontier of natural and social science where economic, ethical and political issues converge, this programme helps students explore the many dimensions of sustainability and the environment. From the classroom to the field, our practical teaching provides students with a strong foundation to investigate specific interests and gain hands-on experience. The course is led by research specialists working as part of a multidisciplinary research community.

Further information, contact:

Professor Iain Stewart

Chair of Geoscience Communication in the School of Geography, Earth and Environmental Sciences:
istewart@plymouth.ac.uk