EPSRC Centre for Doctoral Training in Aerosol Science

PhD Title: Evaluation of the health impacts of aircraft nanoparticles using a surrogate soot source and in vitro cell exposure

Details of Mentoring Team

	Name	Institution/Organisation	School/Department
Lead academic(s)	Marc Stettler	Imperial College London	Civil and Environmental Engineering
Co-supervisor(s)	Prof Peter Lindstedt Prof Terry Tetley	Imperial College London Imperial College London	Mechanical Engineering NHLI
Partner(s)	Dr Paul Williams Dr Rachel Smith	University of Manchester Public Health England	Earth and Environmental Science Nanoparticle Inhalation Research Group

Is this a Tier 3 (industry led) proposal? ~~Yes~~ / No

PhD Project Description

Context: Air travel is forecast to grow by 3.5% per year over the next two decades, leading to a doubling in passenger numbers from today's levels. Aircraft engines emit pollutants that degrade the air quality around airports, which may affect the health of local residents and employees at the airport. Specifically, nanoparticles emitted from gas turbine engines comprise soot aggregates, sulphur compounds, semi-volatile organic carbon and metallic ash. As the aircraft engine jet cools and mixes with the surrounding atmosphere, nucleation and condensation processes lead to a rapid growth in nucleation mode particles and condensation of semi-volatile compounds onto non-volatile soot aggregates. Aircraft nanoparticle emissions are characterised by their small size (<60 nm) relative to other combustion sources, e.g. road transport. They may therefore have particular health consequences that are currently under-studied and not well understood. A recent study[1] has conducted in-vitro toxicology tests to evaluate the effects on human bronchial epithelial cells to exposure to aircraft soot emissions from one type of aircraft engine. The authors found that the specific cellular response (cytotoxicity and oxidative stress) is dependent on the size and morphology of the soot particles, and fuel composition. However, much more work is needed to understand the different effects of aircraft nanoparticles and the role of their different properties and chemical constituents.

Specifically, the health impacts of aircraft nanoparticles may depend on the following properties:

- The size of the soot aggregates
- Their morphology and surface area
- Composition of coatings of organic carbon derived from unburned fuel or lubrication oil, e.g. presence of aromatic hydrocarbons
- Sulphur derived from naturally occurring sulphur in fuels
- Atmospheric ageing and oxidation of aerosols

Aims and objectives: This project aims to contribute to the understanding of the health impacts pathways of nanoparticles by developing and experimental methodology to test cellular responses to different sized nanoparticles and chemical compositions. The specific objectives of the project are to:

1. Review the literature on aircraft nanoparticle emissions, nanoparticle measurements near airports, and health impacts of different types and sources of combustion aerosols, including cellular response studies.
2. Develop laboratory source of soot particles that can be used to generate a tuneable surrogate aircraft aerosol in terms of particle size distribution and morphology, chemical composition and different coatings, and atmospheric ageing and oxidation. The soot source will be based on a burner design that has been used as a surrogate for aircraft soot particles before, and additional features such as organic carbon coatings and atmospheric ageing will be developed.
3. Use the surrogate soot source to design and conduct a comprehensive matrix of experiments to evaluate cellular responses to particle size and morphology, chemical composition of coatings, and atmospheric ageing. For example, aerosol classifiers could separate particular particle sizes before deposition on the cell culture to control for the effects of particle size. Similarly, particles could be coated with different materials, or have their coating removed by the use of a catalytic stripper. These methods are already established and involve exposure of primary human lung cells to increasing concentrations of the particles and determination of cell viability (MTT/LDH/apoptosis assays), mediator production (ie pro-inflmmatory responses; ELISA assays), oxidative stress (ROS measurement), mitochondrial integrity (mitotracker), cellular antioxidant depletion (GSH oxidation) and particle uptake. Positive controls (eg ZnO nanoparticles) with known toxicity will be tested in parallel.
4. Evaluate potential health impacts of aircraft nanoparticle emissions around airports using existing evidence and new modelling works to understand how health risks may vary with distance from the airport, and other factors such as weather conditions.

Finally, new regulations on (non-volatile) particle emissions from aircraft engines means that there is a need to develop methods to calibrate particle analysers and particle sampling losses. The thematic broadening sabbatical will therefore explore the use of a surrogate soot source for instrument calibration.

References:
1. Jonsdottir, H.R., Delaval, M., Leni, Z., Keller, A., Brem, B.T., Siegerist, F., Schönenberger, D., Durdina, L., Elser, M., Burtscher, H., Liati, A., Geiser, M., 2019. Non-volatile particle emissions from aircraft turbine engines at ground-idle induce oxidative stress in bronchial cells. Commun. Biol. 2. doi:10.1038/s42003-019-0332-7
2. Stettler, M.E.J., Swanson, J.J., Barrett, S.R.H., Boies, A.M., 2013. Updated Correlation Between Aircraft Smoke Number and Black Carbon Concentration. Aerosol Sci. Technol. 47, 1205–1214. doi:10.1080/02786826.2013.829908

Thematic Area (see note below): Aerosols and Health

Description of Thematic Broadening Sabbatical

The thematic broadening sabbatical project will take place with Dr Paul Williams at University of Manchester. The project will be based on atmospheric aerosol measurements from the new urban supersite for monitoring ambient air quality. The student will complete relevant training and be given access to a whole range of ambient aerosol measurements. The project will analyse a year's worth of ambient air quality measurements and then focus in on specific pollution events. The project will emphasise the importance of meteorology in influencing properties of ambient aerosols and give an appreciation of how combustion aerosols are transported and processed in the atmosphere.

Thematic Area (see note below): Atmospheric Aerosol Studies

Placement with Partner
The student will have the opportunity to spend time with the Nanoparticle Inhalation Research Group at Public Health England (information below). During the placement (to take place in year 3), the student will use PHE's air-liquid aerosol exposure systems (Vitrocell and/or Cultex) to expose cell cultures to a panel of particles produced by the surrogate soot source and to evaluate the effects of aerosol deposition. The student will also have the opportunity to interact with members of the Air Quality group at PHE, who provide advice and guidance in relation to air pollution. The Nanoparticle Inhalation Research Group within the Toxicology Department at the PHE Centre for Radiation, Chemical and Environmental Hazards was established in 2009 to address concerns about the potential public health implications of the growing use of nanomaterials. The group undertakes basic research into the toxicity of nanomaterials and also potential exposure levels, with a focus on the inhalation pathway, and provides advice to Government (e.g. Defra) and other bodies, local, national and international, in this area. The group has state of the art facilities for the creation, delivery and characterisation of aerosols and associated chemical analysis facilities (e.g. ICP-MS/spICP-MS/Laser Ablation ICP-MS). We have undertaken toxicity studies for a range of nanomaterials including: silver, cerium dioxide, zinc oxide, iron oxides and carbon nanotubes. The key research interests of the group are: the deposition, clearance and translocation (toxicokinetics) of inhaled poorly soluble nanoparticles; the development and use of 'alternative' (in vitro) toxicity testing approaches using aerosol exposure air liquid interface (AE-ALI) systems; the use of radioactively labelled nanomaterials; the application of microarray techniques to evaluate gene expression changes in pulmonary cell types; the effect of inhaled nanomaterials and other air pollution components on pre-existing health conditions (e.g. asthma); the development of methodologies and approaches for on-line characterisation of nanoparticle aerosols, especially carbon nanotubes; and the chemical and biophysical nature of interactions between components of lung surfactant and nanoparticles.

Explanatory Notes:

- Academic mentoring team: The lead academic supervisor and academic co-supervisor should be researchers in complementary thematic areas of aerosol science. The lead academic will be the main PhD supervisor; the co-supervisor will host the student in their research team for a 3-month thematic broadening sabbatical in the spring/summer of Year 1. There are no restrictions on the institution of the co-supervisor: they may be in the same institution as the lead academic or in one of the partnering institutions. It should be remembered that students will reside in Bristol in months 1-6 of Year 1. Many students may then prefer to move to the city they will reside in for the remainder of their PhD, so co-supervisors from nearby institutions (e.g. Leeds with Manchester, Bath with Bristol etc.) may be preferred by students, making recruitment easier. See Annex 1 for a full list of academic members of the supervisorial team to assist lead academics in identifying an appropriate co-supervisor.
- Partner mentor: For *regular (non-Tier 3) studentships*, the partner will, most likely, have a broad interest in the area of the PhD project, but the research will be academic led. The partner will host the student for a 2-3 month placement at their organisation in Year 2 or 3. For *Tier 3 studentships*, the partner will co-fund the studentship at a level of £40k (£10k/year) and will work with the academic team to design a PhD project that addresses research of particular value to the partner.

- Identifying partners for the second cohort: Although a partner may be readily identified by the academic team for some projects, an appropriate partner may be less clear for others. If a partner cannot be readily identified by the academic team, the CDT leadership team can assist in identifying an appropriate partner to join the mentoring team. A list of industrial and public sector partners is given in Annex 2 to assist the academic team in identifying potential partners.
- Thematic broadening sabbatical: Supervised by the co-supervisor, this should have a focus in an area of research complementary to the final PhD project. Run as a mini-project during months 7-10 of the first year, a short project report is one element discussed in the progression interview at the end of Year 1. Brief project details should be provided on the form. Travel costs (e.g. travel to Leeds if the student is residing in Manchester, short term accommodation if further afield) and project costs will be paid by the CDT.
- Placement with partner: For regular studentships, this should be a 2-3 month placement anytime during Year 2 or 3. Placements for Tier 3 can be more extensive/frequent, as agreed by the mentoring team. A general overview of the likely area of activity should be provided, including potential training opportunities. Travel costs will be paid by the CDT.
- Thematic Area: You should identify the thematic area of the primary PhD project and the thematic broadening sabbatical. These should be in complementary areas of aerosol science using the definitions provided by the European Aerosol Assembly. The five thematic areas are: Basic Aerosol Processes, Aerosols and Health, Aerosol Technology, Atmospheric Aerosol Studies, Aerosol Measurement Techniques. See the "Working Groups" link at http://www.gaef.de/eaa/. Also, note that further information on the coverage of the 5 themes is given at the links in the top left of the "Working Groups" page.

More Information and How to Apply

Candidates who aspire to work in a multidisciplinary field, and hold or will achieve a minimum of an upper second-class undergraduate degree in any of these areas are encouraged to apply: chemistry, physics, biological sciences, life and medical sciences, mathematics and computer science, chemical and mechanical engineering, pharmaceutical and environmental sciences.

Visit our website:
https://www.aerosol-cdt.ac.uk/

Contact us:
aerosol-science@bristol.ac.uk

Apply by 3rd February 2020– applicants with a suitable academic background will be invited to attend a recruitment and assessment day in Bristol on February 10th. Applications after this date will be subject to remaining availability of studentships.

Equality, Diversity and Inclusion

We are committed to furthering issues of equality, diversity and inclusion and are keen to attract the most highly talented individuals from diverse backgrounds. The needs of individuals will be accommodated during the recruitment process and while studying with the CDT. Further information on our commitment to equality and diversity can be found on our website.

Application Enquiries

Name: Kate Lucas (Aerosol CDT Administrator)

Email: aerosol-science@bristol.ac.uk

Applications Tel: +44(0)117 928 8681

Applications WWW link: https://www.aerosol-cdt.ac.uk/how-to-apply/

Annex 1: Core supervision team for EPSRC Centre for Doctoral Training in Aerosol Science

Name	Position	School/Department and Institution	Expertise
Jonathan Reid	Professor of Physical Chemistry	Chemistry, University of Bristol	Aerosol microphysics, optical properties of aerosols, drug delivery to the lungs, formulation science, bioaerosol
Bryan Bzdek	Independent Research Fellow	Chemistry, University of Bristol	Atmospheric aerosols, analytical techniques, new particle formation
Michael Cotterell	Independent Research Fellow	Chemistry, University of Bristol	Optical properties of aerosols, laboratory and airborne spectroscopy techniques
Alberto Gambaruto	Lecturer	Mechanical Engineering, University of Bristol	Inhalation models and therapeutics
Anwar Khan	Senior Research Associate	Chemistry, University of Bristol	Dispersion models, secondary organic aerosol, gas-particle partioning
Andrew Orr-Ewing	Professor of Physical Chemistry	Chemistry, University of Bristol	Optical properties of aerosols and spectroscopy
Matt Rigby	Reader in Atmospheric Chemistry	Chemistry, University of Bristol	Atmospheric box models, dispersion models, secondary organic aerosol, gas-particle partitioning, machine learning, big data
Dudley Shallcross	Professor of Atmospheric Chemistry	Chemistry, University of Bristol	Atmospheric Chemistry research group, Atmospheric box models
Matt Watson	Reader	Earth Sciences, University of Bristol	Atmospheric aerosols, instrumentation, geo-engineering
Michael Hill	Professor of Inorganic Chemistry	Chemistry, University of Bath	Aerosol-assisted chemical vapour deposition
Andrew Johnson	Lecturer	Chemistry, University of Bath	Aerosol-assisted chemical vapour deposition
Matthew Jones	Lecturer	Pharmacy and Pharmacology, University of Bath	Inhalation therapeutics and drug delivery (esp. device usability), formulation science
Anton Souslov	Lecturer	Physics, University of Bath	Levitation in air. Theory and modelling of soft materials. Phases of soft matter.
Adam Squires	Senior Lecturer	Chemistry, University of Bath	Basic process studies and new techniques for aerosols (e.g. synchrotron small-angle X-ray)
Jethro Akroyd	Senior Research Associate	Chemical Engineering and Biotechnology, University of Cambridge	Combustion, nanoparticles, soot

Name	Position	School/Department and Institution	Expertise
Adam Boies	Director of ANAM, Reader	Engineering, University of Cambridge	Particle synthesis using aerosol flow reactors (e.g. carbon nanotubes, carbon black)
Megan Davies Wykes	Lecturer in Engineering	Engineering and Applied Mathematics, University of Cambridge	Pollution dispersion modelling, experimental fluid dynamics
Simone Hochgreb	Professor of Engineering	Engineering, University of Cambridge	Combustion, particle formation and optical diagnostics
Markus Kraft	Professor of Engineering	Engineering, University of Cambridge	Particle synthesis using aerosol flow reactors (e.g. carbon nanotubes, carbon black)
Sebastian Mosbach	Senior Research Associate	Chemical Engineering and Biotechnology, University of Cambridge	Computational modelling
Robert Chilcott	Professor in Pharmaceutics	Life and Medical Sciences, University of Hertfordshire	Aerosol dispersal, exposure to chemical and radiological aerosols, toxicology and exposure remediation
Richard Greenaway	Senior Research Fellow	Physics, University of Hertfordshire	Particle instrumentation, data-analysis, optics
Ian Johnston	Associate Professor of Research	Engineering, University of Hertfordshire	Microfluidic systems, experimental aerosol sampling and collection techniques, biodetection
Joanne Larner	Senior Research Fellow	Life and Medical Sciences, University of Hertfordshire	Chemical analysis of aerosol composition, bio exposure
Daniel McCluskey	Associate Professor of Research	Engineering, University of Hertfordshire	Aerosol sampling techniques & system design, fluid dynamics, advanced microfluidics, biodetection
Darragh Murnane	Professor in Pharmaceutics	Life and Medical Sciences, University of Hertfordshire	Inhalation therapeutics and particle-lung interactions, delivery device design
Chris Stopford	Associate Professor	Physics, University of Hertfordshire	Optical properties of aerosol and novel instrumentation
Laura Urbano	Lecturer in Pharmaceutics	Life and Medical Sciences, University of Hertfordshire	Novel nano-diagnostics and therapeutics. In-vitro models to contribute to the fields of drug safety, drug delivery and translation
Denis Doorly	Professor of Fluid Mechanics	Engineering, Department of Aeronautics, Imperial College London	Fluid mechanics

Name	Position	School/Department and Institution	Expertise
Yannis Hardalupas	Professor of Multiphase Flows	Mechanical Engineering, Imperial College London	Multiphase flows and sprays, droplet and nanoparticle sizing, exhaust after-treatment, combustion in gas turbines and IC engines
Jerry Heng	Reader in Particle Technology	Chemical Engineering, Imperial College London	Nucleation, crystallisation, surface properties, powders
Peter Lindstedt	Professor of Thermofluids	Mechanical Engineering, Imperial College London	Combustion and soot
Asha Patel	Lecturer in Cell & Gene Therapy	National Heart & Lung Institute, Imperial College London	Inhaled delivery of advanced therapeutics such as mRNA
Alex Porter	Professor of Bio-imaging and Analysis	Materials, Imperial College London	Toxicology of particles, enhanced Electron Microscopic Imaging
Marc Stettler	Lecturer in Transport and Environment	Civil and Environmental Engineering, Imperial College London	Nanoparticle emissions sources, measurements and models, transport sector, ambient pollution
Terry Tetley	Professor of Lung Cell Biology	National Heart & Lung Institute, Imperial College London	Cellular and molecular mechanisms of pulmonary diseases
Omar Usmani	Reader in Respiratory Medicine	National Heart & Lung Institute, Imperial College London	Inhalation therapeutics, drug delivery to the lungs
Andrew Bayly	Professor of Chemical Engineering	Chemical and Process Engineering, University of Leeds	Materials processing, spray drying and particle fabrication
Dwayne Heard	Professor of Physical Chemistry	Chemistry, University of Leeds	Laboratory studies of atmospheric aerosols and oxidation chemistry
Nik Kapur	Professor of Applied Fluid Mechanics	Mechanical Engineering, University of Leeds	Droplets, sprays and coatings, fluid flow and heat transfer
Ben Murray	Professor of Atmospheric Science	Earth and Environment, University of Leeds	Laboratory studies of atmospheric aerosols including ice
Catherine Noakes	Professor of Environmental Engineering for Buildings	Civil Engineering, University of Leeds	Indoor air quality and airborne infection, ventilation and building performance
John Plane	Professor of Physical Chemistry	Chemistry, University of Leeds	Laboratory studies of interstellar chemistry on dust
Andrew Brass	Professor of Bioinformatics	Computer Science, University of Manchester	Health informatics and immunology, allergies and environmental factors

Name	Position	School/Department and Institution	Expertise
Hugh Coe	Professor of Atmospheric Composition	School of Earth and Environmental Sciences, University of Manchester	Particle detection, physical and chemical characterization, gas/ particle conversion, instrumentation, sampling and data analysis methods
Sheena Cruickshank	Professor of Public Engagement and Biomedical Sciences	Biological Sciences, University of Manchester	Impact of pollutants and airborne microbes on barrier cells, public engagement and citizen science
Amanda Lea-Langton	Lecturer in Bioenergy Engineering	Mechanical, Aerospace and Civil Engineering, University of Manchester	Smoke formation and organic carbon emissions, environmental aerosol
Gordon McFiggans	Professor of Multiphase Atmospheric Processes	School of Earth and Environmental Sciences, University of Manchester	Atmospheric Composition, Clouds & Aerosols, Computer Modelling, Marine Atmospheric Chemistry
Benedict Rogers	Reader	School of Mechanical, Aerospace and Civil Engineering	Smoothed particle hydrodynamics (SPH) with novel applications to aerosol problems
David Topping	Senior Lecturer	Earth and Environmental Science, University of Manchester	Aerosol microphysics, air quality, environmental aerosol, computer modelling and data science/ machine learning
Paul Williams	Independent Research Fellow	Earth and Environmental Science, University of Manchester	Vehicle emissions, new instrumentation, environmental aerosols

Annex 2: Current List of Potential Partners

3M Healthcare UK Ltd
Agilent
Alphasense
Astra Zeneca
Bayer Crop Science - Bioaerosol detection
Bespak Europe Ltd
Biral
Cambustion
Centre for Ecology and Hydrology
Chiesi
CMCL Innovations
CN Bio
DEFRA
Droplet Measurement Technologies
DSTL
Dyson
Echion Technologies
Emissions analytics
Environment Agency
Filter Integrity
GSK
Intertek Melbourn
Johnson Matthey
LettUs Grow
Malvern Instruments
MedPharm
Met Office
NanoPharm
National Physical Laboratory
Nyquist Solutions Ltd
Philips / PMO and Technology Respiratory Drug Delivery
Pirbright
Public Health England
Rolls Royce
Rothamsted Research
RSK
Siemens
Steer Energy
Syngenta
TH Collaborative Innovation
Tortech
Trolex
TSI
Vectura
Venator
Waters Mass Spec