Institution: University of Oxford

Unit of Assessment: UoA7 (Earth Systems and Environmental Sciences)

Title of case study: UoA7-3: Cycling of mercury in the environment and informed mercury policy

1. Summary of the impact

Mercury is extremely toxic and there is a worldwide need to limit its use and manage redundant stocks. Diverse research in the UoA on mercury in the environment led to a knowledge-exchange initiative: 'Integrating Knowledge to Inform Mercury Policy' (IKIMP). Since 2009, IKIMP's policy briefings and reports have had a significant impact on mercury policy at UK, European and global levels. The United Nations Environment Programme (UNEP) adopted IKIMP's decision-making framework to help countries deal with their redundant mercury. Defra used IKIMP reports to communicate the UK's position on mercury issues at EU and international levels, and IKIMP has influenced UNEP's development of the Minamata Convention, the international, legally-binding convention to limit mercury use agreed in 2013.

2. Underpinning research

Of all potentially toxic elements, mercury is arguably the one currently associated with the most widespread human health concern. Exposure to mercury and its compounds has a range of serious health impacts including brain and neurological damage, especially among young people and unborn children. Mercury poses a particular ecological and human health risk due to its volatility, solubility and mobility in the environment, where it often forms organo-metallic compounds.

With an atmospheric lifetime of around a year, the impact of mercury sources can be felt at considerable distance, making mercury pollution a global as well as local issue. It is therefore important to know the sources and fluxes of anthropogenic mercury emissions as accurately as possible, and to set these in the context of the natural mercury cycle.

Research conducted in the UoA has advanced understanding of the natural cycling of mercury, and developed microbial/mineralogical remediation strategies for mercury contamination. Other research, also conducted in the UoA, has identified approaches to improve the transfer of relevant scientific understanding into policy at an international level, and utilised these approaches to communicate the latest research on mercury cycling to relevant policy organisations.

Natural volcanic mercury emissions

Since 2006, University of Oxford researchers (Pyle, Mather, Witt) have transformed the understanding of global volcanic mercury emissions. In collaboration with the University of Palermo, they provided the first systematic analysis of the various forms of mercury (gaseous and particulate) in volcanic emissions, and established that Mount Etna alone contributed ≈5% of all mercury emissions in the Mediterranean region (Bagnato et al. 2007 [1]). Further research showed that the volcanic mercury flux is ~100 t yr^{-1}, and primarily emitted as gaseous elemental mercury with an extended atmospheric lifetime, but may undergo rapid reaction as it is transported, leading to local deposition and hence affecting environmental mercury levels (Witt et al. 2008 [2]).

Marine mercury cycle

Oceanic cycling of mercury is significant, but remains poorly constrained due to the challenges of measurement in remote marine areas. The resulting lack of data restricts scientists' ability to predict the response of ocean and atmospheric reservoirs to changing emissions and climate. University of Oxford researchers, in collaboration with UEA, measured atmospheric and aqueous mercury in remote marine environments, extending the global data coverage of mercury measurements to the Indian Ocean for the first time (Witt et al. 2010 [3]).

Environmental microbiology

Other Oxford researchers (Jackman, Gardner, Porcelli) investigate the possible use of microbes for remediation of chemical pollution, including that of mercury. For instance, in a study funded by the Russian International Science and Technology Centre, they developed a remediation strategy for

an anthropogenic mercury spill in Kazakhstan (Kajenthira et al 2008 [5]) using unique sorbent materials involving sulfate-reducing bacteria (SRBs). These enhance the natural transformation and immobilization processes taking place in the environment.

Science and policy
Other researchers in the Earth Sciences Department (Holmes, Howard) conduct research that investigates the best approach for effective transfer of up-to-date environmental knowledge into policy. Funded by the Environment Research Funders Forum and the Environment Agency, Holmes undertook research to assess best practice for such science-to-policy exchange in Europe (Holmes and Savgard, 2009 [6]), research which informed IKIMP's activities to influence development of mercury-contamination policy.

Names of the key researchers and what positions they held at the institution
Professor David Pyle (University Lecturer, 2006-present)
Dr Tamsin Mather (University Lecturer, 2006-present)
Dr Melanie Witt (PDRA, 2006-present)
Dr John Holmes (Senior Research Fellow, 2004-present)
Dr Murray Gardner (PDRA, 2007-present)
Dr Simon Jackman (Research Scientist, 1997– 2009)
Dr Don Porcelli (University Lecturer, 2002 – present)
Dr Bruce Howard (Project Manager ES-KTN, 2006 - 2010)

3. References to the research

The three asterisked outputs best indicate the quality of the underpinning research.

1. * Bagnato E, Aiuppa A, Parello F, Calabrese S, D'Alessandro W, Mather TA, McGonigle AJS, Pyle DM & Wängberg, I. Degassing of gaseous (elemental and reactive) and particulate mercury from Mount Etna volcano (Southern Italy). Atmospheric Environment, 41, 7377-7388, 2007. DOI:10.1016/j.atmosenv.2007.05.060 (27 citations in Scopus)
   First measurements of the full speciation of mercury (particulate, gaseous elemental and gaseous oxidised) from a volcano.
2. * Witt MLI, Mather TA, Pyle DM, Aiuppa A, Bagnato E & Tsanev VI. Mercury and halogen emissions from Masaya and Telica volcanoes, Nicaragua. Journal of Geophysical Research - Solid Earth, 113, B06203, 2008. DOI:10.1029/2007JB005401 (28 citations in Scopus)
   Extended the geographical coverage of fully-speciated mercury measurements to include a subduction zone volcano.
3. Witt MLI, Mather TA, Baker AR, de Hoog C-J & Pyle DM. Atmospheric trace metals over the South-West Indian Ocean: Total gaseous mercury, aerosol trace metal concentrations and lead isotope ratios. Marine Chemistry, 121, 2-16, 2010. DOI:10.1016/j.marchem.2010.02.005
4. Witt MLI, Meheran N, Mather TA, de Hoog C-J & Pyle DM. Aerosol trace metals, particle morphology and total gaseous mercury in the atmosphere of Oxford, UK. Atmospheric Environment, 44, 1524-1538, 2010. DOI:10.1016/j.atmosenv.2010.01.008
5. Kajenthira KA, Jackman SA, Porcelli D, Ilyushchenk MA, Kamberov RI, Wingate J and Hutchings T. Bioremediation of Mercury Contamination in Kazakhstan: A Multifaceted Approach. In CD: Bruce M. Sass, Proceedings of the Sixth International Conference on Remediation of Chlorinated and Recalcitrant Compounds (Monterey, CA) 2008. http://hg-kazakhstan.narod.ru/pdf/H-009_Abs.pdf
6. * Holmes J and Savgard J. 2009. The planning, management and communication of research to inform environmental policy making and regulation: an empirical study of current practices in Europe. *Science and Public Policy*, 36(9), November 2009, 709–721. DOI: 10.3152/030234209X475227
   Report on an empirical study to identify how the substantial investments made in research on environmental issues in the EU can be better managed and communicated to support an evidence-informed approach to environmental policy-making and regulation.

4. Details of the impact

The research described above has shaped and influenced international mercury policy. The combination of diverse expertise in the University of Oxford's Department of Earth Sciences (i.e. understanding of mercury emissions and cycling; expertise in environmental remediation; and skill in the use of science to inform environmental policy) led to the formation of the IKIMP initiative in October 2008. IKIMP was led by researchers in the UoA, relying on their scientific expertise and contacts, and funded by NERC. Its aim was to ensure that scientific evidence and expertise was used to inform public policy relating to mercury.

In October 2008, the EU banned exports of mercury with effect from March 2011. This required that a report be submitted to the European Parliament by January 2010, reviewing safe mercury disposal options. Defra (the lead UK department on mercury) asked the newly-formed IKIMP to gather scientific evidence to help inform them of UK storage options and to communicate the UK's position to the EC during preparation of its report. IKIMP also worked with Defra and the United Nations Environment Programme (UNEP) as they developed a legally-binding Multilateral Environmental Agreement (MEA) to reduce global mercury use and pollution (the Minimata Convention). IKIMP helped develop robust policy guidance, and synthesized science evidence, to inform negotiations at UN Intergovernmental Negotiating Committees (INCs) leading to the Minimata Convention.

Between 2009 and 2011, IKIMP hosted three successful workshops, each leading to the writing of influential reports on the science and policy of mercury. These workshops built on Oxford University research, and on the reputation and contacts of Oxford University researchers.

1. **Safe Storage and Disposal of Redundant Mercury**
IKIMP's October 2009 workshop was the first international event to address the question of mercury storage following the decision to draw up a MEA. The resulting report was delivered to Defra, who sponsored the event. Outcomes of this workshop and report include:

- Production of a decision-making framework for the safe management of redundant mercury in developing countries; a framework quickly adopted and built upon by UNEP;
- Presentation of a revised strategic framework for storage and disposal of mercury to an EC meeting in Brussels in November 2009 [8];
- Influence on the 2010 EU report on safe mercury storage;
- IKIMP's presentation of the report at UNEP's first INC on mercury in June 2010 [9];
- UNEP implementation of two Mercury Storage Projects in South America using IKIMP's framework for decision making, following presentation to the UNEP Inception Workshop on Mercury Storage and Disposal in Latin America [10].

These developments marked the beginning of pre-ratification implementation of the Minimata Convention. A UNEP science advisor confirms that IKIMP was, '*extremely active in helping UNEP develop the decision making framework for the long-term storage and disposal of redundant mercury*' [11]. The 2009 workshop and report drew on Holmes' science and policy research, and were informed by the University of Oxford teams' wider understanding of mercury behaviour in the environment.

2. **Mercury arising from oil and gas production in the UK and UK continental shelf**
IKIMP co-hosted the sixth 'Mercury Emissions from Coal' conference in 2009, which highlighted the lack of data on mercury releases from the oil & gas industry. IKIMP published a subsequent report in January 2012 [7] drawing together all available data on mercury emissions from the UK oil and gas industry, and identifying a paucity of data in the public domain. This report informed UNEP policy discussions, as confirmed by a UNEP representative [11]: '*when it comes to sources such as oil and gas, the data are extremely limited. In fact, the report by IKIMP is perhaps the only recent and relevant report on this subject. [It] is used as the basis for the argument that the oil and gas sector need to be encouraged to have greater representation during negotiations.*' The report has also been influential at national level. For example, the Director of the Center for Ecology and Economics at the Norwegian Institute for Air Research, has used the report, '*to convince [the] oil and gas industry in Norway and Abu Dhabi ... to arrange projects that will help estimating the*

contribution of this industry to the Hg emission budgets' [12].

3. **Current understanding of the global mercury cycle: implications in the context of reducing anthropogenic emissions**

IKIMP's second major workshop (Oxford, May 2011) brought together experts to consider natural emissions and the global mercury cycle. Discussion of critical volcanic and marine mercury fluxes was directly informed by University of Oxford research. Defra representatives at the meeting sought a document outlining baseline natural emissions of mercury and their variability, to contextualize future guidance on anthropogenic mercury emissions. The resulting IKIMP policy-briefing document influenced a subsequent UNEP INC on mercury. A Defra's Senior Scientific Officer confirmed that the document, '*enabled policy makers to establish practical emission and release objectives for the UN Convention*' [13]. A UNEP representative comments that, '*the IKIMP work to evaluate emissions from natural sources [...] and exposing the knowledge gaps in the global mercury cycle has been a valuable tool when putting global mercury emissions into perspective*' [11].

Research and knowledge exchange activities led by Oxford University have thus led to major impacts on national and international policymakers and regulators, including helping to shape the Minimata Convention, which was agreed by national governments in January 2013 and represents a significant advance in global management of mercury. Defra's Senior Scientific Officer for Chemicals and Emerging Technologies states that, '*IKIMP has been very successful in transferring knowledge and technical expertise to policy developers at national, European and UN levels. It has proved an invaluable asset in a wide range of negotiations and has certainly helped expedite the development of the Minimata Convention*.' [13]

5. Sources to corroborate the impact

7. All IKIMP policy briefings and reports can be found at http://www.mercurynetwork.org.uk/ including the oil and gas industry emission report at http://www.mercurynetwork.org.uk/ikimp-oil-gas-report-published/
8. Requirements for facilities and acceptance criteria for the disposal of metallic mercury. *European Commission, DG Environment, Brussels 2009* http://ec.europa.eu/environment/chemicals/mercury/pdf/bipro_study20100416.pdf IKIMP input and advice is specifically referred to on pages 28, 126, 138 and 140.
9. Details of the first UNEP INC meeting, detailing IKIMP's involvement in the discussions on mercury storage and handling, can be found at http://www.unep.org/hazardoussubstances/Mercury/Negotiations/INC1/Technicalbriefingpresentations/tabid/4118/Default.aspx
10. Final report on Mercury Two Countries Storage Project, delivered to UNEP in October 2012: http://www.unep.org/hazardoussubstances/Mercury/PrioritiesforAction/SupplyandStorage/Activities/LACMercuryStorageProject/MercuryStorage2CountriesProject/tabid/79070/Default.aspx The concept note and agenda (link in paragraph 2 on the webpage) specifically mentions IKIMP input on page 2.
11. Letter from the Lead for the UNEP Coal Partnership Area and Senior Environment Consultant at the International Energy Agency Clean Coal Centre (held on file)
12. Letter from the Director of the Center for Ecology and Economics, Norwegian Institute for Air Research Programme (held on file)
13. Letter from the Senior Scientific Officer for the Chemicals and Emerging Technologies Division, Department for Environment, Food and Rural Affairs (Defra) (held on file)
14. Letter from Head of Chemicals branch, DTIE, United Nations Environment Programme – (held on file). Corroborates contribution in briefing United Nations delagates who were preparing a legally binding instrument on mercury.