Summary of Research Interests

I study how biogeochemical processes affect the fate, transport and food web bioaccumulation of trace metals and organic chemicals in aquatic ecosystems. I develop and apply models at a variety of scales ranging from ecosystems and ocean basins (e.g., the Gulf of Maine [1, 2], the North Pacific [3] and Arctic Oceans [4]) to global [5, 6] applications to characterize how changes in climate and emissions affect human and ecological health, and the potential impacts of regulatory activities. My group also makes key measurements of chemical concentrations and reaction rates in environmental samples (natural waters, sediments, and aquatic biota) and humans (hair, blood) to parameterize and evaluate our models. I co-lead both the Atmospheric Chemistry modeling group at Harvard (http://acmg.seas.harvard.edu/index.html) and the Aquatic Biogeochemistry Research group (http://www.hsph.harvard.edu/water/). I have appointments in both the School of Engineering and Applied Sciences and the School of Public Health to facilitate my interdisciplinary research program.

My ongoing research is elucidating the biogeochemical cycling of three classes of compounds with contrasting physical and chemical properties that can be used to obtain insights into the varying exposure pathways and environmental lifetimes for industrial chemicals: (a) inorganic mercury (Hg) and methylated mercury species, (b) perfluoroalkyl and polyfluoroalkyl substances (PFASs), and (c) polychlorinated biphenyls (PCBs).

The innovation in this work is to quantitatively analyze the entire exposure pathway for these compounds to identify their properties in air and water (e.g., stability in the atmosphere, photodegradation in water, environmental partitioning behavior) that enhance chemical persistence and ultimate accumulation in biota. Mercury is a heavy metal that exists as several chemical species, has both natural and anthropogenic sources, and has been released by humans since antiquity [5]. PFASs and PCBs are persistent organic pollutants (POPs) with only human production sources and contrasting chemical properties and environmental partitioning behavior. PCBs are a classic “legacy” pollutant with production sources that have been heavily regulated while PFASs are considered an “emerging” class of chemicals compounds because of their prevalence in modern chemical manufacturing. The organic form of mercury, MeHg, is a well-known neurotoxin that causes long-term neurocognitive deficits in children. Societal costs of IQ deficits associated with MeHg exposures have recently been estimated at ~ $16 billion in the U.S. and EU alone [7, 8]. PCBs also cause neurodevelopmental delays, are immunotoxic, and some congeners are also suspected carcinogens [9, 10]. PFASs are of particular interest because my collaborators recently showed that they are associated with the most severe immunotoxic effects ever observed in a human population. A dramatic decline in children’s antibody production (~50%) was observed in response to specific vaccine toxoids for each doubling of serum concentrations of certain PFASs [11]. These findings, if causal, imply that children who are highly exposed to these contaminants could be without protection, despite a complete series of vaccinations, which could ultimately affect the “herd” immunity of the population. I am now investigating the temporal correlation between production of PFASs and children’s blood from the same prospective birth cohort in the Faroe Islands between 1987-present. We are using chemical concentrations in the pilot whale tissue consumed by the Faroese over this same period to understand how changes in the marine environment are affecting exposures.

My prior research has had demonstrable impact on both the scientific and regulatory communities. My research on the biogeochemical cycling of mercury in marine ecosystems and resulting human exposures has been featured frequently in various media outlets over the past decade (e.g., Nature News, NPR, USA today, New York Times). The U.S. EPA recognized the contributions of my research to environmental policy with a National Honor Award (Gold Medal for Exceptional Service) in 2005 and the highest level (Level 1) Scientific and Technological Achievement Award (STAA) in 2008 and a Level II STAA in 2010. Internationally, I was the invited opening plenary speaker for the 16th International Conference on Heavy Metals in the Environment in Rome in 2012 and an invited plenary speaker for the 11th International Conference on Mercury as a Global Pollutant in Edinburgh this past summer. In 2010, I was a lead chapter author for the assessment report by the United Nations Economic Commission for Europe Task Force on Hemispheric Transport of Air Pollutants. My H-index on the ISI Web of Science is 17 and is increasing rapidly. For example, my total citations doubled between 2011 (105) and 2012 (213). Presently, I have 35 peer-reviewed papers that mainly focus on various aspects of the environmental mercury cycle. Publications on some of my newer research directions such as the environmental cycling of flurochemicals and implications for immunotoxicity are presently in the pipeline and will come out in 2014.

Research Proposal

My goal is to continue the development of an interdisciplinary research program that combines environmental measurements, global and regional modeling of the fate, transport, and bioaccumulation of toxicants, and epidemiological research on their health impacts. My long-term research goals are to: (1) better understand the relationships between physical and chemical properties of major classes of compounds and their environmental behavior and exposure risks; (2) provide information to regulators and the chemical manufacturing industry on sound production choices.

Ongoing work within my laboratory supported by the U.S. National Science Foundation (NSF), the U.S. Environmental Protection Agency, and a number of private sources and foundations has produced simulations of atmospheric [12, 13], terrestrial [14] and oceanic [6, 15] cycling of mercury, PCBs and PFASs within a global chemical transport model, and a generic framework for bioaccumulation in marine ecosystems [16]. We are presently collaborating with researchers at MIT to couple the chemistry in our state-of-the-science chemical transport model (GEOS-Chem) with an ocean general circulation model that includes a simulation of ocean ecology (the MITgcm and "Darwin model" [17] simulation). We have been simulating the impacts of climate changes using 30-year (1980-present) assimilated meteorological data from the NASA GEOS-MERRA system. The MERRA system includes assimilation of research satellite observations and uses consistent physics and assimilation schemes to reconstruct 1980-present interannual variability and trends, which removes some of the uncertainty associated with future climate projections. This work is producing a computational framework for linking chemical production and environmental drivers of global change to biological concentrations of contaminants and associated health risks. Such a tool will help inform proactive environmental management strategies for chemical manufacturing and releases.

Statement of Teaching Philosophy

In my classes, I use case studies and hands-on tutorials such as measuring trace metal concentrations in student's hair. My lectures focus on relating fundamental concepts to real-world applications. I find in-class debates a great way have students learn from each other. For example, my risk assessment students debate the merits of reopening the Gulf of Mexico fisheries following the *Deepwater Horizon* oil spill by taking the positions of the U.S. Food and Drug Administration (FDA) and various non-governmental organizations (NGOs) in the region. Once the debate has concluded I ask them to look at temporal trends in polycyclic aromatic hydrocarbon (PAH) tissue residues before and after the spill to reevaluate their positions since there is no evidence for an increase in most species.

I also use field trips to facilitate experiential learning, as well as to get to know the students more personally. This year I took my undergraduate class to one of the main distribution points for a major seafood restaurant chain where we watched the fish arrive in the morning and received a tour from the CEO on quality assurance for pathogens and contaminants. I like to be challenged as a teacher by questions, debate and engagement of my students. These challenges can be incredibly productive both in helping me refine my ideas, as well as for continually improving as a teacher.

I was very pleased last year when my risk assessment class received commendation from the Department as one of the most highly rated classes. My undergraduate class this year received an overall evaluation score of 4.4/5.0 by the students. I look forward to future opportunities to refine my teaching skills.

Graduate and Undergraduate Courses Developed/Taught

I am very comfortable teaching within my disciplinary area (Environmental Chemistry, particularly aquatic and marine chemistry). I also teach a risk assessment course at Harvard that includes environmental toxicology and management of chemicals in the environment.

- Risk Assessment (RDS-500), Harvard School of Public Health, Graduate Level (primary instructor). This course provides an overview of the fundamentals of quantitative risk assessment and environmental toxicology as well as science-policy interactions, risk perception and communication. It is a required course for all graduate students concentrating in our program and generally has an enrollment between 14-20 students.
- Seminar on Global Pollution Issues (ES-169), Harvard School of Engineering and Applied Sciences, Undergraduate (primary instructor). This course covers the scientific foundations of environmental research methods (i.e., analytical chemistry, ecology, use of environmental archives, environmental modeling) and uses original research data sets to give the students experience conducting multidisciplinary environmental research.
- Environmental Science, Harvard Extension School, Graduate (co-instructor). This course provides a general overview of environmental science.

My other teaching experiences include developing a staff level training course for the U.S. Environmental Protection Agency on the use and application of environmental models to inform decision-making. I was appointed by former EPA Administrator, Mike Leavitt to a team of five Agency experts to conduct training on the environmental behavior of mercury for environmental journalists, White House staff and senior political appointees. I have given numerous seminars and conducted many training activities at the federal and state level. While in graduate school, I taught several classes as a teaching assistant including environmental modeling (graduate level), environmental toxicology (graduate level), and population ecology (undergraduate).

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Subject: lab facilities/ongoing work
From: "Sunderland, Elsie M" <esunder@hsph.harvard.edu>
Date: 4/1/14, 6:40 PM
To: Steve Wofsy <swofsy@seas.harvard.edu>

Hi Steve,

Further to our conversation, here is a description of my ongoing lab/field activities. All of my HSPH students and postdocs are doing some lab/field based research. I apologize in advance for the length of this email.

I have **4 PhD students** at SPH right now: **Miling Li (G3)**, **Ryan Calder (G2**), **Clifton Dassuncao (G1** but has been working with me since 2011 as a masters student), and **Cindy Hu** (entering doctoral program and graduating from the masters program).

I have **3 SPH postdocs: Anne Soerensen** (started in 2011), **Amina Schartup** (started in 2012), **Xianming Zhang** (started in 2013).

By project their work is spit into several areas:

1. Oceanic measurements of Hg0 air-sea exchange as part of one of my ongoing NSF projects
- My postdoc **Anne Soerensen** participated in the NSF funded METZYME cruise in 2011 that included 4 biogeochemical provinces of the North Pacific. She collected simultaneous high resolution measurements of atmospheric and aquatic elemental Hg concentrations during the cruise and is currently writing up these data.

2. Impacts of climate and industry on Inuit country foods in the Lake Melville, Labrador region (Lake Melville is a large marine fjord)

This is a large field based program that began in 2012 and is the primary research for my postdoc **Amina Schartup** and my doctoral student **Ryan Calder**. The motivation is planned flooding of the major freshwater tributary flowing into the estuary for hydroelectric power development in 2016 that will likely result in a large pulse of methylmercury in the system. The estuary itself is part of the treaty negotiated traditional hunting and fishing territory for Inuit in the region and they are extremely concerned about this as a health issue.

Since 2012, we have collected sediment, water, plankton, fish and seal and done a variety of experiments on methylation/demethylation rates in the water column, flooded soils, and sediments. The lab work is presently based at UConn using the lab of a close colleague there (Robert Mason). Amina drives back and forth to UConn and has been taking various students and postdocs from my group with her to give them more lab experience. I would like to build up the capability to do this kind of work at Harvard because this is obviously not optimal. Part of the package I negotiated for from UBC included this type of equipment (see attached).

3. Natural mercury isotope fractionation.

This is an emerging area that has great potential in terms of providing empirical data to evaluate various components of the modeling we are doing. My doctoral student Miling Li just completed a first paper on this using the isotope fractionation to track the dietary exposure sources of various seafood consumers. In Lake Melville, we will be looking at natural mercury isotope fractionation in various media and human hair both before and after the hydroelectric flooding planned for 2016. This will provide an empirical measure of differences in methylmercury accumulation in biota and humans. My colleague Dave Krabbenhoft at USGS has just purchased a new MC-ICP-MS (~800 K) that Amina and Miling are both planning on using. They will travel to Wisconsin to do these measurements. Amina will be analyzing the Lake Melville samples and Miling is planning to work on squid and human samples from other areas (we are interested in demethylation in liver as a detoxification mechanism).

4. Measurements of flurochemicals in wastewater, drinking water and fish

My doctoral students Clifton and Cindy and postdoc Xianming are all working on various research questions related to fluorochemicals. Xianming has been working with Chad's student Andrea to set up the instrument in ESL. In addition, Ralph Mitchell has kindly provided us some informal access to bench space in his lab to do the prep work for the fish tissue analysis. We are looking at both a case study of temporal changes in these compounds in pilot whales and human exposures in the Faroe Islands and also pathways of exposure in the US population. We will be measuring concentrations in major US rivers and wastewater and commercial fish from a variety of areas. We are also establishing a partnership with the Silent Spring Institute to look at residential pathways of exposure related to drinking water and commercial products. Finally, one of the major epidemiological studies established in EH (the Nurses Health study) collected a large number of drinking water samples in the mid-1980s from households around the US that Chad and I are interested in looking at a little more closely, particularly in contaminated regions, and comparing to present day values. We can use these data when looking at health outcomes retrospectively in the epidemiological data.

5. Dietary surveys and human health risk assessments

My students (Miling, Ryan) have been analyzing hair mercury concentrations in a variety of population in the trace metals lab at HSPH. This is part of a survey of exposures for high-end fish consumers in the US that we recently completed and the human health risk assessment end of the Lake Melville project.

Please let me know if you need any more information or have any questions.

Best,
Elsie