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Research profile
Martin Harper

I do not know anyone who planned for a career in occupational hygiene while at school, and I suspect this might be a valid sample of the profession. My colleagues have backgrounds in many different disciplines, including engineering, chemistry, biology, aerosol physics, and so on. Interestingly, a large number of the people I have encountered in this profession started out like myself, with the study of geology. Both disciplines have a focus on forensic analysis through, primarily, observation.

I was born in London (UK), in the 1950s, close to the River Thames. Although my father was in the Royal Air Force and we traveled from base to base, we would live in central London between tours, or when he was posted to really exotic locations, so London has always been "home". My major academic subject at school was chemistry, although the school also boasted a geology laboratory (rare, in those days), and I was able to sit for "A-level" examinations in both. Although most of the London colleges I applied for offered joint majors in chemistry and geology, I passed the Oxford entrance exam and was forced to choose between these subjects, settling for geology at Keble College. Oxford at that time had arguably the best geology department in the world, particularly in the field of geochemistry, although from a purely career-oriented perspective geology may have been a mistake since there was little demand for geologists when I graduated in 1977. My entrance to the job market was provided by gaining employment as a technician in the haematology department of a local hospital. In those days, many procedures had yet to be automated, and the biochemical manipulations required for testing and matching blood samples were allowed an error rate of zero, which I never could have achieved without the guidance (and patience) of two excellent young immigrant technicians from the Philippines. My degree did not count towards career enhancement in this field, so the position could only be temporary, but I did learn a deep respect for the abilities of good laboratory technicians. Subsequent jobs allowed me to return to college at nights, weekends and on vacation days to upgrade my qualifications, and I gained a post-graduate diploma in Environmental Pollution Controls (North-East London Polytechnic, 1981), a supplemental Higher National Certificate (HNC) in Advanced Analytical Chemistry (Thames Polytechnic, 1981), and a Master's degree in Earth Science and the Environment (Kingston Polytechnic, 1983). All of these excellent Polytechnics have since become Universities. The HNC supplement allowed entry at the Licentiate level to the Royal Society of Chemistry (RSC). I also took a course at Birkbeck College, London on the medicinal, biological and environmental chemistry of metals (under P. J. Sadler). I was finally able to match a job to the subject area of my qualifications, becoming a technician in the Applied Geochemistry Research Group of Imperial College of Science and Technology, where I was able to use the results of investigations into the metal content of house dusts and garden soils for my Master's degree thesis.

In 1983, I embarked on a course of PhD research with Dr Colin Purnell in the Department of Occupational Health at the London School of Hygiene and Tropical Medicine. The Department (regrettably, now closed) was home to one of the most magnificent assemblages of occupational health and hygiene researchers in the world, such as Professors Schilling, Newhouse, Kazantzis, and Rossiter. I have a particularly fond memory for Dr Tony Waldron, then editor of the *British Journal of Industrial Medicine*, who enjoyed my extra-curricular researches into the history of exposures in the arsenic production industry, and encouraged me to publish. My PhD research was a departure from my previous area of work in that it involved researching techniques for measuring pollution in air, rather than in soil. I started by examining color reactions for direct-reading diffusive samplers, but, due to problems of sensitivity, selectivity, and color fastness, the focus of my research moved to novel sorbents (modified clay minerals) for thermal desorption applications. Initially, the project was supported through a Medical Research Center grant, but the funding ran out, and so I was particularly indebted to Dr Jack Firth, then of the UK Health & Safety Executive (HSE), for his support in recommending continued HSE funding to allow me to finish. I defended my thesis, which required major revision. Unfortunately, I had left LSHTM, and it took two further years to finish, a warning to anyone who thinks that these things can always be done later. Interestingly, I had to make my first home computer purchase, a 286 laptop, which I had to open at airports mainly because the security staff had never seen

DOI: 10.1039/b413406k

one before. My advisor, Dr Purnell, supported my application to Chartered Chemist status at the RSC, and also introduced me to Eddie Salter, the manager of the UK branch of a US company, SKC, Inc. I joined the UK operation in 1988, but I was asked in short order to transfer to the head office and main manufacturing plant near Pittsburgh, Pennsylvania. Pittsburgh became my new home for eleven years, providing me also with a wife, Trudy, and son, Ian (now 14). At the time, Pittsburgh was in the process of casting off its industrial legacy and today it has to rank as one of the most beautiful cities in the world. I am thankful that I still live within reasonable driving distance, and visit about once a month.

I was involved with many aspects of the research, development and production of sampling media products at SKC, and rose to the position of Research Director, with responsibility for the sample media product line. The founder of the company, Lloyd Guild, was a wonderful mentor, and I will never forget his support and generosity to a young immigrant. I worked on sorbents for organic vapors, including Chromosorb 106 and the carbon-based Anasorb 747, and a program for diffusive sampling method validation. I also brought several aerosol sampling devices into the product line, including the GS-cyclone, the Button sampler, and the Biosampler. Some of my projects involved Cooperative Research and Development Agreements with the US National Institute for Occupational Safety and Health (NIOSH), and these contacts were to prove very important in my later career. As a part of my duties, it was necessary to attend the annual conference of the American Industrial Hygiene Association (AIHA). I joined the AIHA, and several of their committees, being introduced to the Gas and Vapor Detection Systems Committee by Rolf Hahne (retired), to the Sampling and Laboratory Analysis Committee by Cliff Glowacki, and to the Laboratory Quality Programs Committee by Fred Grunder. I served on each of these for a number of years, including several officer positions, and was honored for service to each. I passed the examinations for Certification in the chemical practice of Industrial Hygiene (CIH) from the American Board of Industrial Hygiene in 1993, but, in the course of these studies, was exposed again to the wider aspects of occupational hygiene I had first encountered at the LSHTM. A desire to broaden my areas of research led to my leaving SKC in 1999 to accept a position in the industrial hygiene program in the Department of Environmental Health Sciences at the University of Alabama at Birmingham. My lack of teaching experience provided only the salary of an Assistant Professor, significantly less than my remuneration at SKC, but I was able to make up the difference through a variety of consultative work, such as with the US Navy to investigate air quality on submarines, and supporting the US National Center for Environmental Health in its oversight of the US Army's chemical weapons destruction program. I also became a US citizen at that time.

At UAB, I had the honor of working with Dr Ken Dillon and Dr Kent Oestenstad. Dr Dillon unfortunately was struck and killed by a conference bus at the 2004 American Industrial Hygiene Conference and Exposition. Without doubt, he was one of the best-loved teachers of occupational and environmental hygiene, and also one of the most passionate advocates of environmental justice. In addition to teaching a Master's level course on Air Sampling and Analysis, and mentoring several students, I was also asked to work on several projects, including a hazard investigation for the US Coast Guard. A major advantage of becoming an academic was the access I could get to workplaces, where I could test my hypotheses, but also see the real need for hygiene. During this period I was able to advance my interests in aerosol sampling and analysis, obtaining grants to study samplers for wood dust, on-site X-ray fluorescence analysis of metal dusts, sampling and analysis of metalworking fluids, and the examination of mineral fibers by microscopy. Some of my committee assignments changed; I became a member of the American Conference of Governmental Hygienists Air Sampling Instruments Committee, as well as becoming active in the American Society for Testing and Materials (Committee D22.04 on Workplace Air Quality), where I am currently Secretary, and, through their Technical Assistance Group, in the International Organization for Standardization (ISO), where I hold the Chair of the Technical Committee 146, Sub-committee 2 on Workplace Air Quality. These committees are highly active in producing harmonized, consensus standards, in areas including the sampling and analysis of metals, acid anions, isocyanates, silica, *etc*.

After three years with UAB, I received a telephone call that changed my life. In 1996, the NIOSH, which is the major center for occupational health and safety research in the USA, had created a new Division in a new building in Morgantown, West Virginia, called the Health Effects Laboratory. This Division included a Branch devoted to Exposure Assessment. Dr Sidney Soderholm had been appointed to the position of new Branch Chief, and he put together several teams of researchers under his vision for the mission of the Branch. Dr Soderholm had stepped down from this position in order to ensure the success of a large program on dermal exposure under the National Occupational Research Agenda, and had called me to ask if I knew of any potential candidates for his successor. When I asked if my qualifications might be appropriate, Sid suggested I send in my application as soon as possible. It was successful and I have now held the position for the past two years. When I arrived, the Branch had teams devoted to the investigation of particle surfaces (Molecular Biophysics, headed by Dr William "Bill" Wallace), dermal penetration and skin decontamination issues (Dermal, headed by Sid Soderholm), gene-environment interactions (Computational Biology, headed by Dr Eugene Demchuk), and Exposure Monitoring (headed by Dr "Bean" Chen). One of my first decisions as Branch Chief was to commission an external review of the Branch mission and activities, to ensure that these were best aligned with the current and future needs of occupational hygiene research. The reviewers included representatives from academia, business and regulatory bodies. Also, I was appointed co-Chair of the NIOSH Aerosol Coordinating Group (ACG), which was tasked with reviewing the state and future of aerosol-related research within NIOSH.

As a result of these reviews and my own personal vision of research, which I have been encouraged to pursue by my Division Director, Dr Al Munson, there have been some minor adjustments to the Exposure Assessment Branch. A new team has been created, Atmospheric Chemistry, which includes projects concerned with the rates and products of the reaction of ozone and the hydroxyl radical with indoor organic compounds in the vapor phase and on surfaces. Another new project that has been proposed for this team involves exhaled breath analysis, and its correlation with air samplers whose flow-rate adjusts to the workers breathing rate.

An area of personal interest I have been able to carry over from my University researches is on-site analysis for metals using portable X-ray fluorescence monitors. A project in this area already existed within the Branch and the two projects complement each other well, the one looking at various XRF technologies, the other looking at their performance using different samplers. My own project, looking at samplers for collecting lead particulates, requires field samples from a whole range of industries where lead is encountered, including mines, smelters, and lead products manufacturers, and also where lead is a contaminant in other industries.

A major deficiency noted by our reviewers was the emphasis on exposure monitoring and a lack of research into exposure assessment strategies and models. Since this kind of research was not being pursued comprehensively in the other Branches and Divisions of NIOSH, it seemed a natural focus area for the Exposure Assessment Branch. However, we first need to define the research questions to be asked, and then to find suitably qualified and experienced researchers. One area of importance is the recently developed concept of "control banding". Control banding is a form of exposure assessment, followed by risk assessment and control recommendations. It differs from traditional occupational hygiene in not being based on measured exposures as the basis for the exposure and risk assessments. Instead it looks at the management scenario in reverse, postulating a small and discrete number of outcomes (control measures), and proposing that these are derived from risks, which to a first approximation, differ by orders of magnitude. The concept further suggests that these risk bands are based on exposures whose magnitudes can be approximated through the application of two simple properties of the chemical, the amount used, and the ease with which it becomes airborne (vapor pressure, or boiling point for liquids; "dustiness" for solids). While this approach has some merits, inaccurate risk assessments can lead on the one hand to a dangerous lack of controls, or on the other hand to a requirement for expensive and unnecessary control measures. Therefore, it is important that the procedure be validated. Validation requires a very large number of measurements, since it is necessary to ensure all the variation in time (intra-worker) and space (inter-worker) is captured. Large numbers of expert measurements are expensive, while a new technique known as "self-assessment of exposure" (SAE), also known as participatory exposure assessment, where workers themselves are trained to measure exposures through simple, passive technologies, would enable large numbers of measurements to be made with fewer resources. Given that worker participation has been recruited, it was natural to extend the study to include the effect of such involvement on their knowledge, attitudes and practices (KAP) with regard to their health and hygiene issues. Hopefully, these large-scale surveys, unbiased by the concerns of regulators, will provide a unique dataset of importance in future reconstructions of historic exposures, since such data have become scant in recent years.

Occupational or industrial hygiene chemistry is undergoing negative growth. Fewer students are entering the public health profession generally, and the demand for chemical specialists in certain regions of the world has declined even faster, as manufacturing has been outsourced. As a result, the American Board of Industrial Hygiene has withdrawn its Certification specialty in the Chemical Aspects of Industrial Hygiene. A rather low value is also now placed on laboratory work for the Certification Maintenance requirements. Nevertheless, there are still very important questions for occupational hygiene chemists to answer, and some examples are presented below:

Silica. A typical occupational limit value (American Conference of Governmental Industrial Hygienists Threshold Limit Value or NIOSH Recommended Exposure Limit) for silica is equivalent to about a half teaspoon of respirable-sized particles spread evenly over a soccer field to twice the height of the goal posts. A typical sample at around one-half the limit value contains about 25 µg of silica. Proficiency test programs have reported large variations in measurements under 50 µg. Research is underway by occupational hygiene chemists with the intent of reducing this variation through development of more precise measurement procedures. Improved methods will not only enable us to determine if a worker is protected but in some cases could even save industry money.

Fibers. Our procedure for evaluating exposures to fibers, including asbestos, is based on microscopy. For reasons of throughput time and cost, the majority of samples are analyzed by visual microscopy, where the fiber detection and assignation procedures are critically dependant on human abilities and judgments. Therefore, the typical standard deviation for proficiency tests is similar to that for silica. Again, research is in progress to address this issue.

Metals. We have typically measured dust by the weight gain of filters, but many exposure limit values for metals, such as beryllium, are below the limit of quantitation for this technique. Now we are also faced with isolating particular chemical species, such as hexavalent chromium. Occupational hygiene chemists are working on portable and real-time monitors for these chemicals.

Nanoparticles. Increasingly, manufacturing is turning to nano-engineered materials, and there is some evidence that particles in the nanometer size range may have unique physico-chemical properties that affect their interaction with biological systems, and hence their health effects. Again chemists and physicists are creating research efforts to investigate this potential public health problem.

Asthma. The huge rise in childhood and inner city asthma may have a chemical exposure component. When we measure chemicals indoors using traditional techniques we find the typical hydrocarbon solvents (*e.g.* benzene, toluene and xylene) we always do, typically at levels well below those of concern. However, certain chemicals in the environment, such as the terpenes widely used as cleaners, are prone to attack by oxidants including ozone and the hydroxyl radical, producing chemicals of unknown toxicological properties, but potentially upper airways irritants. In the ambient atmosphere, it is now known that these chemical reaction products can be a major contributor to airborne fine particles (PM2.5).

Thermal desorption. Our traditional sampling and analytical methodologies for organic vapors are rugged and simple, and were designed for single chemicals or small groups of chemicals at relatively high concentrations and with few interferences, but they fall short of the flexibility and sensitivity required for today's more complex investigations. There is a need for more formally validated thermal desorption procedures.

Dermal exposure. Many of our lost workdays and productivity, and much human misery are a result of irritant and allergic contact dermatitis. The chemical reactions that lead to dermatitis are not well understood. In fact, even the mechanisms of chemical penetration through the skin have yet to be thoroughly studied.

Particle surface properties. From specific metal surface enrichments on "hard-metal" particles, to clay occlusion of quartz particles, there are many areas of research involving chemists and physicists, as well as with biologists when we interface with the next part of the continuum (dose to target organ) between exposure and the manifestation of disease.

Disease-relevant particle size measurements. Although it has been recommended that airborne particle measurements should account for the probability of penetration and deposition within the human airways so that they can be more relevant to health outcomes that vary with target site, there are still few recommendations for how this should be achieved. Aerosol physicists, chemists and pulmonary physiologists are working to improve this situation.

The areas listed above are the focus of current exposure assessment research, at least within the Exposure Assessment Branch of NIOSH. However, a very important challenge for future research in Exposure Assessment, is to deal with the outputs of modern technology, which can provide real-time information regarding exposure and position. For example, currently, one NIOSH research group is testing real-time dust measurements systems for miners, while another is collocating various sensors with real-time outputs, including noise, heat stress, and organic vapor monitors, with local positioning systems. Further sensitive and specific chemical sensors are being designed at a rapid rate to meet the emergent threats of chemical and biological terrorism. These technologies give us an unparalleled opportunity to make hygienic decisions in real-time. However, it will not be possible to post an expert behind every worker to interpret this data-stream. Two options are possible. We can either train the workers to participate fully in their hygienic situation by allowing them to interpret the data and make decisions based on the results, or we can train the monitoring devices to offer advice and warnings along similar heuristic decision-making logic employed by experts. It is likely that both of these paths offer advantages and disadvantages. For example, making employees responsible for decisions about health consequences is counter to our general paradigm of requiring shared managerial responsibility, and building decision-making into instruments shifts liability from a human professional to an instrument manufacturer. When I first started in this field everyone wanted an instrument similar to that seen in the television show Star-Trek ("the atmosphere is safe, Captain!"), but we all thought this was just a dream, probably not at all practicable. However, the pace of technological change has proved us wrong and such instruments will now probably appear in my lifetime. It is how we decide to use these instruments that most interests me today.

In addition to my work with NIOSH, I am still closely involved with education through an adjunct professorship in the industrial hygiene program at West Virginia University, and through teaching on the Master of Public Health program at the University of the West Indies (UWI). The Caribbean countries are committed to improving their occupational health and safety infrastructure, so I am also on a committee to develop a curriculum for a Bachelor's and Master's program specializing in occupational and environmental health for UWI.

I remain very excited by the potential for research and education in occupational hygiene and exposure assessment in particular, and I believe it has an immense amount still to offer in terms of the alleviation of human suffering through reducing exposure to hazards in the workplace. NIOSH continues to be a world leader in this area of research, and I am very happy to be able to take advantage of the resources working there provides. This includes the ability to interact with so many experienced colleagues, as well as the support of infrastructure, including modern equipment and adequate funding. As I write these words on a transatlantic crossing I am reminded of a young Chinese-American student sitting next to me at the airport who noticed my shoulder bag from the Taipei International Chemistry conference. He asked me if I was a chemist and what I did for a living. I was soon showing him slides of silicotic lungs and dermatitis, and the work we are doing to prevent those diseases. So yes, I suppose I must still be glad I chose this career, because I find myself continuing to recommend it to others.