Graduate Education in Occupational Hygiene: A Rational Framework

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Occupational hygiene has been an important part of occupational health since it first emerged after World War II as the science and art that deals with the anticipation, recognition, evaluation and control of human exposures to hazards in the working environment. A need exists for well-qualified professionals who can not only respond to hazards that are currently known and understood, but also to ones that are not yet known or understood. For this, graduate-level academic programs in occupational hygiene must go beyond the training of skills and imparting of facts. Rather they must provide the education that enables the development of critical faculties, allowing future self-learning and the study of new scenarios not yet anticipated. Ideally, occupational hygiene should be taught firstly in the interdisciplinary context of the whole of occupational health (including occupational medicine, occupational health nursing, occupational safety and ergonomics) and secondly in relation to the wider field of public health (including epidemiology and biostatistics). In addition, modern occupational hygiene education also needs to embrace the management and social sciences. The Education and Research Centers (ERCs) sponsored in the United States by the National Institute of Occupational Health (NIOSH) have refined this approach and provided a useful model for all occupational hygiene education, identifying the need for both masters and doctoral-level endeavor. Other countries might usefully consider integrating existing academic programs in order to emulate the NIOSH approach, perhaps through internal and external partnerships. In terms of content, such education needs to be carried out within a framework that places human exposure to hazardous agents at the center of the anticipation–recognition–evaluation–control rationale. Such a framework also places occupational hygiene in the context of the other occupational and environmental health disciplines. Finally it has to be acknowledged that occupational hygiene is (indeed always was) a changing field. Academic programs need to be responsive to such changes, and the range of responses must include not only curricular modifications but also changes in the way that the education itself is delivered. The internet provides interesting new opportunities for distance learning that appear to have the potential not only to be efficient and convenient in terms of time and resources but also to be valid in terms of meeting the desired educational objectives.

Keywords: occupational hygiene; education; graduate-level

INTRODUCTION

Although the possibility of ill-health arising from exposure to hazardous agents in working environments has been acknowledged for a very long time, much of the early work in terms of understanding and managing the risk was done by physicians. In that era it was only physicians that had the gravitas and standing sufficient to catch the attention of managers and employers on such matters and persuade them to take remedial action. However, in the period post-World War II, greater urgency, driven by changing social priorities, required specialized input from individuals with deep backgrounds in one or more of the core scientific disciplines of physics, chemistry, biology and engineering that addressed the nature of the environment and provided the expertise needed to identify technical solutions. Such specialists were the only ones with educational backgrounds sufficient to provide descriptions of environments, hazardous agents and living organisms at the level required in order to establish criteria for the necessary remedial
action. In time, these were drawn together in the fellowship of national—and eventually international—professional and learned societies, led in the beginning (since 1939) by the American Industrial Hygiene Association and then (since 1953) by the British Occupational Hygiene Society. What we have come to know as ‘occupational hygiene’ grew out of the extension of the activities of those diverse individuals, representing the traditional core disciplines, into the field of occupational health. (The term ‘industrial hygiene’ has also been widely used, and still is in the United States. But its meaning is exactly the same as for the terminology used throughout this paper.)

Over the years, the demand for increasing regulation of the quality of working environments and workers’ exposures to harmful agents required a cohort of professionals dedicated specifically to the field of occupational hygiene. Out of this grew the now-familiar definition of occupational hygiene as the science and art devoted to the recognition, evaluation and control of human exposures to hazards in occupational settings. Later, many felt it was appropriate to include the additional component of anticipation, and this is the definition that appears in the bye-laws of the International Occupational Hygiene Association (IOHA, 2005). Thus the field of occupational hygiene, once seen as a collection of traditional disciplines brought together to address a specific problem area, became established as a discipline in its own right. In turn, a rational framework emerged for the education of occupational hygiene specialists and professionals, in particular graduate-level education. This paper suggests a generic framework for such education, identifying the primary objectives, and its key rationale and ingredients. It then discusses a conceptual core that draws together the disciplinary elements in a way that is useful for discussing current occupational health issues and prepares the ground for the changes that lie ahead.

**OBJECTIVES**

The primary objectives of education in occupational hygiene may be summarized in terms of the need to provide a source of well-prepared people to play a prominent role in

(i) enabling employers to comply with standards set by governments;
(ii) dealing with specific hygiene-related technical and management problems;
(iii) providing new knowledge through research;
(iv) providing leadership in the organization and maintenance of occupational hygiene programs in work settings and
(v) providing leadership in policy and standards development.

Undergraduate programs in occupational hygiene have emerged in recent years in some countries, and these go some way towards meeting some of these objectives. However, it is only at the graduate level where the necessary depth can be achieved across a discipline that is already broad and diverse, building on the familiar core scientific background achieved at the undergraduate level and extending it to occupational hygiene, adding core disciplinary areas along the way. In particular, it is the combination of depth and breadth that underpins investigative curiosity and leadership, qualities that provide confidence for the individual to apply lateral thinking, take responsibility, take firm positions to ‘do the right thing’ when called upon to do so (even when unpopular with some parties), and gain entry to and earn respect in the upper echelons of industry, government agencies, unions, etc.

In addition, as a secondary objective, graduate-level education in occupational hygiene should provide aspiring professionals with the background required to pass the professional certification examinations. However, it should be clearly stated that this aim is not specifically to prepare candidates for the examinations themselves. In the first instance, it is not appropriate for graduate-level—or even undergraduate-level—education to prepare candidates to undertake what are usually large diets of multiple-choice examinations on questions of fact. Indeed, it is not a necessary requirement that any such education should even cover all the subject matter that is likely to be encountered in the world of professional enquiry or practice, or that might appear on the certification examination paper. The point about education, as opposed to ‘training’, is that a well-prepared graduate may expect to undergo self-teaching as and when required as priorities change. This is especially important in an era where the scope of occupational hygiene is widening, a trend that is likely to continue. Therefore, most important is the development of critical faculties and the confidence to use them, underpinned by a broad base of knowledge in key areas, which can be brought to bear on occupational hygiene problems that cannot be known until they appear, often much later. The distinction between education and training is therefore important. At the graduate level at least, the academic purpose should go far beyond simply the presentation of facts and the teaching of skills. Instead it should be geared more towards the development of a broad base of knowledge within a conceptual framework that (i) integrates the various relevant component disciplines, (ii) can be applied across the whole breadth of occupational hygiene and (iii) can provide an overarching view from which one can address any problem in the real world of occupational hygiene, even during periods of intense change. In other words, it should be towards a whole philosophy. In the wider
field of higher education it has been said that ‘...a person may be highly trained and skilled, and yet remain uneducated. If there is no development of one’s critical intelligence and independence of judgment, one tends to accept uncritically what one reads and hears; one tends not to lead but rather to be led' (Stewart, 1996). This is very apt to teaching and learning in occupational hygiene.

A final objective is directed at the academic program itself as it relates to the professional bodies that have emerged alongside the development of the occupational hygiene discipline. External oversight, and in turn accreditation, of academic programs is a well-established culture in many fields, including medicine and engineering. During the past two decades such accreditation has been sought by many academic occupational hygiene programs. In the United States, this is acquired through the Accreditation Board of Engineering and Technology, the same body that accredits engineering programs at US institutions. Such accreditation imposes strict requirements on enrollment criteria and program content and so aims to ensure consistency of quality and substance across all programs. This is said to be beneficial to students and prospective employers. For students, it provides the opportunity to count 1 year of the time spent in an accredited program towards the duration of professional experience required in order to qualify to appear for the professional certification examination. However, the process of applying for accreditation and then maintaining it is bureaucratic and time-consuming, and in turn costly. The academic value has been questioned in some quarters and, at various times since the 1980s, some academic programs have either declined to apply for such accreditation or have allowed accreditation to lapse.

**PROGRAM DEVELOPMENT**

*Structures*

Although occupational hygiene has been identified as a discipline in its own right, with its own rationale and philosophy, it exists within the wider field of occupational health. In fact, occupational hygiene does not exist without occupational health. It follows, therefore, that it is inescapably linked with the other disciplines within occupational health, including occupational medicine, occupational health nursing, occupational safety and ergonomics. In 1989, the British Occupational Hygiene Society, under the Presidency of Dr Charles Veys, acknowledged these important links by taking the initiative in setting up the Occupational Health and Safety Forum, by which learned and professional bodies within occupational health in UK would come together to ensure optimum interactions between the various component disciplines. It continues to this day in the form of a new group, Professional Organisations in Occupational Safety and Health.

Such linkages provide an important rationale for education in occupational hygiene. In particular, a rounded occupational hygiene educational program cannot be achieved in isolation simply by addressing the elements identified in the definition of the discipline (i.e. the ‘anticipation–recognition–evaluation–control’ paradigm), but it must also include meaningful elements that relate to the other component disciplines. In the United States, the scheme sponsored by the National Institute for Occupational Safety and Health (NIOSH) in the form of its system of Education and Research Centers (ERCs) explicitly not only requires reference to those additional elements but also meaningful interdisciplinary interactions between them. This system represents the ‘flagship’ activity in graduate-level occupational health education in the United States. There are currently 16 such centers, widely distributed at premier academic institutions throughout the length and breadth of the country (Fig. 1). Many are sited in schools of public health, and this may be considered as optimal because it means that students at those institutions are routinely exposed, day-to-day, to the wider field of public health and its associated disciplines of epidemiology, biostatistics, health management and policy, environmental health, health behavior and health education.

For a program to qualify for sponsorship as an ERC, it must meet the following criteria:

(i) it must contain sub-programs in at least three of the primary disciplines within occupational health, namely, occupational hygiene, occupational medicine, occupational health nursing, occupational safety and ergonomics;

(ii) there must be demonstrable interdisciplinary interactions between these sub-programs, including joint participation in classes and project work; and

(iii) it must also contain a sub-program in continuing education, by which professionals already working in the field can have the opportunity to return for further study on a topical basis, depending on their individual needs.

For ERCs that are sponsored under the NIOSH scheme, funds are provided in order to support students (tuition and stipends, as far as possible) and contribute towards administrative and faculty costs. It is fair to say that such support has, at least within the experience of the writer, never been able to meet the full cost of running the activities in question. But it nonetheless provides a significant level of support without which the programs might not be sustainable. Individual ERCs undergo competitive review for renewal on a 5-yearly basis, during which sub-programs—including occupational hygiene—are
rigorously examined by peer review with respect to the stated criteria. Most importantly, such review procedures require ERCs and their sub-programs to provide strong rationales and philosophies for the education that is offered. This inevitably must include discussion about the conceptual framework that defines education within each component discipline itself and how the various disciplines relate to one another. Overall, the peer-review process that underpins the selection and the continued support of the ERCs ensures a consistent high quality.

In addition to the ERCs, NIOSH also sponsors graduate education in occupational health through Training Project Grants (TPGs) at other institutions. There are currently 13 of these, specifically in the area of occupational hygiene (Fig. 1 shows the locations of 12 of these programs, with another one located in Puerto Rico). In addition there are more than 20 such grants elsewhere (data not shown) in closely related areas of occupational health, including occupational safety, occupational health nursing and occupational medicine. These complement and extend the range of opportunities available through the system of ERCs. The net result is an overall large program of publicly-funded graduate education in the United States, which is unmatched anywhere else in the world, producing large numbers of new occupational hygiene graduates, close to 190 every year, as summarized in Table 1. The table also indicates the distribution of placement of these graduates, reflecting the strong demand for individuals educated in occupational hygiene to this level. Over the years this program may occasionally have seemed vulnerable during periods of unfavorable political climate. However, it remains strong. If this invaluable resource were ever to disappear, it is highly unlikely ever to re-appear. So, as long as occupational health is a priority (which it is and always will be) it is vital that it should be continued to be nurtured. Statistics like those summarized in the bottom part of Table 1 confirm that there is indeed a market for such graduates in the United States, and this must surely be the case in other developed countries. But it is probably unlikely, in the foreseeable future, that public funding on a scale commensurate with that provided by NIOSH will be forthcoming elsewhere on an individual country basis. That said, however, that Taiwan appears to be a notable exception. In 2004, the Ministry of Education funded three new ERC-equivalent programs located regionally in the northern, central and southern parts of the country at National Taiwan University, China Medical University and National Cheng Kung University, respectively. These institutions contain outstanding, internationally recognized occupational hygiene faculty. The overall broad goal of the Taiwan scheme is...
to initiate effective health and safety management programs in those regions at levels ranging all the way from high school to graduate school. An important component is the support provided for doctoral-level study in occupational hygiene or safety at the rate of 12–15 new entrants each year. For these entrants, it is an important requirement that they must help the regional ‘ERC’ fulfill its overall mission, and—in so doing—become engaged locally in the real-world practice of occupational hygiene. More recently still, these regional ERCs have been recognized by the Taiwan Council of Labor Affairs and authorized by the Workers’ Occupational Injury Protection Act.

For occupational hygienists and occupational hygiene educators everywhere the ERC-type model provides much food for thought. Apart from the fact that the NIOSH scheme provides a source of funding to US institutions, albeit modest in relation to the support given to some other academic areas, it calls for a coherent, science-based rationale by which it is possible to optimize the content, form and validity of occupational hygiene education and in turn the usefulness of the end product. There are excellent traditions in advanced occupational hygiene education in many countries. The United Kingdom, one of the ‘homes’ of occupational hygiene, has had outstanding programs at a number of institutions, including the London School of Hygiene and Tropical Medicine, University of Manchester, University of Birmingham, University of Aberdeen and University of Newcastle. But it is perceived by this writer that the availability of such programs to aspiring British occupational hygienists has diminished in recent years. Excellent programs also exist in other countries, and a full list of graduate-level programs around the world in occupational and environmental health and safety may be found on the web (International Gradschools, 2005).

Bearing in mind the undisputed continuing need for occupational hygiene graduates educated at this advanced level, as well as the properties of the ERC-type approach (in particular the links with other occupational and environmental health disciplines, and with public health) it might be worthwhile exploring possible partnerships, for example, those involving existing programs at institutions in countries in Europe, Asia, Australasia and Africa. Possible partnerships with NIOSH itself might be explored. Some similar such partnerships already exist. For example, the John E. Fogarty International Center, which is the focus for international activities at the US National Institutes of Health, sponsors collaborative programs for advanced study in the health sciences involving US institutions and those in selected regions. For example, at the University of Michigan in collaboration with the Universities of Cape Town and Natal in South Africa, a Fogarty grant supports research and education in occupational and environmental health for individuals from the whole of Southern Africa. Students from South Africa, Zimbabwe and Mozambique are currently enrolled and it is expected that they will return home in due course to become leaders in the development of the occupational hygiene discipline and its practice in their own countries. More generally, the international promotion and practice of occupational hygiene is greatly enhanced by the development of such tangible interactions. So it is hoped that this article will at least provoke a vigorous open discussion about further such possibilities between those involved in the future of occupational hygiene everywhere.

**Ingredients**

The traditional ingredients of occupational hygiene education derive directly from the scientific core disciplines reflected in the backgrounds of individuals drawn to the discipline during the early years of its emergence. Notable are the natural sciences and engineering. Typically these scientific elements are
formed into groupings that more immediately relate to workplace environments and their control, and human exposures and their effects. They are then placed into sensible sequences, as shown in the following examples:

(i) Nature of hazards.
   (a) Nature of workplace environments.
   (b) Properties, behavior and measurement of airborne hazards.
   (c) Nature, behavior and measurement of physical hazards.
   (d) Microbiological hazards.

(ii) Exposure.
   (a) Routes of exposure.
   (b) Exposure assessment.

(iii) Health effects.
   (a) Toxicology.
   (b) Physiology.

(iv) Control.
   (a) Ventilation and air cleaning.
   (b) Ergonomics.

In addition it is desirable that a well-balanced program should also contain ingredients that reflect the wider context of public health, including epidemiology and biostatistics. Also, modern occupational hygiene recognizes the importance of the role of management, social and political sciences, including (i) management structures and methods, (ii) human behavior and communication, (iii) policy and regulatory frameworks and (iv) occupational health law and standards.

In these, although technical knowledge provides the basis of what needs to be done and provides the tools to achieve it, the management sciences provide the means by which technical actions are identified and prioritized, directs that they are carried out and in the right sequence, and ensure that the outcome of those actions is appropriately monitored. The social sciences address the human interactions that are required to ensure that the affected parties—industry, government and, most particularly, the workers themselves—are appropriately engaged. The political sciences represent the interactions between occupational health and society at large.

In addition to didactic courses along the lines indicated, there is the need for a practical ‘hands-on’ component that provides exposure to the range of experiences that a professional occupational hygienist might meet on a day-to-day basis. This may be achieved by appropriate laboratory work (e.g. in exposure assessment, including such things as gas/vapor and aerosol sampling), field visits (to provide experience of the range of types of occupational hygiene situation to be expected in the real world) and field project work (to provide experience, under expert supervision, of occupational hygiene investigation and enquiry).

The preceding framework describes a field that, as has already been mentioned, has widened considerably since it first emerged as an essentially scientific discipline. The new challenge in designing occupational hygiene programs that can meet current needs is to ensure maintenance of the required depth in key individual subject areas whilst allowing for the desired increased breadth. It is clear that this is a concern of many of those engaged in the teaching of occupational hygiene at the graduate level. However, the challenge can be met by fully embracing the philosophy of ‘education-over-training’ that was mentioned earlier. In this way, for each topic area, appropriate depth can be maintained in individual high priority areas by reducing the direct content in lower-priority areas. Well-educated graduates should be capable of ‘filling the gaps’, just as they are expected to be able to respond to the inevitable changes that will emerge during the course of their careers.

Prerequisites

In order to have a reasonable chance of success, students entering a graduate program in occupational hygiene must have demonstrated good performance in prior education in relevant subject areas. Preferred primary backgrounds are in the core scientific disciplines of physics, chemistry, biology, chemical engineering and other engineering subjects. Any of these can provide evidence of in-depth scientific potential. Broader-based subjects such as environmental science, and even occupational hygiene itself, are widely considered to be secondary preferences.

Although actual performance indicators of undergraduate performance vary greatly from one institution to another, suggested broad guidelines may be useful. In the United States, undergraduate performance in appropriate disciplinary areas should indicate a grade point average at least of the order of 3.00 on a 4-point scale, backed up with good performance in the more general graduate record examination that tests aptitude in quantitative, analytical and verbal categories. Specific expertise should be demonstrated in the areas of physics, organic chemistry, biology and calculus. In UK, undergraduate performance in one of the appropriate disciplinary areas should be at least commensurate with second-class honours, lower division (2:2). In all cases, however, it is appropriate to interpret such guidelines flexibly in order to take account of individual circumstances and, in particular, previous relevant work experience.

Endpoints

Usually the Masters degree is the desired qualification for an individual who aspires to a career in the professional practice of occupational hygiene. So this needs to be complete and terminal in itself, covering
the primary areas listed above. During most of the history of the discipline of occupational hygiene, the Master of Science degree has tended to be the primary ‘currency’ qualification. This has occasionally presented difficulties, at least in the United States, because of the perception in some quarters that the Master of Science degree suggests an emphasis on research. However, in recent years, for programs located within schools of public health, there has been increasing adoption of the Master of Public Health degree (including at the University of Michigan), reflecting the increasing interactions of occupational hygiene with other areas of environmental health and public health. The time taken for students with good first degrees in one or more of the prerequisite areas listed above is typically 1.5–2 years.

The Masters degree represents a high level of academic achievement, reflecting the successful acquisition of in-depth knowledge across the wide spectrum of occupational hygiene and the potential ability to put it into practice in the real world. The Doctoral degree goes further, extending beyond the Masters degree and now introducing the ability to conduct long-range investigative research and the development of advanced general and specialist cognitive skills as primary components. In general, doctoral-level education in science brings individuals to a heightened level of awareness and problem-solving ability through extended periods of study and reflection addressed at understanding and solving difficult problems, many of which may, at the outset, seem intractable. As has been observed by many mentors of doctoral students, it is here where an individual’s self-discovery of ‘insight’ marks the transition to that new level. Perhaps not for nothing, therefore, the degree sought is usually ‘Doctor of Philosophy’ (PhD). The fundamental nature of insight was the subject of the seminal work of the philosopher Bernard Lonergan (1992), and has been discussed in the context of science education by Marroum (2004). It is relevant not only to basic, sometimes esoteric, scientific disciplines such as physics and chemistry but also to more mundane (?) applied science disciplines such as occupational hygiene. In the first instance, research in occupational hygiene science continues to be in demand, requiring individuals possessing just the same qualities of ‘insightfulness’ as their counterparts in the more basic disciplinary areas. In addition, the development of advanced cognitive processes that come from doctoral-level education is important to many areas of occupational hygiene practice and leadership.

The doctoral trajectory is followed by a relatively small proportion of individuals in graduate level education in occupational hygiene (e.g. Table 1). However, graduates educated at this level have always been, and remain, highly sought after, in particular by government agencies or departments, academic institutions and some branches of industry (e.g. pharmaceuticals). In the United States, NIOSH is a strong supporter of this component of graduate education in occupational hygiene, through not only its ERCs and TPGs but also extramural research programs, where a significant proportion of the funds go to support doctoral students. Similar support is available in other countries, although in programs that are generally less structured and less well-financed than those of NIOSH. Although many graduates at this level go into positions that relate directly to occupational hygiene, a significant proportion move into careers that apply their new abilities in the related fields of environmental and public health. Although the version of the degree that is sought by most such aspiring graduates is the PhD, in most American schools of public health it is an option for students to study for the more practice-oriented Doctor of Public Health (DrPH) degree. Typically the time taken to achieve Doctoral degrees of either type is between 3 and 5 years beyond achievement of the Masters degree.

**A RATIONAL FRAMEWORK**

A rational framework is sought that integrates the various subjects relevant to occupational hygiene, and links them with the other occupational health-related disciplines. A useful model is shown in Fig. 2, providing a set of basic ideas guiding how to think about occupational hygiene. In it, the central component is exposure. It shows the presence of a hazard in the working environment that, by interaction with the workers, leads to exposure, the first step on the path to risk of adverse consequences. The subsequent sequence of exposure–dose–response–defence–outcome describes simplistically what is familiar to toxicologists. All these elements include
the important dimension of time, and the distinction between what is instantaneous and what is cumulative. In particular it requires a very clear definition of exposure itself, and an understanding of the differences between exposure intensity (i.e. instantaneous exposure), time-weighted average exposure and exposure history. Such considerations are particularly important when such knowledge is applied to the setting of standards, exposure limits and control strategies. In the context of the occupational hygiene paradigm, the elements to the right hand side of Fig. 2 fall broadly in the areas of anticipation and recognition. Those to the left tend to fall into the areas of evaluation and control.

Presented in the way shown, Fig. 2 provides a rational overarching philosophy for education in occupational hygiene and occupational health. Indeed it may be extended still wider to environmental health more generally. It follows what may be referred to as a ‘toxicological model’. Inspection of the application of this model with respect to any occupational hazard shows that it can be applied across a wide spectrum of occupational risk factors, including not only chemical, biological and physical agents but also safety and the risk of injury.

THE CHANGING SCENE

Occupational hygiene has been in a state of evolution ever since it first emerged. Until the 1990s, this was reflected in continuing growth of the need for the profession and new knowledge, leading to increased opportunities for new recruits to the discipline and, in turn, the growth of academic programs, especially at the graduate level. Since its initial origins in the United States, UK and a small number of other countries, the occupational hygiene concept has spread around the world. The IOHA was inaugurated in 1987 and now includes more than 20 national organizations representing over 20 000 occupational hygienists worldwide. The state of occupational hygiene in the United States is one—although not exclusive—indicator of the health of the discipline more widely. There, in the early 1990s, occupational hygiene was widely noted in the media as being one of the most promising career options for science graduates. This stimulated a good flow of well-qualified new graduates applying for entry into graduate-level occupational hygiene programs. This was good for the discipline and practice of occupational hygiene, for the new graduates and for the academic programs themselves. But occupational hygiene is a field that is especially sensitive to external forces, and so change has been inevitable, and the direction of the change has not always been perceived as favorable to those working in the field. Change is always uncomfortable and many would want to ‘wish it away’. However, as one leading occupational hygiene practitioner has observed, ‘We have too many people complaining about why it is not like it used to be instead of striving to evolve the discipline to ensure that it meets the needs of today.’ The fact is that change is a reality and must be addressed—and this includes graduate-level education.

External forces

A major external influence on the study and practice of occupational hygiene is the political climate of the day, and this may vary from one country to another and at different times. In the United States, changes in the regulatory environment since the late 1990s have been significant. These have included diminution of both occupational and environmental health regulation, particularly the former. Another major influence is the shift of employment demographics that has taken place in developed countries in the recent years. In particular there has been a decrease in the proportion of the total workforce engaged in large industrial concerns and a corresponding increase in the proportion working in small and medium-sized enterprises. In the first instance this in itself has led to changes in the nature of basic occupational hygiene practice, with smaller cohorts exposed to different agents under different working conditions. In turn, there is now reduced employment of occupational hygienists in industrial corporations and an increase in the outsourcing of occupational hygiene ‘services’ to consultancy companies. Overall there have been falls in levels of primary production and manufacturing industries in the developed countries, matched by increases in the developing countries as corporations have migrated in order to seek cheaper labor markets. So while the needs for occupational hygiene have shifted in the developed world, the ‘traditional’ demands are greater than ever elsewhere.

In general, there is the widespread perception that there is a downsizing of interest in occupational safety and health. But, it may be as noted by another occupational health leader, ‘... (it) may be cyclical, simply waiting for another series of workplace disasters to remind people that government needs to be watching occupational hazards (more) carefully and that regulatory enforcement is important.’

Effects on occupational hygiene

External forces like those mentioned have placed changing demands on occupational hygienists and their work. For many years of course, occupational hygiene has spread far beyond traditional industrial settings to include non-industrial workers (office workers, health care workers, etc.). At the same time, professional occupational hygienists are becoming increasingly involved in the wider field of environmental hygiene, including hazardous materials, emissions to the general environment, safety and
security. This requires knowledge not only about a wider range of scientific issues but also of much more diverse regulatory framework. Meanwhile, the role of the hygienist is becoming less hands-on as the requirement for aggressive ‘measurement-of-the-environment’ is replaced increasingly by the administration of programs and management systems. The occupational hygienist’s job is therefore moving closer to what is referred to elsewhere as a ‘risk manager’. To a traditionalist this may or may not be desirable, but it is reality, driven by the regulatory climate of the time. However, in terms of graduate-level education, while it does not reduce the level of scientific content, it requires an ever-increasing level of management and communication expertise than was expected of occupational hygienists of previous generations.

With these changes have come changes in the job-opportunity scenario for new occupational hygiene-graduates. We now see less opportunity in primary production and manufacturing industries themselves, as once-large occupational hygiene or occupational health departments are trimmed and, in some cases, moved into the domain of human resources with less-direct reporting lines to higher corporate management. Indeed, there has been a sharp rise in the tendency to out-source occupational hygiene-related activity in order to remove what had increasingly been seen as an ‘overhead’. With this has come a corresponding rise in occupational hygiene consultancy. Here the professional occupational hygienist needs to be even more of a ‘generalist’ since he/she can no longer expect to spend their entire career in one industry dealing with a single set of occupational hygiene problems that, although they evolve, remain constrained. With these changes, there is a perception in some quarters that occupational hygiene is a less desirable career option than it was previously, less secure with less clearly-defined career structures. Elsewhere, on the other hand, there are many who feel that the increased emphasis on consultancy provides great opportunity for well-qualified and well-motivated occupational hygienists, especially for those with leanings towards entrepreneurship or wishing to work outside conventional corporate structures.

**Effects on occupational hygiene graduate-level education**

The first effect of the changes referred to have been on the students themselves. We have seen a fall in the number of applicants for graduate-level programs, especially those with good first degrees in the primary core areas of interest. This has raised the level of competition between programs, particularly noticeable in the United States in the NIOSH-ERCs. Here, since all programs are consistent in the quality of the occupational hygiene education provided, applicants make choices on the basis of other factors, including location, reputation and—not least—the cost of tuition. This places programs at some of the high-cost institutions, including those at private universities or the higher-cost public ones, at some disadvantage, which is only partially offset by the aura of reputation or standing (even if it existed in the first place).

As far as the programs themselves are concerned, the changing scene is prodding curricula towards broader-based risk management approaches. But this, in itself, creates a tension with the basic disciplinary needs of a good program in occupational hygiene (as already outlined) and with criteria set out by the program sponsors and accrediting bodies. On the one hand there is the temptation to add new courses that address the issues relevant to the desired new approach and on the other to continue with existing courses that maintain the strong scientific base of the discipline. One solution is to increase the duration of the programs. But this is not acceptable. A 2-year Masters program is the maximum that can be sustained. The challenge remains.

The shift towards an increase in emphasis on occupational hygiene consultancy has, in itself, triggered changes in how we think about academic programs. Success in the very competitive world of occupational hygiene consultancy requires, even more so than before, the broad background, vision and confidence that derive from educational exposure to well-designed academic programs.

**Responses**

In order to remain relevant, graduate programs in occupational hygiene need to move with the times. In the first instance, this requires appropriate liaison with all stakeholders and interested parties. So, in the first instance, programs should be advertised among prospective students and so making them visible, in particular through active promotion of relevant undergraduate academic programs in their own and other institutions. The days have passed when prospective students simply ‘arrived’.

Most importantly, programs should include the participation of professional hygienists and other occupational and environmental health professionals who are practicing in the real world. An excellent way to achieve this, and so maintain contact with professional trends, is through the establishment of, and regular input from, advisory committees. In many institutions, the recruitment of practicing professionals into part-time (or adjunct) teaching positions has been used effectively, serving academic needs in key subject areas not covered by regular faculty and providing students with contact with credible real-world expertise. Mentorship of graduate students...
by high-level occupational hygienists can serve not only to educate but also to inspire them.

The leaders of academic programs themselves must stay abreast of external forces and trends in their respective countries so that they may influence—or at least anticipate—changes ahead of time. Adaptation of academic curricula cannot be achieved overnight, so we must be prepared to exercise foresight, and so continue to make programs continue to be attractive and relevant to stakeholders and prospective students alike.

**Evolving educational models**

Some responses to change require a paradigm shift. The conventional model for higher education, undergraduate or graduate, is that students enroll for extended periods of sustained full-time study. For graduate-level occupational hygiene, this typically requires a 2-year commitment for the Masters degree with an extra 3 years or more for the Doctoral degree. This may be unacceptably onerous for many prospective enrollees. Many individuals who aspire to further education in occupational hygiene have come to this view after periods of post-graduate employment in fields that have drawn their interest to the field. By now, however, many such individuals will be earning salaries in jobs that are difficult to walk away from, many have families and are buying homes, etc. For these, the option of full-time study at the institution in question is not attractive. A number of models have emerged to meet this need. At the University of Michigan, for example, an ‘On-Job/On-Campus’ (OJ/OC) program in occupational health has been in existence for more than 20 years. Environmental health was added more recently. Other such programs exist within the School of Public Health (e.g. health management and policy). These have proved highly effective, both in recruiting students and in the successful graduation of a large number of people who have immediately gone out and become effective professionals. The Michigan model requires students to attend the University in Ann Arbor every month for a period of 2 years for an intensive 4-day period of instruction and interaction sessions with faculty and other students. In this way all the programmatic ingredients alluded to earlier are achieved.

Distance learning (DL) is emerging as a new tool for graduate education in occupational hygiene. In its purest form, this provides the means for students to enroll in a degree program and study without ever having to attend the institution in question. In the earlier days of this approach, the teaching and learning were achieved by the distribution of written materials, completion of written assignments and various modes of direct contact with instructors (including telephone conference or face-to-face tutorials). In some cases, broadcast media (radio and television) were used. In UK, the Open University, founded in the 1960s, was built on such approaches, providing access to higher education for a whole generation for whom the traditional on-campus experience was not feasible. Such education is referred to as ‘supported open learning’, in which students study in their own time, but are supported by tutorial and student services staff. The success and validity of the Open University approach are reflected in the fact that the University itself is now ranked among the top UK universities for the quality of its teaching. This bodes well for the DL approach if the method is well chosen and applied accordingly.

In more recent years, DL has been greatly enhanced by the availability of the internet, so much so that a new range of alternative approaches are available. In the United States, Tulane University (in New Orleans) has been a pioneer in offering on-line Masters degree programs in occupational health and safety management and industrial hygiene, respectively, in what is referred to as ‘...the only truly synchronous (real-time, live interaction) programs of their kind.’ A small number of other programs with a DL component are listed at the website that is often considered by individuals considering study in occupational hygiene (Distance Gradschools, 2005). It is reasonable to expect that the availability of such programs will increase in the future as new internet options and software emerge. Among the options that may be considered are (i) talking head synchronized with Microsoft Powerpoint slides, (ii) narrated computer screen recording, (iii) video of actual class synchronized with Microsoft Powerpoint slides, (iv) web conferencing, and a wide range of other possibilities. Colleagues in the Department of Health Management and Policy at the University of Michigan have conducted surveys of student satisfaction using these various modes. The last three were generally quite well received. But the ‘talking-head-with-slides’ model, the least interactive of the four options listed, was by far the least popular. Importantly, it was shown that academic performances for the more popular modes were commensurate with those for traditional face-to-face instruction. More recently still, a ‘mixed OJ/OC-DL’ model has been considered, in which students would come to campus for up to 50% of the weekends in the current OJ/OC model, and the DL approach would be adopted for the other parts. The challenge then is to decide which parts of courses are best delivered in which mode.

**CONCLUDING REMARKS**

The preceding draws heavily from the United States experience, mainly because this is where, even during days of decline, the largest and most structured system of education in occupational
hygiene and the other occupational health disciplines remains. But experience gained from excellent programs elsewhere adds greatly to our understanding of modern trends in graduate education in occupational hygiene. The overall picture that emerges is therefore generic and transcends individual national systems.

In the first place, it is easily argued that graduate education in occupational hygiene meets needs that cannot be satisfied by undergraduate programs. Such graduate programs should focus on education as opposed to simply training, providing a source of individuals who will be capable for going on to professional positions requiring specialized leadership and innovative ability. To this end, the education should be concept-based so that what is learned today can be carried forward into a changing future and applied to problems that are not yet known and whose solutions will require the generation and application of new knowledge. It is essential that the educational experience should integrate occupational hygiene with other occupational and environmental health disciplines, and with public health concepts. A large majority of graduates from such programs leave with Masters degrees (e.g. Master of Science or Master of Public Health) and are qualified to take on roles in professional practice in the discipline. In turn, they will be well-prepared to take the appropriate professional certification examinations. A smaller fraction will go on to take Doctoral degrees (usually the PhD) and there has consistently been a significant demand for graduates educated to this level from industry, government organizations and academia.

Occupational hygiene has been evolving since it first emerged as a discipline in its own right. Recent changes, driven by external factors (political, regulatory and economic) are driving new thinking about the content and style of graduate programs. Occupational hygiene will continue to evolve. It is important that its professional practice remains strong and relevant, and advanced graduate-level education will always be in the forefront of that effort. The need is still there.

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