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GRADUATE EDUCATION IN INDUSTRIAL HYGIENE

Final Progress Report

to the

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Training Grant

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Table of Contents

	Page
Title Page	1
Table of Contents	2
Abstract	3
Significant Findings	4
Progress	6
A. Students, Trainees, and Graduates	6
B. Curriculum	8
C. Research	9
D. Enhancement	11
E. Invention/Intellectual Property	11
Publications List	12

Abstract

The University of South Carolina's Industrial Hygiene Program, founded in 1974 and accredited in 2002 by the Accreditation Board for Engineering and Technology (ABET), is firmly committed to the education of students in industrial hygiene and related fields at the Masters and Doctoral levels. The program is one of three tracks in the Department of Environmental Health Sciences. The other two tracks are Environmental Quality and Hazardous Materials Management.

The Department is set within the University of South Carolina's fully accredited Arnold School of Public Health, which provides a rich environment for interdisciplinary teaching and research. The Arnold SPH received its initial accreditation by the Council on Education for Public Health (CEPH) in 1977, and its most recent accreditation in 2002. The University of South Carolina is accredited by the Southern Association of Colleges and Schools, with an initial accreditation in 1917, and the most recent accreditation in 2001. The continued accreditation by all relevant organizations is an objective indication of the strength of the Industrial Hygiene Program.

The goal of the Industrial Hygiene Program is to improve the quality of the occupational environment by training professionals in industrial hygiene, conducting important research on the causes and prevention of diseases and injuries related to occupation, conducting research on the safety of work environments, and by providing direct service to workers, employers, occupational health professionals, and the community. Our principal educational objective is to provide our students with a solid foundation in the fundamentals of industrial hygiene, which include anticipation, recognition, evaluation, and control of hazards in the occupational environment, and other key areas related to industrial hygiene and occupational health. This objective is achieved by a multidisciplinary faculty using a wide range of training methods, including traditional classroom lectures, hands-on laboratory course work, supervised practice and internship projects in industrial or governmental settings, and supervised thesis and dissertation research. Students also gain valuable knowledge by attending scientific and professional meetings and symposia, by taking field trips to local industries, by attending guest seminars, and through graduate assistant work experience.

The required core curriculum provides students with an understanding of the fundamental areas of public health, while the track course requirements ensure that students learn the basic concepts of industrial hygiene, including survey and hazard evaluation skills, analytical and instrumental methods, relevant medical and toxicological principles, and control of occupational health hazards. Also, elective courses are available in specific content areas such as health physics, toxicology, air pollution, health and safety management, air monitoring and modeling, aerosol science, and hazardous materials management. The program offers the Master of Public Health (MPH), Master of Science in Public Health (MSPH), and Doctor of Philosophy (PhD) degrees.

Graduating students typically have good success finding jobs. The need for our graduates has always outpaced our ability to train students, even during economic slumps. The shortage of industrial hygiene graduates has been exacerbated in recent years by a nationwide decrease in graduate school applications in industrial hygiene. The Department regularly receives phone calls from recruiters, as well as job announcements from employers, many of whom are program graduates. Over 90% of the Industrial Hygiene graduates from 1999 through 2004 are employed as environmental health professionals or have pursued higher academic degrees. Several graduates have started their own companies in areas such as industrial hygiene training, environmental and industrial hygiene consulting, and industrial hygiene products manufacturing and distribution.

Significant Findings

Significant findings of the Industrial Hygiene Program consist of two types: training program developments and research results. Only the most important findings are listed below.

Training

(1) The mean program enrollment was 23 students over the project period. During this period, 53% of our students were enrolled part-time. An average of 5 full-time students were supported annually with NIOSH Traineeships. Many of these students would have been unable to attend full time without NIOSH funding. Approximately 85% of training grant funding was used for student support.

(2) Twenty-four (24) students graduated from the Program during the project period, including 19 MPH, 4 MSPH, and 1 PhD degrees. One MPH graduate had a prior doctoral degree. One MPH graduate subsequently entered a doctoral program in environmental science, another entered law school and a third entered medical school. Almost all of the other graduates have found employment in industrial hygiene or other occupational safety and health positions. (See Table II for more information.)

(3) The presentation of required courses at night on a rotating schedule continues to be well-received and allows many students with full-time jobs to pursue degrees in the Program.

(4) The NIOSH Training Grant has greatly enhanced the training capabilities of the Industrial Hygiene Program. A major contribution is the provision of salary support (10% for Karen Piegorsch). Ms. Piegorsch developed two new courses, Occupational Ergonomics I and II. She has also developed, with University support and donations, an ergonomics laboratory. In addition, the training grant has provided funds for supplies which are essential for student research projects and laboratory courses. These supplies included: propylene used as a tracer gas, zero air, rotameters, sampling media, and tubing. Also, NIOSH support has allowed Trainees to attend the biannual meetings of the Carolinas Section of the American Industrial Hygiene Association. Attending these meetings is an important part of our students' education, and this close association with the Carolinas Section helps immeasurably with the activities of our AIHA Student Section. Travel to the American Industrial Hygiene Conference and Exhibition for students presenting papers was partially provided by the NIOSH Training Grant.

(5) The School broke ground for a new building in early 2004 and is scheduled to move in by 2006. This will provide the Industrial Hygiene Program with new, expanded, state-of-the-art laboratory facilities. Currently, the Department of Environmental Health Sciences occupies the third and fourth floors of the Health Sciences Building, which provides adequate classroom and laboratory space for industrial hygiene training. Of the Department's 12,628 sq. ft, 2,926 sq. ft are offices, and 6,850 sq. ft are laboratories. Approximately 1,300 sq. ft are allocated for student offices. The Industrial Hygiene Program has 1,389 sq. ft for faculty research, and 1,367 sq. ft of teaching lab space.

(6) During the reporting period, additional efforts were made to incorporate real-world problems into our education of industrial hygienists. Dr. Feigley has involved students in several consulting activities. For example, NIOSH Trainee Traci Whitaker Williams received an assistantship for helping RiskTech, Inc., a consulting company, to develop courses that prepare medical personnel to recognize and respond to terrorist attacks. These courses were developed to meet requirements of both OSHA and the Joint Commission for Hospital Accreditation. They have been offered several times in South Carolina and nearby states. Ms. Williams also did extensive field work on building mold contamination and subsequently was hired as an industrial hygienist by RiskTech.

(7) In the spring of 2001, the School of Public Health was reviewed for re-accreditation by the Council on Education for Public Health (CEPH). The School was found to have 'met' or 'met with commentary' 23 of the 24 criteria. We were notified in 2002 that the School was awarded a 7-year CEPH accreditation, an elusive goal for many larger, older schools.

(8) One of our goals was to have our masters programs in industrial hygiene reaccredited by the Accreditation Board for Engineering and Technologies (ABET). We were evaluated by an ABET site visit team in the fall of 2001. The team's on-site program audit indicated that all criteria were satisfied; and, in the summer of 2002, we were reaccredited for a 6-year period.

(9) An objective during the last two project periods was to recruit an additional tenure-track faculty member for the Program. A new faculty position was advertised in Science in early 2002, and we received nine applications. However, none were considered completely appropriate for the position, so we re-advertised in early 2003. In the summer of 2003, we hired Kristina M. Zierold, Ph.D., to fill this position. She holds dual degrees in Epidemiology and Occupational and Environmental Health Sciences from the University of Illinois in 2001. Upon completing her degrees, Dr. Zierold spent two years with the Centers for Disease Control and Prevention as an Epidemic Intelligence Service (EIS) Officer. At CDC, she was engaged in several epidemiological projects evaluating the effects of occupational exposures on children and adults. Dr. Zierold recently received a grant to investigate environmental and occupational exposures among people with neurodegenerative diseases. She taught "Fundamentals of Air Pollution" (ENHS 760) in spring 2004 and will be teaching "Fundamentals of Industrial Hygiene" (ENHS 762) in fall 2004.

Research

(1) Relative to other schools of public health, the University of South Carolina's Arnold School of Public Health is small in size, but in the top 10 in research funding. The Arnold SPH has 3% of the faculty at USC but produces about 20% of the sponsored program funding. At USC, it is first in research funding per tenure-track faculty FTE.

(2) The industrial hygiene faculty have obtained additional equipment and developed new analytical capabilities. During the reporting period, we developed the capability to perform ELISA analysis of allergens to study the relationship between allergen exposure and lung diseases. In addition, we have been working with faculty in the medical school using GC/tandem mass spectrometry to measure chemical markers of bacteria in air and in settled dust. Finally, we developed an automated sampling network in a simulated workroom to measure the three-dimensional distribution of a tracer gas within the room. NIOSH Trainees have played significant roles in both of these projects.

(3) NIOSH Training grant funds were used to build a dynamic system for calibrating photoionization detectors and a system for testing tubular diffusive sampling devices. These systems have been used in Trainees' thesis research.

Progress

a. Students, Trainees, and Graduates

TABLE I
Industrial Hygiene Program Enrollment and Graduation

	Fall Enrollment			Graduates			
Project Year	FT	PT	Total	MPH	MSPH	PhD	Total
'99 - '00	13	11	24	3	0	0	3
'00 - '01	10	16	26	3	3	0	6
'01 - '02	12	12	24	4	0	0	4
'02 - '03	10	11	21	7	0	1	8
'03 - '04	8	10	18	2	1	0	3
Total				19	4	1	24

We are very proud of the success of our graduates (see Table II below). Twenty-four (24) students graduated from the Industrial Hygiene Program during the last project period (July 1, 1999 - June 30, 2004). The employment status of one graduate is unknown, and two others, both of whom graduated in the past year, are now looking for employment. The remaining 21 either obtained professional jobs in the occupational safety and health field or continued their education in the fields of medicine, law, or environmental science.

TABLE II
Graduates during the project period and their employer
(* = NIOSH Trainee)

Name	Degree and Date awarded	Initial Employment
Brad Wiggins*	MPH 8/1999	not known
Geoffrey Smoland*	MPH 12/1999	Industrial Hygienist, Westinghouse Savannah River Site, Aiken, SC
Komilla Bhatty*	MPH 5/2000	Compliance Officer, North Carolina OSHA, Charlotte, NC
Russell McCue*	MPH 8/2000	Compliance Officer, North Carolina OSHA, Charlotte, NC
Mark Schweder*	MSPH 8/2000	Consulting with SC employers for University of South Carolina
Jake Ward*	MSPH 12/2000	Compliance Officer, North Carolina OSHA, Charlotte, NC
Mike Hendrikson*	MPH 5/2001	Health and Safety Manager, VA Hospital System - Southeast, Augusta, GA

Mark Stewart*	MPH 5/2001	Environmental Engineer, SC Dept. of Health and Environmental Control, Columbia, SC
Tom Beasley*	MSPH 5/2001	Consultant, Charlotte, NC
Colleen Kelly Eubanks	MPH 12/2001	Industrial Hygienist, S & ME, Columbia, SC
Mohammad Y. Ali, M.D.	MPH 5/2002	Pfiesteria & Hepatitis C Surveillance Coordinator, SC Dept. of Health and Env. Control, Columbia, SC
Julie E. Bowers	MPH 5/2002	Industrial Hygienist, General Electric Gas Turbines, Greenville, SC
Nigel Burkhardt	MPH 5/2002	Health Physicist, Dorn VA Medical Center, Columbia, SC
Michael L. McCaskill*	MPH 8/2002	PhD program, Env. Sci., Florida A & M University, Tampa, FL
Rebecca Wheeler Shultz*	MPH 8/2002	Industrial Hygienist, Crandall Corporation, Lexington, SC
Kelvin Deon A. Wright*	MPH 8/2002	Entered law school, USC, Columbia, SC
Everette Horne, C.I.H.	MPH 12/2002	Industrial Hygienist, Medical College of Georgia, Augusta, GA
Michael Cownie*	MPH 5/2003	Industrial Hygienist, S&ME, Inc., Spartanburg, SC
Karen Knight*	MPH 5/2003	Industrial Hygienist, Tembec Paper, St. Francisville, LA
Chris Moore*	MPH 5/2003	Looking for employment
Wayne Gaul	Ph.D. 5/2003	Nuclear Engineer, Westinghouse Savannah River Site, Aiken, SC
Tim Fontaine*	MPH 8/2003	Entered medical school
Dainnya Busbin*	MSPH 5/2004	Looking for employment
Amanda Price*	MPH 5/2004	Industrial Hygienist, Occupational Safety and Health Administration, Charlotte, NC

b. Curriculum

1. In addition to providing the only Industrial Hygiene program in South Carolina, we provided unique courses in ergonomics, radiation health (ionizing and non-ionizing radiation), aerosol science, and air pollution monitoring and modeling. Thus, industrial hygiene students may elect to take courses in areas closely related to industrial hygiene to broaden their expertise. The introductory ergonomics course (ENHS 681) is now a requirement for Industrial Hygiene students.
2. An Ergonomics Laboratory has been developed by Karen Piegorsch for teaching, research, and as a mechanism through which her expertise can be shared with the community. Donations continue to enhance our ability to provide hands-on student learning opportunities (e.g. anatomical models for learning about musculoskeletal disorders; a variety of adjustable seating and adjustable computer workstations, and an adjustable industrial workstation for practice in fitting workstations to workers in a variety of types of jobs). The Department has been supporting this Laboratory (e.g. providing space, a large screen T.V., VCR, video camcorder, tripod, A-V cart, and anatomical models), and the Dean funded the acquisition of training and software for performing cost-benefit analyses on health and safety investments.
3. In response to the demand for graduate programs by employed people in South Carolina, the Department of Environmental Health Sciences had established a schedule for offering all our required courses in the evening. Each required course is offered at night once during a three year period. This has been very well received by students who work full-time during the day.
4. At this time, there is no adequate textbook for teaching industrial hygiene at the graduate level and to the best of our knowledge, there is no prospect for publication of a suitable text in the near future. Both standard texts (The National Safety Council's *Fundamentals of Industrial Hygiene,* and the American Industrial Hygiene Association's *The Occupational Environment*) are too oversimplified to be the sole text for a master's level program. To fill this gap, we developed the equivalent of an electronic text for industrial hygiene. To accomplish this, the individual lectures given in the basic courses (ENHS 762 *Fundamentals of Industrial Hygiene* and ENHS 764 *Industrial Hygiene Evaluation*) were written out and placed on floppy disks, and a disk given to each student. A printed version of each was also made available to each student. The former is 230 pages (single spaced); the latter 165 pages (also single spaced). Such lecture material on disk is easily updated to take into account both changes in the field as well as changes in interest and fields of specialization. A conscientious attempt was made to cover in depth every area that is important to the industrial hygienist not dealt with in other required courses. Also this electronic text serves as a high level review for the certification examination given by the American Board of Industrial Hygiene.
5. Interaction between the students and the University of South Carolina Health and Safety Programs Unit has provided many students in the industrial hygiene program with very valuable practical experience. The Health and Safety Programs Unit provides the USC System with services in the areas of radiation protection, occupational health, occupational and environmental hygiene, hazardous waste management, fire protection and safety. Problems encountered in the University include: asbestos, pesticides, lasers, animal care facilities, wood dust, noise, indoor air quality, biological hazards, and the need for ergonomics. Students from our industrial hygiene have worked with the professionals in Health and Safety Programs Unit in all of these areas, and some of the student practica were based on these experiences.

6. We continue to be successful in partnering with area companies and governmental agencies to provide our MPH students with meaningful and valuable practicum experiences. During the last project period, our students completed practica at Albemarle Corporation (Orangeburg, SC), Risk Tech LLC (Charleston, SC), Westinghouse Savannah River Site (Aiken, SC), South Carolina Electric and Gas Co. (Columbia, SC), Crandall Corp. (Lexington, SC), S&ME (Spartanburg, SC), G.E. Gas Turbine (Greenville, SC), Medical College of Georgia (Augusta, GA), the Dorn Veterans Administration Medical Center (Columbia, SC), Providence Hospital (Columbia, SC), and the SC Dept. of Health and Environmental Control (Columbia, SC).
7. In 2002, Dr. Feigley became the P.I. on a new multidisciplinary project, "USC Center for Public Health Preparedness." The Center requires collaboration of faculty from many of the departments within the Arnold SPH, several other USC colleges, and various people from outside the University. One NIOSH Trainee worked with Dr. Feigley to hire staff and acquire space for the Center. Another IH student helped to develop educational materials concerning several bioterrorism agents.
8. There are a number of local traditionally black colleges and universities having bachelor level science programs, but few successful outlets for many of these students except in areas of medicine and dentistry. We believe that the completion of our industrial hygiene program represents a very attainable goal for many of these graduates and we have publicized our program widely in these institutions.

c. Research

1. In the near future, it is likely that much, if not most of our knowledge of industrial exposure to gases and vapors will be through diffusive sampling. This trend is occurring for several reasons. Our inability to identify intuitively the worker with the highest exposure means that more workers must be monitored, and the accuracy of diffusive sampling is improving.
    i. With this understanding, the Industrial Hygiene faculty has undertaken a research program to understand the fundamentals of diffusive sampling. Areas of investigation include: 1) boundary layer effects; 2) saturation effects; 3) mathematical modeling in terms of nondimensional parameters; 4) direct measurement of convective effects; 5) optimal design of diffusive samplers; 6) optimal design of diffusive samplers for radon measurement; 7) direct measurement of back diffusion in diffusive samplers; 8) body wake effects on air flow near samplers and on mass transfer characteristics of samplers.
    ii. Research on diffusive samplers is relatively inexpensive to carry out, and industrial hygiene students have been quite actively involved. Recently, four masters thesis projects were completed on this topic. Yet this research is at the forefront of establishing what will be industrial hygiene technology in the twenty-first century. Results of many of these studies have been published in peer reviewed journals such as *Analytical Chemistry, Talanta*, *American Industrial Hygiene Association Journal,* and *Applied Occupational and Environmental Hygiene*. Our students have gained considerably from their close contact with our research program. This contact has demonstrated both the need for research in industrial hygiene and the protocols needed for successfully carrying out such work. We expect our students to see industrial hygiene in the broadest possible terms, and the research is an important part of our presenting industrial hygiene as a constantly developing science and art.

2. During this project period, two students, Mark Schweder, MSPH, and Mike Reed, Ph.D. candidate, have worked on the idea of using reverse diffusion for validating performance of diffusive samplers. Another student (Dainnya Busbin, MSPH) performed careful experimental determinations of the mass transfer characteristics of Palms tube diffusive samplers as a function of wind speed and wind direction.
3. One of the fundamental procedures for the control of toxic gases and vapors is their removal by adsorption beds. These beds have uses as diverse as the control of radioactive effluents from nuclear reactors to the gas adsorbing canisters used with gas masks. Despite intensive research for nearly a century, there has been no adequate theory to predict the effectiveness of adsorption beds in the adsorption of gases above their critical temperatures (fixed gases) as well as for the effect of relative humidity on the adsorption of both fixed gases and vapors. The research has shown that the Polanyi potential theory, used in conjunction with digital computing procedures developed for this purpose, gives a highly accurate estimate for the adsorption of fixed gases under a very wide range of conditions. Examples of the use of this theory include the design of adsorption beds for the removal of indoor radon, and respirators for toxic gases that work at high relative humidities.
4. Dr. Feigley took sabbatical leave during the Spring of 1998 to study computational fluid dynamics (CFD) and its applications in industrial hygiene. In 2001, Dr. Feigley received funding as the P.I. of a project to investigate the fundamental physical determinants of workplace exposure. This project is a collaboration of the industrial hygiene program with faculty and students from the USC Department of Mechanical Engineering, including the Co-P.I., Dr. Jamil Khan. The study uses computational fluid dynamics to generate plausible concentration fields in workrooms. Simplistic models, the 1- and 2-zone completely mixed models, and the uniform turbulent diffusivity model are being evaluated and their limits defined. The study is unique in that it is one of the few NIOSH funded research efforts aimed at the core assumptions of industrial hygiene practice. One industrial hygiene doctoral student (Eungyoung Lee) and one industrial hygiene MSPH student (James Jenkins) have been working on this project. Both are also NIOSH Trainees.
5. During the project period, Dr. Feigley was the Co-P.I. on a study of pediatric asthma with P.I. Dr. Tim Aldrich, an environmental epidemiologist in the Department of Family and Preventive Medicine, USC School of Medicine. Three industrial hygiene graduate students, two of whom are NIOSH trainees (Briana Childers, Charlotte Toole, and Dr. Raluca Semeniuc) worked on this project with several epidemiologists and physicians, to evaluate environmental triggers of asthma attacks. One Industrial Hygiene student (Raluca Semeniuc) will be using data collected on this project as her thesis research.
6. Another funded research project is a study of airborne microbial contamination in school rooms with Drs. Alvin and Karen Fox of the Department of Microbiology and Immunology. Three industrial hygiene graduate students, two of whom are NIOSH trainees (Briana Childers, Charlotte Toole, and Raluca Semeniuc) have worked on this project and one NIOSH Trainee (Charlotte Toole) will be using data collected on this project as her thesis research.

d. Enhancement

The NIOSH Training Grant has greatly enhanced the training capabilities of the Industrial Hygiene Program. A major contribution is the provision of salary support (10-15%) for Karen Piegorsch. Dr. Piegorsch developed two new courses, Occupational Ergonomics I and II. She also developed, with University support and donations, an ergonomics laboratory. In addition, the training grant has provided funds for supplies which are essential for student research projects and laboratory courses. These supplies include chemicals, glassware, sampling media, and tubing. Also, NIOSH support has allowed students to attend meetings of the Carolina Section of the American Industrial Hygiene Association. Of course, the principal contribution of the training grant is to provide stipend and tuition for Trainees who would otherwise not be able to attend graduate school or who would be forced to attend part-time. Thus, the program has been greatly enhanced for our NIOSH Trainees.

e. Invention/Intellectual Property

Drs. Underhill and Feigley were awarded a patent for a diffusive sampler with the ability to detect improper usage such as failure to remove the cap or poor cap sealing. As noted earlier, two IH students have been performing related research on diffusive samplers. Such contact with research has demonstrated to our students both the need for research in industrial hygiene and the protocols needed for successfully carrying out such work. This sampler may also be developed to correct for variation in the mass transfer characteristics of a sampler. This promises to make diffusive sampling "fool proof" and more accurate.

Publications List (NIOSH Trainees names are underlined.)

Peer Reviewed Papers

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Conte, B.C., C.M. Aelion and T.J. Miller. Identifying factors to assess susceptibility to ground-water contamination in residential wells located near TRI facilities. Podium Presentation at the 53rd Annual Meeting of the National Ground Water Association, Nashville, TN, December 7-9, 2001.

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