Impact of Epidemic Intelligence Service Training in Occupational Respiratory Epidemiology

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ABSTRACT

The Centers for Disease Control and Prevention's Epidemic Intelligence Service (EIS) is a fellowship in applied epidemiology for physicians, veterinarians, nurses, scientists, and other health professionals. Each EIS fellow is assigned to a position at a federal, state, or local site for 2 years of on-the-job training in outbreak investigation, epidemiologic research, surveillance system evaluation, and scientific communication. Although the original focus of the program on the control of infectious diseases remains salient, positions are available for training in other areas of public health, including occupational respiratory disease. In this Perspective, we describe the EIS program, highlight three positions (one federal and two state-based) that provide training in occupational respiratory epidemiology, and summarize trainees' experiences in these positions over a 30-year period. For early-career health professionals interested in understanding and

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preventing occupational respiratory hazards and diseases, EIS offers a unique career development opportunity.

Keywords:
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THE EPIDEMIC INTELLIGENCE SERVICE

Started at the Centers for Disease Control and Prevention (CDC) by Dr. Alexander D. Langmuir in 1951, the Epidemic Intelligence Service (EIS) is a 2-year applied epidemiology training fellowship for health professionals to develop quantitative and analytical skills through service to the community (1, 2). Originally, the EIS fellowship was designed to train physicians on surveillance and control of infectious diseases including polio, influenza, vector-borne diseases, and hospital-acquired infections. Over the years, the CDC expanded their responsibilities to include chronic diseases, health statistics, occupational and environmental health and safety, injury prevention and control, and reproductive health; therefore, the scope of the EIS fellowship was expanded to align with the CDC's responsibilities (1). Furthermore, the EIS fellowship is now open to other health professionals, including veterinarians, nurses, dentists, and doctoral-level scientists (3).

The EIS fellowship curriculum consists of a combination of classroom instructions, case studies, exercises, e-learning, and hands-on epidemiology investigations of public health topics. EIS Officers (EISOs) also respond to disease outbreaks and urgent public health threats as part of their training. EISOs learn how to conduct field investigations, design and carry out epidemiologic studies, evaluate public health surveillance systems, communicate complex scientific concepts to lay audiences, write scientific manuscripts for peer-reviewed journals, and provide recommendations for prevention and control measures for a wide range of diseases (4). Furthermore, EISOs learn to define clinical pathology, epidemiologically link cases, describe laboratory findings, and review exposure assessments to characterize the exposure–response relationship. To complete the 2-year fellowship, EISOs are required to accomplish a specific set of Core Activities for Learning (CALs) (Table 1).

To apply for the EIS fellowship, a candidate must be a United States–licensed physician, veterinarian, nurse, physician assistant, or other doctoral-level healthcare professional or a doctoral-level scientist. Candidates complete an online application (https://www.cdc.gov/eis/application/online-application.html), which opens in the spring of the year before the July start date. After online application review, strong applicants are granted an interview, and EISOs are selected from the interviewed applicants. Position assignments are determined through a matching process during the annual CDC EIS Conference. Incoming EISOs can match with positions at CDC headquarters in Atlanta, with positions on other CDC campuses, or with positions at state, territorial, city, county, or tribal health departments (Figure 1). Regardless of the position, EISOs work under the supervision of an experienced epidemiologist (2).

Table 1. CALs required to complete the EIS Fellowship

CAL	Description	Requirements
Field investigation	Conduct or participate in a field investigation of a potentially serious public health problem that requires a timely response	• Collect original data • Work with state, local, tribal, international or nongovernmental organization partner • Commit ⩾10 working days to the project
Epidemiology analysis	Design, conduct, and interpret an epidemiologic analysis	• Develop a data analysis plan • Use statistical software to manage data • Use epidemiologic methods that account for study design, sample size, bias, power, confounding, and effect modification • Interpret analyses and make public health recommendations
Surveillance evaluation	Evaluate a public health surveillance system	• Conduct an evaluation of a surveillance system • Submit surveillance evaluation report • Provide SMART objectives • Communicate plan to stakeholders • Follow-up to assess SMART objectives
Long presentation	Give an in-depth public health presentation on the officer's original work or in their field of study	• Present to a scientific, medical, or public health audience • Give a formal presentation of ⩾30 min
Short presentation	Give a 5–15-min oral presentation to a scientific audience	• Present to a scientific, medical, or public health audience • Give a formal presentation of original work completed during the fellowship
Peer-reviewed manuscript	Write a scientific manuscript for a peer-reviewed journal	• Officer must be first author • Present officer's original work conducted during fellowship • Include public health recommendations
Concise public health update	Write a concise public health update communicating timely information	• Officer must be first author • Write a brief public health updated with ⩽1,400 words for an external scientific, medical, or public-health audience
Abstract	Write a scientific abstract	• Officer must be first author • Write and submit an abstract based on officer's original work
Lay audience	Communicate complex scientific concepts to a lay audience	• Written or oral presentation material • Communicate message with appropriate level and style • Disseminate message to public, media, or congressional audience
Service to agency	Provide service to the agency	• Grant reviewer • Conduct peer review for a journal • Public health committee member • Short-term student mentor

Definition of abbreviations: CAL = core activity for learning; EIS = Epidemic Intelligence Service; SMART = specific, measurable, achievable, relevant, and time-bound.

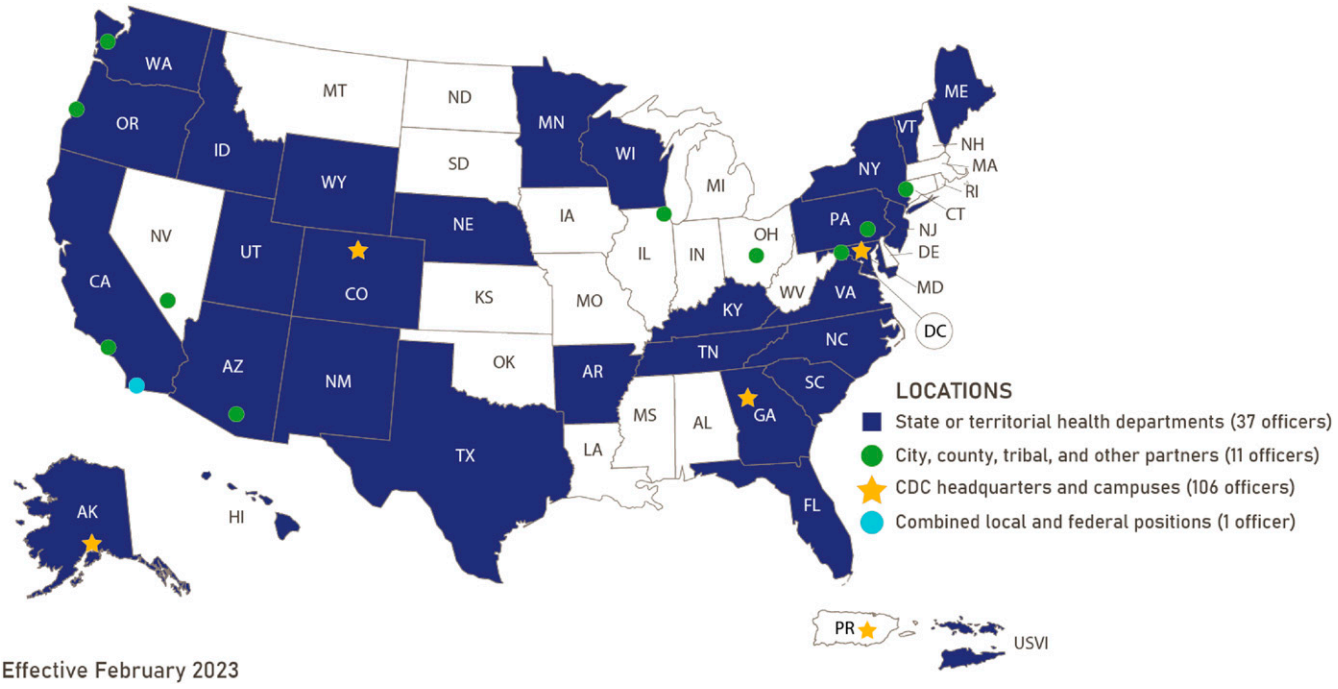

Figure 1. Locations of Epidemic Intelligence Service Officers assignments for classes of 2021 and 2022. Data published by the U.S. CDC/National Center for State, Tribal, Local, and Territorial Public Health Infrastructure and Workforce, Division of Workforce Development. Last updated March 30, 2023. CDC = Centers for Disease Control and Prevention.

EIS OPPORTUNITIES IN OCCUPATIONAL RESPIRATORY EPIDEMIOLOGY

Occupational exposures contribute substantially to nonmalignant respiratory diseases (5). Because of the economic and social burden of occupational lung disease, novel and reemerging occupational respiratory hazards lead to important public health investigations (6–8). However, assessing a causal link between work exposures and occupational lung disease can be challenging, requiring strong epidemiology skills to associate exposure with lung disease or respiratory symptoms (5, 9).

Several EIS fellowship position assignments offer epidemiology training that includes developing and strengthening epidemiology skills needed to investigate occupational lung diseases. One position is with the Respiratory Health Division (RHD) of the National Institute for Occupational Safety and Health (NIOSH), which was known as the Division of Respiratory Disease Studies from 1991 through 2015. EISOs assigned to the NIOSH/RHD focus their epidemiology curriculum on work-related exposures that lead to respiratory illness and death. EISOs in the NIOSH/RHD lead and participate in investigations through the Health Hazard Evaluation (HHE) program that was established through the Occupational Safety and Health Act of 1970 to help employees, unions, and employers identify and control occupational health hazards (10). In addition to the RHD/NIOSH position, the state health departments in California and Wisconsin have EIS positions in their environmental and occupational health divisions that offer opportunities to conduct occupational lung disease investigations.

EISO investigations focused on respiratory diseases in the workplace have led to the identification of novel or reemerging occupational hazards and have provided important recommendations for disease prevention and control (6). However, to our knowledge, with the exception of outbreaks involving respiratory pathogens (4), these investigations have not been systematically examined. In this Perspective, we describe the experience with occupational respiratory epidemiology training through the EIS fellowship program during the past three decades by examining EISOs' demographic and educational backgrounds, their outputs in terms of published reports and peer-reviewed journal articles, and their current employment (Table 2). We also highlight some of the most representative investigations and their impacts.

EXPERIENCE FROM 1991 TO 2020

Over the course of this 30-year period, 41 EISOs completed EIS training in positions at NIOSH/RHD ($n = 22$), the Wisconsin Department of Health Services (WDHS) ($n = 10$), and the California Department of Public Health (CDPH) ($n = 9$). Most were female physicians, and the majority had at least one graduate degree beyond their EIS qualifying degree (Table 3). Of the 25 EISOs with available current career information, 16 (64%) work in state or federal government, three (12%) in private practice, and three (12%) in industry; 21 (84%) currently have a supervisory position. By reviewing the National Institute for Health website (https://reporter.nih.gov/search/ReTiEoKKLESUt7JrYoFuhg/projects), we identified five (12%) EISOs who received federal extramural funding after the fellowship training.

These 41 EISOs published 156 peer-reviewed journal articles from their fellowship work (four peer-reviewed journal articles were coauthored by multiple EISOs but only counted once), for a median of 3.5 peer-reviewed articles (range, 1–10) per EISO. Of these papers, 70 focused on occupational respiratory health concerns; the other 86 journal articles focused on other public health topics. Furthermore, RHD/NIOSH EISOs authored 37 HHE reports. A wide variety of disease outcomes, occupational exposures, and industries were investigated (Table 4). Notably, 13 EISOs worked on an investigation of a novel occupational respiratory disease or a novel occupational exposure for a known disease, including indium lung disease, obliterative bronchiolitis from diacetyl exposure, silicosis in workers who cut engineered stone, flock workers' lung disease, and asthma related to peracetic acid and acetic acid exposure.

Below, we highlight some of the investigations involving the most represented exposure categories and their occupational respiratory health impacts.

NOTABLE EIS INVESTIGATIONS

Indoor Environmental Quality

In the 1980s, epidemiologists reported a high prevalence of respiratory symptoms associated with poor indoor environmental quality (IEQ) (11–13). In the 1990s, the NIOSH started receiving HHE requests to investigate indoor environments for carbon dioxide, ventilation system issues, asbestos, water incursion, odors, and mold contamination (14–20). Five NIOSH/RHD EISOs participated in IEQ HHE investigations and completed seven HHE reports. Although, in many cases, NIOSH IEQ investigations did not link specific exposures to reported respiratory symptoms, these investigations found an

Table 2. Methods used to identify Epidemic Intelligence Service Officers (EISOs) and peer-reviewed journal articles

What was done	How It was accomplished	Included	Excluded
Identified EISOs	Searched EIS directory, EIS Alumni Association, and National institute for Occupational Safety and Health (NIOSH)'s EIS list for EISOs who were assigned at NIOSH Respiratory Health Division (RHD), Wisconsin Department of Health Services (WDHS), and California Department of Public Health (CDPH)	EISO who completed EIS at NIOSH/RHD, WDHS, or CDPH during 1991 and 2020	EISO who did not complete the EIS program, transferred to another EIS assignment, completed EIS program before 1991 or after 2020
Identified EISO demographics	Searched publicly available sources including: LinkedIn®, Google™, and the EIS Alumni Association website	Information confirmed by identifying reference to EIS fellowship on source	N/A
Identified peer-reviewed journals	Searched through Pubmed, NIOSHTIC2, Scopus, and Google™ Scholar using the EISO's name. Peer-reviewed journal article searches were expanded five years past completion of the EIS fellowship to allow for time required to submit a peer-reviewed journal	N/A	EISO author affiliation did not list CDC, the EIS fellowship site, or the EIS program; the data collection and analysis timeline did not align with EIS fellowship dates
Identified Health Hazard Evaluation (HHE) Reports	Searched EISO's name on NIOSH's HHE Report webpage	HHE request submitted during EISO's fellowship date and data collection occurred during fellowship dates	N/A
Identified current job positions	Searched publicly available sources including: LinkedIn®, Google™, and the EIS Alumni Association website	Information confirmed by identifying reference to EIS fellowship on source	N/A

Definition of abbreviations: CDC = Centers for Disease Control and Prevention; CDPH = California Department of Public Health; EIS = Epidemic Intelligence Service; EISO = Epidemic Intelligence Service officer; HHE = health hazard evaluation; NIOSH = National Institute for Occupational Safety and Health; RHD = Respiratory Health Division; WDHS = Wisconsin Department of Health Services; N/A = not applicable.

Table 3. Demographics, education, clinical training, position assignments, and outputs of EISOs who completed EIS Fellowship training in NIOSH/RHD, WDHS, and CDPH during 1991–2020 ($N = 41$)

Characteristic	Value
Gender	
Female	24 (59%)
Male	17 (41%)
Education	
Physician (M.D., D.O., M.B.B.S.)	25 (61%)
Ph.D./Sc.D./Dr.P.H.	10 (24%)
Veterinarian	4 (10%)
Nurse	2 (5%)
Additional degrees*	
M.P.H./M.H.A.	27 (75%)
Ph.D./Sc.D.	4 (11%)
M.S./M.Sc.	3 (8%)
Other	2 (6%)
Clinical training†	
Occupational medicine	9 (43%)
Internal medicine	8 (38%)
Family medicine	3 (14%)
Pediatrics	2 (10%)
Pulmonary	2 (10%)
Allergy and immunology	1 (5%)
Anesthesia	1 (5%)
EIS positions	
NIOSH/RHD	22 (54%)
WDHS	10 (24%)
CDPH	9 (22%)
Post-EIS careers	
State or federal government	16 (64%)
Private practice	3 (12%)
Industry	3 (12%)
Other‡	3 (12%)

Table 3. *Continued.*

Characteristic	Value
Publications	
Peer-reviewed journal articles	156
HHE reports	37
No. of publications by professional degree[§]	
Physician (M.D., D.O., M.B.B.S.)	3 (1–9)
Ph.D./Sc.D./Dr.P.H.	5.5 (1–10)
Veterinarian	2.5 (1–7)
Nurse	4.5 (4–5)

Definition of abbreviations: CDPH = California Department of Public Health; D.O. = Doctorate of Osteopathic Medicine; Dr.P.H. = Doctor of Public Health; EIS = Epidemic Intelligence Service; EISO = Epidemic Intelligence Service officer; HHE = health hazard evaluation; M.B.B.S. = Bachelor of Medicine, Bachelor of Surgery; M.D. = Doctor of Medicine; M.H.A = Master of Health Administration; M.P.H. = Master of Public Health; M.S. = Master of Science; M.Sc. = Master of Science; NIOSH = National Institute for Occupational Safety and Health; No. = number; Ph.D = Doctor of Philosophy; RHD = Respiratory Health Division; Sc.D. = Doctor of Science; WDHS = Wisconsin Department of Health Services.
Data presented as median (range) where applicable.
*Some EISOs had more than one additional degree.
[†]Some EISOs completed more than one clinical training program.
[‡]"Other" includes EISOs who went into careers in academia or private institutions.
[§]Median calculated using only peer-reviewed journal articles.

association between work in buildings with IEQ issues and adverse respiratory health outcomes.

In addition to the HHE reports, six EISOs from the NIOSH/RHD, WDHS, and CDPH worked on IEQ projects that led to the publication of six peer-reviewed journal articles. (13, 21–26). The investigations completed by the EISOs evaluated respiratory morbidity and mortality related to carbon monoxide and particulate matter smaller than 2.5 μm at an indoor go-kart facility, carbon monoxide exposure in an industrial kitchen, IEQ problems in a water-damaged office building, and mold exposure during remediation after a natural disaster (21–23, 26). The work from the HHE investigations and peer-reviewed journal articles added to the knowledge and understanding of how IEQ is associated with respiratory symptoms and contributed to the evidence linking indoor environmental exposures to a range of adverse respiratory outcomes, with implications for diagnosis and care as well as building design and maintenance.

Diacetyl

Nine EISOs investigated diacetyl exposures. In 2000, NIOSH received a request through the HHE program to investigate fixed obstructive lung disease among workers without a history of an exposure to hazardous chemical spills or high levels of known occupational hazards at a microwave popcorn manufacturing facility (27, 28). This early investigation epidemiologically linked a butter flavoring chemical, diacetyl, to respiratory symptoms and obliterative bronchiolitis among the facility's workers (27, 29, 30). Experimental animal studies at NIOSH demonstrated biological plausibility, as diacetyl was found to damage the respiratory epithelium (31). This work

Table 4. Summary of occupational respiratory disease investigations in which Epidemic Intelligence Service Officers participated during 1991–2020

Disease Category (Refs.)	Occupational Exposures	Industries/ Context	HHE Reports	Peer-reviewed Publications	No. of EISOs who Worked on Topic*	No. of Publications		No. of HHE Reports	
						EISO First Author†	EISO Coauthor†	EISO First Author†	EISO Coauthor†
Hypersensitivity pneumonitis (91–93)	Metal working fluid; diphenylmethane diisocyanate	Manufacturing; agricultural; occupational surveillance	1	2	4	1	1	1	N/A
Asthma (94–101)	Asthmagens	Food processing facilities; insect-rearing; syntactic foam manufacturing, health care, chemical	4	4	6	4	N/A	1	3
Silicosis (58–60, 62, 64–66)	Crystalline silica/ respirable dust	Engineered stone; sandblasting and painting; graphite mill	3	4	5	3	1	2	1
Obliterative bronchiolitis (30, 35, 37–40, 102–112)	Diacetyl exposure	Coffee processing; popcorn manufacturing; food processing; flavor manufacturing	9	8	9	3	5	7	2
Chronic beryllium disease (79–83)	Beryllium	Manufacturing	0	5	3	3	2	N/A	N/A
Indium lung disease (87, 89, 113)	Indium-tin oxide	Indium-tin oxide production	1	2	1	N/A	2	N/A	1
Coal workers' pneumoconiosis and progressive massive fibrosis (45, 48–56, 114–116)	Coal mine dust	Coal mining	1	12	8	11	1	N/A	1

Table 4. *Continued.*

Disease Category (Refs.)	Occupational Exposures	Industries/ Context	HHE Reports	Peer-reviewed Publications	No. of EISOs who Worked on Topic*	No. of Publications		No. of HHE Reports	
						EISO First Author†	EISO Coauthor†	EISO First Author†	EISO Coauthor†
Malignant mesothelioma (117, 118)	N/A	Surveillance systems	0	2	2	1	1	N/A	N/A
Idiopathic pulmonary fibrosis (119)	Metal and wood dust	Surveillance systems	0	1	2	1	N/A	N/A	N/A
Respiratory infectious disease (67–77, 120–122)	Respiratory infectious pathogen	Health care; construction; forestry services; animal care services	3	12	9	7	5	3	N/A
Nonspecific respiratory symptoms (13–18, 20, 21, 23, 25, 26, 123–144)	N/A	Health care; manufacturing; educational services	15	18	19	10	8	5	10
Total publications	N/A	N/A	37	70	N/A	44	26	19	18

Definition of abbreviations: EISO = Epidemic Intelligence Service officer; HHE = health hazard evaluation; IPF = idiopathic pulmonary fibrosis; N/A = not applicable.
*For some publications and HHE reports, more than one EISO was listed as an author, therefore the number of EISOs will not match the number of publications. Publications were only counted once if multiple EISOs were listed as authors.
†For publications with multiple EISOs listed as authors, publication was counted under the heading based on the position of the first listed EISO. For example, if two EISOs wrote a paper and one was first author and the other was a contributing author, the publication was counted as an EISO first author publication.

led to further investigations in flavor manufacturing industries, bakery mix production facilities, and coffee production facilities with exposures to diacetyl or its substitute, 2,3-pentanedione (32–36). Five NIOSH/RHD and CDPH EISOs authored peer-reviewed journal articles or HHE reports that detailed epidemiologic investigations of the effects of diacetyl and 2,3-pentanedione on respiratory health (28, 30, 31, 35, 37–40). The work completed by the NIOSH/RHD and CDPH EISOs helped lead to the development of a NIOSH Alert, a Criteria Document that recommended occupational exposure limits for diacetyl and 2,3-pentanedione, guidelines for workers exposed to diacetyl and 2,3-pentanedione (41, 42), and, in California, a regulation to limit diacetyl exposure in workplaces (43).

Coal Mine Dust

Coal miners' exposure to coal mine dust increases their risk of respiratory illnesses including coal workers' pneumoconiosis (CWP) (44–46). Since the mid-1990s, the prevalence of CWP among coal miners has doubled, including coal miners whose employment started after the initiation of the federal respiratory dust exposure limits (47, 48). Nine EISOs from the NIOSH/RHD published peer-reviewed journal articles evaluating radiographic outcomes from coal mine dust exposure among coal miners (48–56). Two EISOs published a study that indicated the prevalence of CWP had decreased in the preceding decades at the time of the study, but the number of severe CWP or progressive massive fibrosis cases was increasing, especially among younger miners in central Appalachia (49). The results from this study led to further EISO epidemiologic studies to better understand the increase in severe CWP among some miners (48, 50, 54). One follow-up study highlighted inadequate coal dust prevention through engineering and administrative controls and reinforced findings from a previous study that identified mining practices as a reason for increases in progressive massive fibrosis (54, 57). This work contributed to the Mine Safety and Health Administration moving forward with a proposed permissible exposure limit and increased enforcement efforts for silica air sampling during tasks in which miners were likely being overexposed to silica. One EISO's peer-reviewed journal article reported an association between the presence of radiographic abnormalities and lung function abnormalities among miners with CWP when controlling for smoking status, body mass index, and tenure (52). This study demonstrated the importance of monitoring lung function along with chest radiographic surveillance of coal miners and resulted in an expansion of medical surveillance to include spirometry and surface miners, who were not previously included.

Respirable Crystalline Silica

Exposure to respirable crystalline silica has been associated with a range of adverse health outcomes, including silicosis, chronic obstructive pulmonary disease, lung cancer, autoimmune disorders, and infections. Two NIOSH/RHD EISOs authored four HHE reports describing silica exposures at sandblasting and painting operations, a graphite mill, a sheet-glass production facility, and a coal slag processing facility (58–61). In addition, three EISOs from the NIOSH/RHD, WDHS, and CDPH published peer-reviewed journal articles evaluating silica exposures and health effects in a variety of industries (62–66). Notable publications include a report of 18 cases of severe silicosis among countertop fabrication workers in California and three other states (62).

These cases highlighted a global epidemic of silicosis related to engineered stone, a quartz-based composite material that can contain >90% crystalline silica, resulting in high silica exposures when cut and ground (63). A follow-up study by a CDPH EISO of one workplace with two fatal cases documented a radiographic silicosis prevalence of 12% among current workers (64).

Respiratory Pathogens

Nine NIOSH/RHD, WDHS, and CDPH EISOs worked on projects and published peer-reviewed journal articles evaluating the occupational transmission of respiratory infectious diseases, including H1N1 influenza, tuberculosis, hantavirus pulmonary syndrome, coccidioidomycosis, and coronavirus disease (COVID-19) (67–77). Some industries with outbreaks of respiratory infectious diseases investigated by NIOSH/RHD, WDHS, and CDPH EISOs included solar farming, entertainment, health care, forestry, food processing, and animal care. One EISO published a study using data from four state health departments with laboratory-confirmed 2009 H1N1 influenza and indicated that healthcare, public administration, educational services, and accommodation and food-service employees could have an occupational risk for exposure to 2009 H1N1 influenza and occupational patterns should be further investigated to protect workers at high risk (67). Another EISO evaluated respirator-use preparedness of California acute care facility employees during the H1N1 pandemic (69). Two EISOs published peer-reviewed journal articles investigating occupational exposure to the fungus that causes coccidioidomycosis among wildland firefighters, solar power farm construction workers, and entertainment workers (70, 72–74). One EISO's work involved evaluating occupational transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes COVID-19, from a patient to healthcare personnel and describing COVID-19 among U.S. food production and agriculture workers (75, 76).

Beryllium

Beryllium is a lightweight metal with unique mechanical and thermal properties that is used in many industries, including defense, aerospace, telecommunications, automotive electronics, and medical specialties. Exposure to beryllium can cause lymphocyte-mediated beryllium sensitization and a granulomatous lung disease, chronic beryllium disease (78). NIOSH/RHD EISOs published five peer-reviewed journal articles addressing various aspects of beryllium exposure and adverse health effects, with a focus on prevention (79–83). One described an 11-year longitudinal follow-up of a beryllium oxide ceramics manufacturing facility, documenting an ongoing risk of beryllium sensitization and chronic beryllium disease and supporting the need for medical monitoring (79). Three papers examined the effectiveness of a preventive program in beryllium metal, oxide, and alloy production facilities, suggesting that respiratory and dermal protection and particle migration control could prevent beryllium sensitization among workers (80–82). Finally, one paper reexamined the phenomenon of acute beryllium disease, which had traditionally been considered an irritant reaction to very high beryllium exposures (83). This paper used historical descriptions, previously unreported clinical cases, and evolving insights into the pathophysiology of beryllium sensitization and chronic beryllium disease to make the case that acute beryllium disease was also an immune-mediated process.

LESSONS LEARNED

EISOs who completed the EIS fellowship with the NIOSH/RHD, WDHS, and CDPH represented multiple professional and training backgrounds. A majority of the EISOs were female, likely reflecting a broader pattern in the public health profession (84). These EISOs authored almost 200 HHE reports and peer-reviewed journal articles from work conducted during their 2-year fellowships, reflecting occupational respiratory health concerns and hazards among a wide range of industries. The publications highlighted novel occupational respiratory hazards, identified recurrence or resurgence, and added to our evolving understanding of work-related inhalational risks and respiratory disease. Furthermore, many of these investigations contributed to the knowledge foundation for future recommendations to improve worker health.

It is evident from these publications that the EIS fellowship provides benefits to early-career professionals. First, health professionals benefit from strong writing communication skills, regardless of career path. The EIS fellowship Core Activities for Learning require EISOs to complete and submit at least one first-author scientific manuscript to a peer-reviewed journal. On average, EISOs in our analysis published more than three scientific manuscripts from their fellowship work. Furthermore, we noted during our searches that many of the EISOs continued to write and publish peer-reviewed journal articles after completing the EIS. Next, the highlighted investigations illustrate how EISOs had opportunities to develop skills in collecting data about respiratory health and inhalational exposures and lead epidemiologic investigations in occupational settings. Other career benefits of the EIS fellowship include a structured learning program under the guidance and mentorship of experienced public health professionals. The EIS fellowship can be an opportunity for health professionals and scientific researchers to expand their formal training to make themselves more competitive in their field of interest.

Even though the impact of the EIS in training public health leaders is well documented, the work completed by EISOs at the NIOSH/RHD, WDHS, and CDPH collectively contributed to improving the understanding and prevention of occupational respiratory hazards and diseases, particularly by characterizing novel and emerging issues. One example is how EISOs' IEQ work contributed to improved worker safety and health with the development of the NIOSH Alert on indoor dampness and mold (34, 85). The EISOs' work also contributed to the development of the NIOSH dampness and mold assessment tool, which is used by NIOSH, public health professionals, employers, building owners, and facility managers to assess dampness and mold in buildings to prevent water damage or identify areas that need remediation (86). EISO diacetyl and 2,3-pentanedione work highlighted in this paper played an important role in developing the 2003 NIOSH Alert on flavorings and establishing NIOSH recommended exposure limits for diacetyl and 2,3-pentanedione (34, 41, 42). EISOs who worked on indium lung disease investigations characterized a novel disease and helped establish an epidemiologic link between lung function abnormalities and higher indium-tin oxide exposure, which led to research to quantify the relationship between exposure and early indium lung disease biomarkers and, ultimately, to a new occupational exposure limit for indium compounds (34, 87–90).

Investigations of occupational transmission of SARS-CoV-2 among healthcare and food processing workers are examples of more recent contributions of EISOs to occupational respiratory epidemiology (75, 76). These investigations informed public health guidelines and regulatory requirements to prevent occupational transmission of SARS-CoV-2 virus.

EISOs who completed the fellowship with the NIOSH/RHD, WDHS, and CDPH investigated a diverse set of occupational respiratory health concerns and documented much of their work through peer-reviewed journal articles. As such, these EISOs collectively contributed to the understanding and prevention of important occupational respiratory hazards and diseases, drawing attention to new and emerging issues in the field. As indicated by the known career paths, many EISOs use the fellowship training to help prepare for leadership positions in government public health. However, for healthcare professionals and scientific researchers with an interest in occupational respiratory epidemiology, the EIS fellowship provides EISOs with a basis for occupational lung disease epidemiology and builds a foundation for a successful career in clinical medicine and academia.

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