In exposure reconstruction for occupational epidemiologic studies, methods based on professional judgment are often used to augment available quantitative exposure data or to provide quantitative adjustments that are applied to existing data. In judgmental methods, workers, managers, and/or industrial hygienists use their knowledge of processes to assign levels or measures of exposures to subgroups of a cohort, or to variations in processes or to changes in the environment. Any simple mixing of quantitative and essentially qualitative estimates will produce a set of numbers with the appropriate units of exposure. However, it is not always clear how these exposure estimates or ordinal ranking of exposures should be interpreted. In addition, there are inherent limitations to the applicability of the methods used to combine judgmental and quantitative estimates.

The mathematical processes used in exposure reconstruction are dependent on the characteristics of the measurement scale used to classify exposures. In exposure reconstruction, by considering only the empirically meaningful relationships, we show that the four measurement scales, absolute, additive, ratio and power, are sufficient to fully describe all judgmental and quantitative combination processes. For example, an absolute scale may be illustrated by the assignment of exposure to ordinal classes. Similarly, the gauging of control measure effectiveness an example of a ratio scale.

By the discussion of measurement scales and extensive examples of their use in exposure reconstruction, the theoretical issues involved and the limitations imposed on the use of each scale are illustrated. We show that forbidden scale mixtures in combining judgmental and quantitative data exist such that their use will make interpretation difficult. In addition, the results of the theoretical analyses presented suggest that there are some tractable resolutions for some of the problems discovered.

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VOLUNTARY SURVEILLANCE SCHEMES AS A SOURCE OF DATA FOR RISK EVALUATION. N. Cherry, J. McDonald, University of Manchester, ManchesterIn the United Kingdom, voluntary confidential reporting by more than 2000 specialist physicians of new cases of occupational disease provides a unique source of information about the distribution of occupational disease and its causes. Since 1989, when specialist chest physicians began reporting cases of occupational lung disease, the reporting schemes have been extended to include occupational physicians, dermatologists, rheumatologists, auditory physicians, communicable disease specialists and, most recently, psychiatrists. Physicians are asked to report every new case arising from work with, for example, 1500 new cases of contact dermatitis and urticaria reported each year by dermatologists, and a further 1600 by occupational physicians.

The information from these schemes is important for regulators, industry groups, and occupational health professionals. In the United Kingdom, if a "no effect" level cannot be established, or if there are economic reasons why such a level cannot be observed, a "maximum exposure limit" may, after full rebate, be introduced. A cost benefit analysis is required as part of these deliberations and, in the absence of formal epidemiological investigations, voluntary reporting schemes may be the only source of information on human costs at existing exposures. Analysis by industry and occupation identifies groups in which intervention is most strongly indicated and where changes in exposure may have the greatest benefit. More sophisticated analyses, for example, of disability or exposure/response, may be possible with the collaboration of the reporting physicians.

The surveillance schemes also contribute importantly to continuing vocational development. Monthly case reports are circulated, quarterly statistical reports compiled, and full reports published annually. Adaptations of the schemes have been put in place in Quebec, Norway, and South Africa. The role of hygienists in such reporting remains to be explored but their contribution would be considerable.

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URINARY FLUORIDE AS A SURROGATE FOR IRRITANT EXPOSURES IN AN ALUMINUM REDUCTION PLANT. N.S. Seixas, S. Carter, J. Kaufman, University of Washington, Seattle, WA; M. Cohen, M. Cotey, Washington Department of Labor and Industries, Olympia, WA; B. Zevenbergen, Palo Alto, CA

During the electrolytic reduction of alumina to form aluminum, high concentrations of respiratory irritants including hydrogen fluoride, other fluoride compounds, and sulfur dioxide may be released into the work atmosphere. Workers in this industry are at increased risk of developing occupational asthma (OA), and the irritants are commonly suspected etiologic agents. As part of a prospective cohort study of OA in aluminum potroom workers, we examined urinary fluoride as a marker of irritant exposure. Thirty-two subjects were monitored for air total and fluoride particulate and hydrogen fluoride on days 1 and 3 of their 3-day workweek. On each day subjects also provided pre- and postshift urine samples that were analyzed for fluoride and creatinine. In addition, postshift urine samples were obtained on a majority of the cohort during the winter and again during the summer. Airborne exposures were generally high (total particulate: 15.7 ± 8.9 mg/m^3; total fluoride: 4.1 ± 2.2; hydrogen fluoride: 0.74 ± 0.33 mg/m^3). Preshift urinary fluoride was significantly increased between days 1 and 3, whereas no significant change was observed in postshift urinary concentrations, indicating an average increase in preshift concentrations over the workweek. Among those individuals with lower average air fluoride exposures who did not wear respiratory protection, a larger pre- to postshift increase in urinary concentrations was observed, and a strong linear relationshop (R^2=0.74) between air concentrations and urinary concentrations was seen. Postshift urinary fluoride concentration was thus adopted as the primary indicator of exposure for the asthma study. In the larger cohort (winter n=91, summer n=72), average postshift urinary concentrations were 2.4 ± 1.8 mg fluoride per gram creatinine. Models were developed to express the difference in exposure between season, jobs, shift, and crew assignment. These results are used to design a strategy for ongoing prospective exposure assessment for the OA study.

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SILICA EXPOSURE AND SILICOSIS AMONG TIN MINERS IN CHINA: EXPOSURE-RESPONSE ANALYSES AND RISK ASSESSMENT. Z. Zhuang, M. Attfield, B. Chen, P. Gao, W. Wallace, NIOSH, Morgantown, WV; W. Chen, J. Chen, Tongji Medical University Wuhan, People's Republic of China

A cohort study of 3010 miners employed at least 1 year during 1960 to 1965 in four Chinese tin mines was conducted to investigate the risk of silicosis and cumulative exposure to silica-containing dust. Historical Chinese total dust data, which were collected differently from American total dust sampling method, were used to create a facility/job title/calendar year exposure matrix. Each worker's work history was abstracted from the complete employment records in mine files. Silicosis diagnoses were based on 1963 Chinese pneumoconiosis Roentgen diagnostic criteria, which classified silicosis as suspected or stages I-III. Suspected cases were not counted as silicosis cases in this study. There were 1015 (33.7%) miners who developed silicosis at an average age of 48.3 years, with an average duration of 21.3 years after first exposure. The risk of silicosis was found to be strongly related to cumulative total dust (CTD) exposure, and it can be well fitted by the Weibull distribution, with the risk of silicosis less than 1% when CTD exposure was under 10 mg/m^3-years, and the risk increasing to 68.7% when CTD exposure was 150 mg/m^3-years. This study predicts approximately a 30% cumulative risk of silicosis of a 40-year lifetime exposure to these tin mine dusts at the Chinese total dust exposure standard of 2 mg/m^3. Total dust exposure data also were converted to respirable free silica exposure estimates (which introduces additional uncertainty into the exposure estimates) for comparison with findings from other epidemiologic studies of silicosis. This showed that the results were similar to most, but not all, findings from other large-scale exposure-response studies.

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A SYNTHESIS OF EPIDEMIOLOGIC RESEARCH ON CANCER RISKS FROM POWER-FREQUENCY MAGNETIC FIELDS AT WORK. J.D. Bowman, R.J. Smith, L. Stayner., NIOSH, Cincinnati, OH

Nearly 100 epidemiologic studies have examined cancer risks from occupational exposures to power-frequency electric and magnetic fields (EMF). Some have reported significant associations with brain cancer and leukemia, but these findings have been inconsistent. One explanation for these results is that EMF interact with biological structures through unproven physical mechanisms to increase the risks of some adult cancers during later stages of carcinogenesis. An alternative hypothesis is that most workplace EMF are too weak to affect biological tissues so the epidemiologic associations are artifacts. To assess the strength of the epidemiologic evidence on occupational EMF and cancer, we conducted a meta-analysis of the studies with personal measurements for the TWA magnitude of power-frequency magnetic fields. These eight studies all used sound epidemiologic methods, but differed in the size of the study population, work environments (electric utilities vs. other industries), outcomes (cancer incidence vs. mortality), and specificity of links

between exposures measurements and subject work histories. When we considered the highest quality studies that assessed exposures 5B10 years before cancer diagnosis or death, the dose-response relationship was significant for brain cancer (1.86-fold increase in the odds ratio for 1 mT increase in exposure, p<0.001) and nearly significant for chronic lymphocytic leukemia (4.07-fold increase per mT, p=0.082). Including the weaker study, the brain cancer dose-response was not significant (p=0.16). No significant dose-response with power-frequency magnetic fields was found for any other cancer studied in men. This synthesis of epidemiologic findings provides some support for the hypothesis that increasing workers' TWA magnetic field exposure may raise their risk of brain cancer and, with less certainty, chronic lymphocytic leukemia.

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THE BEGINNING, MIDDLE, AND END: DEVELOPMENT OF A JOB EXPOSURE MATRIX FOR THREE CHEMICALS OVER FOUR DECADES FOR ONE EPIDEMIOLOGIC STUDY. S.H. Ahrenholz, NIOSH, Cincinnati, OH

The process to develop a job exposure matrix (JEM) includes the identification, acquisition, assembly, manipulation, interpretation, and application of data. Original industrial hygiene data collected over 40 years (at a gaseous diffusion plant) were used to estimate airborne concentrations of uranium, nickel, and fluorides. This process began with the identification of about 16,000 industrial hygiene surveys and initially covered over 100 buildings. Sampling methods ranged from Greenberg-Smith impingers to current day filter cassettes. Unification of contaminant identities and units was necessary to facilitate subsequent exposure characterization. A total of 5220 industrial hygiene sample results were used in the final JEM. Problems encountered during data processing included censored data, missing limits of detection, unknown sample volumes and durations, and unsampled time intervals. Buildings ultimately included in the JEM were those with 50 or more samples. Industrial hygiene data were pooled by decade based on historical knowledge of site activities and to compensate for unsampled periods. The skewness of the historic industrial hygiene data prompted the development of exceedance values for the uranium and fluoride data assigned to a decade. Exceedance values represented the proportion of airborne contaminant values that exceeded an occupational exposure limit during a decade. Reference exposure limits used were the threshold limit values existing at the start of plant operations. The process enabled an assignment of exposure based on the proportion of time contaminant levels may have exceeded an advisory level, utilizing contaminant data collected during the time period of interest. The effort required to produce the JEM was more involved than the final product suggests.

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A COMPARATIVE ANALYSIS OF INDOOR ENVIRONMENTAL MANAGEMENT STRATEGIES. J.R. Guernsey, C. Daly, Dalhousie University, Halifax, NS, Canada

The resolution of indoor environmental problems continues to pose difficult challenges for building owners and managers. In an attempt to seek a new approach, we developed a list of themes comprising requisite elements of an overall proactive indoor environmental policy for building managers. We then compared this list with currently available indoor air quality (IAQ) management schemes.

The requisite themes were identified through a review of the indoor air quality and sick building syndrome literature and IAQ litigation case law and through an assessment of published IAQ guidelines and standards.

A matrix of suggested elements for an indoor environmental management policy was then constructed using the themes. These elements were validated through interviews of building managers who had experienced IAW problems on-site. Eight IAQ management strategies were then compared and contrasted for the presence of these elements. While, collectively, the IAQ management strategies addressed all the elements, individual schemes were found to be lacking in one or more components. We conclude that a formal, proactive approach to indoor environmental management that includes all policy elements and is part of the normal building management practice will most likely lead to the absence of building-related environmental problems.

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REMEDIATION OF AN OFFICE WITH FUNGAL CONTAMINATION IN THE HEATING, VENTILATION, AND AIR-CONDITIONING SYSTEM. L-L. Hung, U.S. Public Health Service/FOH, Philadelphia, PA; K. Kawar, Bridge Environmental Management Group, Naperville, IL

During an indoor environmental quality investigation in a one-story office, visible fungal growth was observed on the fiber glass insulation inside the ductwork. The objectives of this survey were to evaluate and characterize the fungal population in this office, design remediation specifications, develop and implement a monitoring strategy for clearance sampling, and perform postremediation evaluation. Baseline air, wipe, contact plate, and bulk samples were collected from various locations in the office and a reference area. Bioaerosol samples were collected by an Anderson N-6 sampler with flow rate of 28.3 L/min. Two percent malt extract agar plates were used for recovery of fungal species. Carpet dust samples were collected from various locations with a high efficiency particulate air (HEPA) vacuum cleaner.

Fungal concentrations in the interior fiber glass insulation were at the 10^7 colony forming units (CFU)/g level, with *Cladosporium* as the predominant fungi. *Cladosporium* was also the predominant fungal genus recovered from various sample types. Initial indoor airborne fungal levels were comparable with those of outdoors. However, high fungal levels were detected on horizontal surfaces, such as window ledges. A diverse fungal population was recovered from vacuumed carpet dust samples with fungal concentrations at 10^5 CFU/g levels.

Remediation included isolating the office area by creating a negative air pressure containment, removal of ceiling tiles, and HVAC duct. Decontamination work consisted of wet-wiping with isopropyl alcohol and HEPA vacuuming. Removal of the ductwork resulted in a significant increase of airborne fungal levels within the containment.

Clearance samples (various types) were collected 48 hours after conclusion of the decontamination procedures. Clearance indoor airborne fungal concentrations were significantly lower than those of the baseline. Similar results were obtained from wipe and contact plate samples. Moreover, fungal concentrations in vacuumed carpet dust were significantly reduced as compared with the baseline.

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SAMPLING FOR FUNGI IN BUILDINGS: HOW SHOULD THE DATA BE INTERPRETED? P.R. Morey, AQS Services, Inc., Gettysburg, PA

Over the past decade considerable progress has occurred on understanding fungal problems in indoor environments. Consensus documents have suggested that in nonproblem buildings the mix of fungi found indoors and outdoors should be similar. The unacceptability of sustained fungal growth on interior surfaces has been widely recognized in several documents. In 1996 the AIHA Field Guide recommended that risk management decisions be made if the presence of certain fungal species indoors was confirmed. Some confusion on the part of practitioners has resulted from this recommendation. The purpose of this presentation is to provide a view of how fungal sampling data can be interpreted.

Air sampling for culturable fungi including *Aspergillus fumigatus* (AF) and *A. versicolor* (AV) was performed in approximately 10 moisture-damaged buildings. In some of the buildings AF and AV occurred at background outdoor concentrations. In other buildings indoor levels of AF or AV were greater than the background but considerably less than the total concentration of culturable fungi. In still other buildings the mix of fungi indoors was becoming unbalanced in the sense that species such as AF and AV were increasingly well-represented and even dominant in some rooms. While every building is different and many variables can effect the indoor mycoblota, several general conclusions as follows were apparent from the study: (a) The presence of fungal species such as AF and AV at concentrations above the background indicates the existence of a moisture problem that should be corrected; (b) the mix of fungal species indoors tends to become more out of balance as the moisture problem becomes more severe; and (c) visibly moldy and water-damaged materials should be removed irrespective of the results of air sampling.

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FUNGAL SPORES DISPERSED FROM AIR HANDLING SYSTEM DUCT: A COMPARISON OF THREE FUNGAL-CONTAMINATED DUCT MATERIALS. L.D. Stetzenbach, M.

Abstracts

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