

housekeeping, ventilation, and work practices. These findings suggest that an appropriate checklist could be used as objective evidence that a quantitative exposure assessment may not be necessary.

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USE OF RISK DENSITY MAPPING TO REFINE RISK ESTIMATES FOR BERYLLIUM EXPOSURE AT HANFORD. K. Ertell, University of Washington, Richland, WA; T. Takaro, B. Stover, University of Washington, Seattle, WA.

Beryllium was used in nuclear fuel rod research and manufacturing at the Department of Energy's Hanford site in eastern Washington from approximately 1950 to 1988. With the increased recognition of chronic beryllium disease as an occupational health issue, there has been great interest in identifying buildings where beryllium was used and characterizing risk for workers. Although there are workplace exposure records and other records indicating where beryllium was used at Hanford, the records are not believed to be complete. Using job histories, an exposure matrix, results of medical screening tests (beryllium LPT test) for both current and retired Hanford workers, and recent building characterization data, risk density maps of Hanford work locations have been produced. These maps show person-years of beryllium exposure and job titles by work location for both sensitized and non-sensitized exposed workers. By combining and comparing these multiple sources of information for the risk density mapping, the list of buildings where beryllium was used has been refined; information about the types of work performed by sensitized workers has been gathered; and the work locations for beryllium-exposed workers have been defined in greater depth. The results of the risk density mapping will help prioritize future building characterization, guide work planning for decontamination and decommissioning, and refine risk estimates for current and former workers.

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SELECTION OF A STUDY POPULATION OF FLIGHT CREW EXPOSED TO COSMIC RADIATION FOR AN EPIDEMIOLOGIC STUDY. M. Waters, E. Whelan, L. Yong, E. Ward, NIOSH, Cincinnati, OH.

Aircraft flight crew are exposed to cosmic radiation of galactic and solar origin, and cosmic radiation dose (CRD) depends primarily on altitude, geomagnetic latitude and solar activity. Epidemiologic studies of flight crew currently underway at NIOSH are evaluating relationships between cumulative CRD and a variety of health outcomes. The quality of the historical CRD reconstruction for individual crewmembers is a prime determinant of the strength of these studies. The objective of this work was to develop criteria for and select a single domicile (home base) with sufficient flight crew at the high end of the range of cumulative CRD. Eleven domiciles were initially selected based on high numbers of international flight crew stationed there, then narrowed to five domiciles based on number and frequency of international destinations and more northerly latitude of the domicile. CRDs were estimated using an FAA computer model for every non-equatorial international flight into each of these domiciles. The model requires origin and destination cities, number and height of in-flight altitudes, and flight duration as input variables, and estimates dose based on the most efficient route incorporating the input constraints. Estimated flight durations were

obtained from published schedules and altitude assumptions were based on pilot estimates for several flight duration and route categories. CRD estimates were computed and ranged from 24.6 to 58.4 uSv/flight. The final domicile was selected balancing the highest dose range for the domicile and frequency and multiplicity of the highest dose routes. This approach allowed selection of a highly exposed study population to be used for recruitment into an epidemiologic study. Future work will include calculation of individual cumulative CRDs for study participants based at the selected domicile using detailed flight histories obtained from the company. Estimation of individual quantitative exposure estimates will strengthen the exposure-response analyses in this study.

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THE USE OF A JOB EXPOSURE MATRIX TO CHARACTERIZE OCCUPATIONAL EXPOSURES IN THE NATURAL GAS INDUSTRY. N. Maher, Occupational Health Clinic for Ontario Worker, Sarnia-Lambton, Point Edward, ON, Canada.

A questionnaire was designed, implemented and analyzed, using a job exposure matrix format, to profile jobs in a natural gas pipeline system with respect to possible hazardous exposures. The categories of chemical, physical, ergonomic, biological and psychological hazards were surveyed. A list of hazardous agents existing in the pipeline operations was formulated and confirmed, by on-site observations, interviews with hygiene and safety supervisors and workers, and review of the literature. The second stage of the project entailed the collection of data about whether or not a particular hazard was present at a location, and if so, which workers had exposure to it, and at what intensity and frequency they were exposed. This assessment was made by groups of expert assessors, senior workers who were familiar with the processes and range of job titles at their location. These experienced workers rated all job titles for workers at that site. Finally, the data were critically examined in three spheres: validity, agreement and sureness. A comparison of similar exposure groups for hazardous noise as defined by the expert assessors, with known outcomes of 1995 hearing tests was performed. Secondly, the agreement between the rating done by the expert assessor group and the rating done by the job holder was examined, resulting in fair to moderate agreement (Kappa scores of 0.31, 0.41 and 0.44). When there was disagreement, most often the expert assessors identified a hazardous exposure which the job holder did not, resulting in most errors falling on the more protective rather than less protective side.

Consideration was given to the sureness expressed by each of the rating groups about the analysis they provided. Similar exposure groups across a geographically and functionally diverse industry were identified so that hygiene, safety and medical surveillance initiatives could be appropriately targeted.

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FUZZY INDUSTRIAL HYGIENE. J. Jankovic, Oak Ridge National Laboratory, Oak Ridge, TN.

A fuzzy number represents a range of possible values and as such has a possibility or belief associ-

ated with it. Fuzzy numbers, just as fuzzy logic, has its origin in fuzzy set theory developed in the 1960s; here the similarity ends. Fuzzy numbers describe uncertain quantities in terms of belief, "best guess," or professional judgment. Hazard assessments made by industrial hygienists are often constructed of just such uncertainties. Difficulties sometimes arise when "bottom line" people just want the number. Fuzzy number analysis provides an approach when hard numbers are not available. This is accomplished by mathematically combining uncertain numbers to produce a belief graph which looks statistical in nature. However, it is not; it is biased towards what one believes most strongly. Two applications involving possible contaminant generation and exposure are developed which demonstrate the process. A third application is provided which is associated with asbestos quantification from bulk samples in which the asbestos amount in the matrix is believed to be small, i.e., in the 1% region. This last example is added to demonstrate the wide ranging applications possible using the fuzzy analysis process.

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A BERYLLIUM SURFACE CONTAMINATION RISK ASSESSMENT METHODOLOGY. J. Jankovic, C. Wilson, Oak Ridge National Laboratory, Oak Ridge, TN.

The process the industrial hygiene group at Oak Ridge National Laboratory is using to find and evaluate the potential risk of "legacy" beryllium possibly remaining from post WWII nuclear technology development is presented. The first step in the process is to identify facilities where beryllium was used by reviewing historical records, equipment designations, and the institutional memory of employees. The second step in the assessment is to find the beryllium. A statistical sampling protocol using the binomial distribution was developed to estimate the number of samples needed to have a 95% probability of finding a positive surface if existing. A length by width grid system is applied to each area with sets of coordinates drawn at random to match the sample number requirement. Each sample grid surface is wiped using an inexpensive beryllium colorimetric screening test (BCST). Areas returning positive results for beryllium on surfaces are risk categorized by using a specialized surface sampling system that measures the resuspension potential of the beryllium in terms of predicted air concentration. Category 0 represents no resuspension potential, category 1 represents a resuspension potential < OEL, and category 2 represents a resuspension level \geq OEL. Category classification is used to establish administrative controls as well as remediation priorities.

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OXYGEN DEFICIENCY HAZARD ASSESSMENT AT THE SPALLATION NEUTRON SOURCE. J. Jankovic, R. Cornwell, Oak Ridge National Laboratory, Oak Ridge, TN.

Oak Ridge's linear accelerator portion (LINAC) of the spallation neutron source (SNS) is superconducting in order to enhance beam output and reduce energy operating costs. Helium cryogenic cooling requires a large inventory, a substantial portion of which is circulating in the limited space of the LINAC tunnel. Large inventory coupled with an expansion ratio of approximately 754:1, going from liquid to gas, makes the potential for oxygen deficiency a primary concern during non-beam periods when the tunnel may be occupied. At SNS a hazard

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ABSTRACTS