and measurement procedures. Field strength meters can have large calibration errors if calibration has been established at or near the frequencies of the RF sources being surveyed. In addition, worker exposures can be underestimated if field direction is not measured. As the present time, little work has been performed on issues related to RF protective clothing, RF burns, ergonomic hazards, or fall protection equipment.

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A MANUAL OF METHODS FOR MEASURING OCCUPATIONAL EMF EXPOSURES. J.D. Bowman, NIOSH, Cincinnati, OH; M.A. Kelsh, Environmental Health Strategies, Inc., Menlo Park, CA

Methods for measuring exposures to electric and magnetic fields (EMF) have evolved rapidly, involving new study designs, instruments, and applications to a wide range of work environments. To assist industrial hygienists and researchers, NIOSH is developing a manual that makes successful methods for assessing EMF exposure more widely available. This project is an extension of NIOSH's decades-long program to publish exposure assessment methods for gases, vapors, and aerosols in the *Manual of Analytical Methods*. Although this predecessor publication has a single validated method for each agent, the EMF manual will contain different protocols that have been used successfully to measure a particular exposure metric. This kind of manual is needed because no single EMF method can meet all research and monitoring needs, given the uncertainty about possible health effects and the relevant exposure metric. Investigators can use this manual as a tool to develop new protocols for their particular needs. Like the *Manual of Analytical Methods*, the EMF manual will consist of self-contained protocols published in a loose-leaf binder so that new methods can be added in future editions. Each method consists of the detailed instructions preceded by a summary table in a standard format to facilitate comparisons between different methods. The methods collected for the first edition include personal monitoring of extremely low frequency EMF, magnetic field characterization in manufacturing, area measurements of static magnetic fields, and spot measurement surveys. The first edition also contains techniques for quality control, calibration, and calculation of other exposure metrics. The manual is designed to be a reliable reference with application to a wide variety of occupational and environmental exposure assessments.

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ASSESSMENT OF ELF MAGNETIC FIELD EXPOSURE PATTERNS BY FREQUENCY-DOMAIN ANALYSIS OF EXPOSURE TIME SERIES. G. J. Mihlan, L. Todd, K.N. Truong, University of North Carolina, Chapel Hill, NC

An exploratory analysis of exposure patterns was conducted in 113 electric utility workers employed as electricians, cable splicers, line workers, and power plant operators. The purpose of the study was to describe extremely low frequency (ELF) magnetic field exposure pattern characteristics of electric utility workers and evaluate strategies for classifying occupational exposures based on summary exposure measures and exposure pattern characteristics.

The exposure of each study sample was described using the workday TWA, coefficient of variation (CV) of the exposure time series, and the exposure pattern characteristics defined by frequency-domain analysis of the exposure time series. Samples were classified into exposure groups using grouping strategies based on occupation, quartiles of the TWA and CV, and cluster analysis of the exposure pattern characteristics. Rules for grouping samples based on their exposure pattern characteristics were determined using linear discriminant analysis with a cross validation study design to evaluate the performance of the discriminant function. The efficiency of each grouping strategy was evaluated using a multivariate analysis of variance test of the exposure pattern characteristics and a univariate analysis of variance test of the sample workday TWA and CV.

Exposure patterns appeared unrelated to grouping strategies based on quartiles of the workday TWA and CV. The cluster grouping strategy proved efficient in grouping samples based on exposure pattern characteristics, producing low misclassification error rates (10%) compared with occupation (50%), CV (67%), and TWA (69%) groups. Significant differences in exposure patterns were observed between clusters and between occupational groups, indicating that at least one of the spectral estimates in two of the groups were significantly different (p-value <0.05). However, the clusters produced the greatest contrast in exposure patterns of all grouping strategies, explaining 83% of the total variation in exposure patterns compared with 35% of the total variation explained by the occupation.

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EXPLORATION OF ELECTROSTATIC PRECIPITATION FOR BIOAEROSOL COLLECTION. G. Mainelis, K. Willeke, S. Grinshpun, T. Reponen, University of Cincinnati, Cincinnati, OH; P. Hintz, NIOSH, Morgantown, WV

Commonly used bioaerosol sampling mechanisms, such as impaction and impingement, are known to impart significant stress on microorganisms during the collection process. For quantitative exposure assessments in outdoor and indoor environments, bioaerosol collection methods with low microbial injury rates are desired. By imposing a small electrical charge on the bioaerosol particles and then exposing them to an electric field, the particles can be gently collected on a collection medium.

In our experiments we used a modified electrostatic aerosol sampler (EAS) (model 3100, TSI Inc., St. Paul, MN) to collect the airborne microorganisms by electrostatic forces. This sampler, originally designed to collect biologically inert particles, was modified to hold an insertable collection trough. The experiments were performed with three types of airborne microorganisms, including one biochemically similar to *Mycobacterium tuberculosis*. Agar, water, and a filter were used as collection media.

The physical collection efficiency of the sampler exceeded 80% for all three collection media and for all three microorganisms. The biological efficiency of this modified sampler was found to be greatly dependent on microorganism and collection medium used. When collected on a filter inside the EAS and then transferred to a nutrient medium, more than 90% of *Bacillus subtilis* spores, but only a few percent of sensitive *Pseudomonas fluorescens* bacteria were cultured. The microbial recovery of spores was also found to be significant, when collecting onto agar or into water.

We conclude that the modified EAS can be used to enumerate culturable airborne bacteria. However, to optimize this technique for the collection of a wide range of bioaerosol particles, including very sensitive ones, the electrostatic and other sampling parameters need to be optimized in a new electrostatic bioaerosol sampler.

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INDIVIDUAL RISK FACTORS IN THE DEVELOPMENT OF NOISE-INDUCED HEARING LOSS; THE APPLICATION OF DATABASE AND EXPERT PROGRAM NOISESCAN. J. Starck, E. Toppila, Finnish Institute of Occupational Health, Vantaa, Finland; I. Pyykkö , R. Kaksonen, H. Ishizaki, Karolinska Sjukhuset, Stockholm, Sweden

To test and further develop our hearing conservation program (NoiseScan), we have analyzed the development of noise-induced hearing loss and various risk factors among 684 subjects consisting of forest work, shipyard work, and paper mill work. The occupational histories and noise exposures of each worker were retrieved from database and completed by hygienic noise-exposure measurements. The measurements were taken to analyze the A-weighted noise exposure level, impulsiveness of noise, and the real protection efficiency of hearing protectors. Impulsiveness was defined by the crest factor method and the protection efficiency of hearing protectors in situ by the measurements with a miniature microphone inside the hearing protector. The usage rate of hearing protectors were included in the calculation of the total noise exposure level entering the ear. When applying the exposure data to the present ISO 1999 standard model, 26% of the observed variation in the hearing levels could be explained. The rate of explanation was increased by the analyses of the individual risk factors such as elevated blood pressure and cholesterol, presence of vibration induced white finger, and other exposures as smoking habits and usage of pain killers. When considering their separate and combined effects to the development of hearing loss, the rate of explanation in observed variation of hearing levels could be increased up to 50%. Although aging is regarded as a significant factor, our results suggest that it is due to the strong dependency between risk factors and age. The results comprised the background for the establishment of NoiseScan database and expert program to predict the development of hearing loss for individual worker.

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COMBINING JUDGMENTAL AND QUANTITATIVE EXPOSURE RECONSTRUCTIONS. N.A. Esmen, T.A. Hall, University of Oklahoma Health Sciences Center, Oklahoma City, OK

Abstracts

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