ence range of <0.1 milligrams per liter (mg/L), which suggests that the internal dose to toluene was low. Also, two workers from one region and three from the other had detectable MEK concentrations in their urine that were all an order of magnitude below the American Conference of Governmental Industrial Hygienists Biological Exposure Index (ACGIH BEI™) of 2 mg/L, but above the reference range of <0.1 mg/L for unexposed populations. Overall, the PBZ and urine samples suggest a very low level of VOC and element exposure from tree-marking operations. These sampling results indicated that the only individual compounds that a tree-marker might have been exposed to in detectable concentrations during these surveys and that have a slight but potential, association to reproductive health effects were MEK, toluene, and manganese. All the measured exposures were well below any current occupational exposure limits, but the relevant occupational exposure limits are not based on reproductive effects. Reproductive systems are quite sensitive, and even very low paint exposure could not be completely dismissed as a possible contributor to reproductive health effects, if any association is documented by the epidemiologic study.

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POLYCHLORINATED DIBENZO-P-DIOXIN AND FURAN SURFACE CONTAMINATION AND CHLOROFORM EMISSIONS AT A PAPER MANUFACTURER. K. Hanley, R. Mouradian, M. Kiefer, NIOSH, Cincinnati, OH

The National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation to assess employee exposures to polychlorinated dibenzo-p-dioxin and furan (PCDD/F) congeners, and chlorinated volatile organic compounds (CVOCs) formed as by-products during wood pulp bleaching. The survey included environmental monitoring for PCDD/F surface contamination and air monitoring for CVOCs.

Surface wipe samples were collected and analyzed for the 2,3,7,8-tetra PCDD/F isomers as well as total tetra-chlorinated through octachlorinated PCDD/F isomers. The PCDD/F concentrations are reported as 2,3,7,8-TCDD toxicity equivalents (I-TEQ) using the 1989 International Toxicity Equivalency Factors. The I-TEQ levels from the wipe samples ranged from 13 to 651 picograms per square meter (pg/m^2) in the bleach plant and from 86 to 1049 pg/m^2 in the paper mill. The highest PCDD/F contamination was obtained near the dry end of a paper machine and on a hardwood bleaching rinse tank. Surface wipe samples confirmed the potential for workers to be exposed to low levels of PCDD/F. However, all I-TEQ concentrations were well below the National Research Council guidelines of 25,000 pg/m^2 for PCDD/F surface contamination.

Area and personal breathing zone air samples were collected and analyzed for CVOCs. Mass spectroscopy analysis qualitatively identified chloroform, 1,1,1-trichloroethane, carbon tetrachloride, dibromochloromethane, and bromodichloromethane as the major compounds; these compounds were quantitatively analyzed with gas chromatography. Area concentrations of chloroform obtained near bleaching rinse tanks ranged from 1.8 milligrams per cubic meter (mg/m^3) to 116 mg/m^3 and were highest at the hypochlorite stage. Some worker exposures exceeded the NIOSH recommended exposure limit (REL) for chloroform of 10 mg/m^3. A follow-up visit was conducted to assess the impact of process changes on airborne chloroform concentrations. Chloroform levels were substantially lower, indicating that reduced use of hypochlorite during pulp bleaching was successful in lowering workers' exposures below the NIOSH REL.

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AN ALTERNATE APPROACH TO ESTIMATING THE FIT OF SINGLE USE RESPIRATORS: DEVELOPMENT OF A QUANTITATIVE FIT TESTING METHOD. J. Campbell, U. Bickis, Phoenix OHC, Inc., Kingston, Ontario, Canada

Traditional quantitative fit-testing (QNFT) methods have involved the purchase of dedicated equipment and have not been applicable for use with single use dust/mist/fume respirators. A method for QNFT single use particulate respirators was developed using equipment and materials readily available to occupational hygienists.

Subjects donned probed respirators and were exposed to a sodium chloride aerosol inside a modified fit-testing hood. Two light scattering aerosol monitors, connected to a computer and chart recorder, continuously monitored the aerosol concentration inside and outside the respirators. Using this apparatus, QNFT was conducted on 25 subjects for 2 different makes of respirators. Fit factors were determined for both of the respirators while the subjects completed activities ranging from normal breathing and talking, to the spectrum described in CSA Standard Z94.4-93.

Geometric mean fit factors determined for individuals ranged from 33 to 1654. Activities that involved facial distortions (e.g., smiling, grimacing) generally yielded lower fit factors than other tasks. In conclusion, it was demonstrated that using traditional occupational hygiene equipment, single use dust/mist/fume respirators may be quantitative fit-tested. As this study was conducted in the laboratory, the reported fit factors are higher than would be expected under workplace conditions.

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IMPLEMENTATION OF A NEGOTIATED CONSENT AGREEMENT BETWEEN THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (USEPA) AND THE REFRACTORY CERAMIC FIBER COALITION (RCFC) TO COLLECT AIRBORNE FIBER EXPOSURE DATA. E. Casey, Unifrax Corp., Amherst, NY; K. Dorman, Thermal Ceramics, Augusta, GA; J. Treadway, Premier Refractories & Chemicals, Inc., Erwin, TN

In 1993, the Refractory Ceramic Fibers Coalition (RCFC; an industry trade association) and the Environmental Protection Agency (EPA) entered into a voluntary consent agreement to assess occupational exposures to airborne fiber. Under Section 4 of the Toxic Substances Control Act (TSCA), the consent agreement was implemented to provide data to assist in the assessment of occupational exposures to refractory ceramic fiber (RCF) both within primary manufacturing and end-user facilities. A major component of the consent agreement was continuation of a comprehensive product stewardship program (PSP) which commenced prior to the signing of the consent agreement. The PSP involves seven key elements: health effects research, workplace monitoring, exposure assessments, communications, product research, special studies, and study of workplace controls. To date, the RCFC has provided data to the EPA involving hundreds of workplace monitoring samples from RCFC manufacturing and end-user facilities. Following the conclusion of the 3rd year of the consent agreement, 90% of airborne fiber samples fell below the 1.0 f/cc 8-hr time weighted average (TWA) industry sponsored recommended exposure guideline (REG). To date, the PSP has shown significant progress in assessing and reducing occupational exposures to RCF.

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AN EXPOSURE ASSESSMENT SURVEY OF AN ISOTHIAZOLINONE-BASED BIOCIDE AMONG POWER PLANT WORKERS. C. Cook, NIOSH, Cincinnati, OH

In September 1995, the National Institute for Occupational Safety and Health (NIOSH) conducted an industrial hygiene survey at a manufacturing plant to assess power plant workers' exposures to biocide containing 1.5% isothiazolinones. After isothiazolinone-based biocide was first introduced at the plant in 1987, workers reported dermatitis, skin rash, eye and upper respiratory irritation while performing maintenance duties on water cooling towers. Employees became particularly concerned about the known mutagenicity properties of the biocide.

Isothiazolinones are heterocyclic organic compounds present in several chlorinated and unchlorinated forms. Isothiazolinones are nonoxidizing antimicrobial agents that are effective against gram-positive and gram-negative bacteria, as well as fungi, yeast, algae, and legionella pneumophila. Isothiazolinones are used industrially as antibiofoulants and slimicides in metalworking fluids, paper mills, swimming pools, leather and fabric, and water cooling towers.

Sixteen personal breathing zone (PBZ) samples (13 full-shift, three 15-minute short-term) and 21 area air samples for isothiazolinones were collected. Analyses of PBZ samples revealed none-detectable levels. A 15-minute area air sample collected above a biocide storage tank measured isothiazolinone concentration of 0.92 milligrams per cubic meter (mg/m^3), exceeding a chemical manufacturer's recommended 15-minute short-term exposure limit (STEL) of 0.30 mg/m^3. A second area air sample revealed a trace concentration at an employee break area. Currently, there are no occupational exposure criteria established by NIOSH or the Occupational

Safety and Health Administration (OSHA) for isothiazolinones. NIOSH concluded a potential for short-term exposure above a manufacturer's exposure criteria of 0.30 mg/m^3. Dermal exposure to the biocide may also pose a health hazard if proper protective clothing is not worn during its use. Recommendations were made to help prevent worker exposure to the biocide during water cooling tower maintenance.

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FIELD STUDY OF THE EXPOSURE OF SANDBLASTERS USING VARIOUS ABRASIVES. C. Dion, N. Goyer, G. Perrault, Institut de Recherche en Sante et en Securite du Travail, Montreal, Quebec, Canada

Several new cases of silicosis caused by overexposure to crystalline silica are diagnosed every year in sandblasting workers. Many substitutes for crystalline silica have been proposed, but few studies have determined the concentration and composition of dust in the air during sandblasting with various abrasives on steel surfaces.

The crystalline silica content in commercial sands and that of metals in other abrasives was determined. Then, the concentration of total dust and its metallic content and respirable dust and its crystalline silica content were determined in the air of sandblasting installations with or without ventilation and at adjacent work sites. These studies were conducted for silica sands, aluminum oxide, synthetic olivine, crushed glass, glass beads, steel garnets, and steel beads. For every abrasive, the concentrations of total and respirable dust at fixed sampling stations varied between 75 mg/m^3 and 2150 mg/m^3, respectively. The concentrations of metallic elements (As, Cd, Cr, Co, Cu, Fc, Mn, Mo, Ni, P, Zn, Ba, Be, Li, V) in total dust were well below the TLV®s except for a few samples at very high concentrations of total dusts in which nickel (olivine) and lead (crushed glass) were close to or above the TLVs. Quartz concentrations were many times greater than the TLVs for sands containing 30% or 90% crystalline silica. Direct reading instruments showed a more rapid decrease in respirable dust concentrations in installations with ventilation.

It is concluded that sandblasting operations with all abrasives absolutely require ventilation and respiratory protection of the workers. However, at values below approximately 100 mg/m^3 the concentration of metallic elements is below the TLVs. It also means that the sampling strategy for workers in the sandblasting room should emphasize the measurement of respirable crystalline silica for sands, and the measurement of total dust and /or respirable dust for all other abrasives.

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ESTIMATING VALUES FOR NONDETECTABLE SAMPLES. W. Sanderson, A. Echt, L. Ewers, R. Hornung, NIOSH, Cincinnati, OH

When estimating worker exposures to a particular toxic agent, sample measurements are sometimes below the limit of detection (LOD) of the analytical method. The industrial hygienist is then challenged to select valid estimates for those samples in order to calculate an unbiased average exposure concentration. Several techniques have been proposed for estimating average concentrations from data containing nondetectable samples. These methods include a maximum likelihood statistical method and two methods involving the limit of detection. The maximum likelihood method is complex and requires laborious calculations, while the other methods involve simply substituting the LOD/2 or the LOD/square-root-of-2 for each nondetectable value. Using Monte Carlo simulation, the LOD/square-root-of-2 has been shown to provide more accurate estimates of the mean and standard deviation when the measurement data are not highly skewed, but the LOD/2 is recommended when the data are highly skewed (GSD $\geq$ 3.0).

Samples for airborne lead concentrations from bridge painters were used to evaluate these recommended values for the LOD. A total of 105 samples were collected on 37-mm polyvinyl chloride filters at a flow rate of 1 liter per minute (Lpm) and analyzed using flame atomic absorption spectroscopy (flame-AA); 25 (23.8%) of the samples were below the analytical LOD. To estimate the true concentrations on these nondetectable samples, they were reanalyzed using graphite furnace atomic absorption spectroscopy, which is a more sensitive analytical method. All 25 samples were above the LOD for the graphite furnace method, and these values were substituted for the flame-AA LOD. The geometric mean (GM) and geometric standard deviation (GSD) of all 105 samples were then compared to the GM and GSD calculated by substituting the nondetectable values with the LOD/2 and the LOD/square-root-of-2. The GM (GSD) for the measurements with the graphite furnace measurements substituted for the nondetectable values were 28.1 (7.0) micrograms/cubic meter, while the GM (GSD) with the LOD/2 and the LOD/square-root-of-2 substituted for the nondetectable samples were 29.1 (6.7) and 31.6 (6.2), respectively. This analysis supports the recommendation that substitution of nondetectable values by the LOD/2 should be used when data are highly skewed.

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EXPOSURE EVALUATION TO TOXIC AND CARCINOGENIC METALS IN NONFERROUS METAL INDUSTRY IN THE UPPER SILESIA INDUSTRIAL DISTRICT, POLAND. J. Sokal, A. Jedrzejczak, I. Stepniewska, R. Knapek, B. Krol, E. Smolik, H. Szacillo, Institute of Occupational Medicine and Environmental Health, Sosnowiec, Poland

The aim of the study was occupational exposure evaluation to toxic and carcinogenic metals in selected nonferrous plants of Katowice region, carcinogenic risk assessment related to the exposure to these metals, and interlaboratory control of air sample collection for analysis.

The study was performed in the four biggest nonferrous metal plants (coded as A, B, C, D). Air samples were collected by individual dosimeters. Detection of metals was performed by flame and flameless atomic-absorption spectrometry. Carcinogenic risk was assessed based on unit risk assigned by WHO experts. Interlaboratory examinations were carried out by the stationary method. The highest mean value of lead concentration in particular phases of technological processes exceeded twelvefold the TLV, and the highest maximum concentration at particular workplace exceeded TLV seventyfold. Only once the mean value of cadmium concentration exceeded TLV but several threefold to fourfold cases of standard exceeding were found at particular workplaces in two of four of the examined plants (B and C). Arsenic concentrations at workplaces of plants B and C ranged from 0.5 to 1.0 of TLV. Several individual results slightly exceeded TLV during lead rafination in plant C. The chromium and nickel concentrations were much lower than the TLV but carcinogenic risk estimated for these metals was higher than the accepted value. The results of the interlaboratory investigation concerning sample collections and metal analysis show differences resulting mainly from the collection of samples.

Technical and organizational activities should be undertaken to decrease the concentration of toxic and carcinogenic metals at workplaces. The assessment of exposure to metals as well as the activities aimed at prevention of the effects of exposure should be based on correlated air and biological monitoring at workplaces. The TLV for Cd, Ni, As, and CR(VI) should be corrected considering their carcinogenic effects.

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CHALLENGES AND SOLUTIONS TO AIR MONITORING OF CONFINED SPACE UNDER HYPERBARIC CONDITIONS. V. Ghetie, GOSH, Inc., Fort Lee, NJ; J.A. Rogers, REM, Inc., South Hackensack, NJ

The hyperbaric work environment (HWE) during the clean up activities at the Gowanus Canal Flushing Tunnel in Brooklyn, NY, presented two issues to be addressed prior to the project commencement: a) finding appropriate methods and instrumentation g, and b) the need for site specific action levels. On site activities consisted of complete dewatering of the tunnel and sludge removal at pressure levels of 5-8psig. The work requiredcontinuous monitoring for methane, VOC, and toxic gas/H_2S, CO, HCN. Our approach to respond to these issues was three fold. First, an alternate method to monitor the contaminants at normal pressure at the outlet of blow-off pipes was evaluated. Secondly, we tested few of the available monitoring instrumentation at different controlled pressure levels. Third, the available literature regarding medical and safety aspects relevant to HWE was reviewed and site specific exposure limits and action levels were developed. Testing at pressure levels of 2, 4, and 8psig indicated a linear response for detector tubes, for PID, and for O_2, CO, and H_2S electrolytic sensors. The LEL was not pressure dependent. It is concluded that methane, VOC, O_2, H_2S, CO can be accurately monitored under a HWE at least up to the tested level of 8psig. The alarm levels and the reading of the detector tubes should be

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