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Welding Fumes:

An Interdisciplinary Annotated Bibliography

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Welding Fumes: An Interdisciplinary Annotated Bibliography

Blade, L. M., et al. (2007). "Hexavalent chromium exposures and exposure-control technologies in American enterprise: results of a NIOSH field research study." J Occup Environ Hyg 4(8): 596-618.

The National Institute for Occupational Safety and Health (NIOSH) conducted 21 field surveys in selected industries to characterize workers' exposures to hexavalent chromium-containing airborne particulate and to evaluate existing technologies for controlling these exposures. Hexavalent chromium Cr(VI) is a respiratory irritant and chronic inhalation may cause lung cancer. Primary evaluation methods included collection of full work shift, personal breathing-zone (PBZ) air samples for Cr(VI), measurement of ventilation system parameters, and documentation of processes and work practices. This study emphasized evaluation of engineering exposure control measures, so PBZ exposures were measured on the outside of personal protective equipment, for example, respirators. Field surveys were conducted in two chromium electroplating facilities, including one where full-shift PBZ exposures to Cr(VI) ranged from 3.0 to 16 times the 1 micro g/m(3)NIOSH recommended exposure limit (REL) despite several engineering controls on the plating tanks. At a painting and coating facility that used Cr(VI)-containing products, full-shift exposures of painters and helpers (2.4 to 55 micro g/m(3)) exceeded the REL, but LEV effectiveness was limited. Other operations evaluated included welding in construction; metal cutting operations on chromium-containing materials in ship breaking; chromate-paint removal with abrasive blasting; atomized alloy-spray coating; foundry operations; printing; and the manufacture of refractory brick, colored glass, prefabricated concrete products, and treated wood products. NIOSH researchers concluded that, in many of the evaluated processes, Cr(VI) exposures at or below the current NIOSH REL are achievable. However, for some processes, it is unclear whether controlling exposures to this range is consistently achievable without respirator use. Some operations involving the application of coatings and finishes may be among those most difficult to control to this range. Most operations judged to be moderately difficult to control to this range involve joining and cutting metals with relatively high chromium content. Nonetheless, exposures in a wide variety of other processes were judged more easily controllable to the current REL or below, or were found to be minimal, including some operations meeting the general descriptions named above but with different specific operating parameters producing lower Cr(VI) exposures.

Boelter, F. W., et al. (2009). "Two-zone model application to breathing zone and area welding fume concentration data." J Occup Environ Hyg 6(5): 298-306.

This study assessed a professional pipefitter/welder performing shielded metal arc welding on carbon steel under field conditions. The resulting breathing zone (near field) and area (far field) welding fume concentration data were applied to the two-zone model for the purpose of determining field-derived personal exposure emission (generation) rates during actual welding work. The study is unique in that one welder was evaluated under high production conditions for 2 days at two different welding locations: a boiler room and a breezeway. Samples were collected and analyzed for total particulate following NIOSH Method 0500 and for select metals following NIOSH Method 7300. Breezeway average personal breathing zone sample total particulate concentrations ranged from 2.89 mg/m(3) to 4.38 mg/m(3), Fe concentrations ranged from 0.53 to 0.63 mg/m(3), and Mn concentrations ranged from 0.10 to 0.12 mg/m(3). The boiler room average personal breathing zone sample total particulate concentrations ranged from 4.73 mg/m(3) to 5.90 mg/m(3), Fe concentrations ranged from 0.48 to 0.85 mg/m(3), and Mn concentrations ranged from 0.06 to 0.16 mg/m(3). Average arc times ranged from 20 to 25% of the total sampling time. Both tracer gas and anemometer techniques were used to estimate ventilation of the boiler room. The steady-state form of the two-

zone model was applied to long-term and short-term sample total particulate, Fe, and Mn concentrations obtained during welding in the boiler room and breezeway. The average generation rate in the boiler room was 39.2 mg/min for TP, 6.4 mg/min for Fe, and 1.3 mg/min for Mn. The average generation rate in the breezeway was 40.0 mg/min for TP, 6.6 mg/min for Fe, and 1.2 mg/min for Mn. The field-based generation rates were considerably lower than laboratory-derived published emission rates of between 280 and 650 mg/min for TP. This study emphasizes the need for field-derived welding fume generation rates and showed the personal breathing zone and area sample concentrations can be described by the two-zone model in a way that may help the industrial hygienist estimate exposures. [Supplementary materials are available for this article. Go to the publisher's online edition of the Journal of Occupational and Environmental Hygiene for the following free supplemental resource: Tables detailing the personal breathing zone and average area sample results for breezeway welding and boiler room welding, two-zone modeling results, and boiler room welding personal breathing zone and area sample results with mixing fans on.].

Bowler, R. M., et al. (2011). "Prospective study on neurotoxic effects in manganese-exposed bridge construction welders." Neurotoxicology 32(5): 596-605.

BACKGROUND: In a group of 43 confined space welders dose-effect relationships had been identified for adverse neurological/neuropsychological functional effects in relation to manganese (Mn) in blood or air (cumulative exposure index). The welders' exposure to Mn was unprotected and with poor ventilation, lasting on average 16.5 months. A follow-up examination 3.5 years later, after cessation of confined space welding, was carried out to re-assess the status of mood, movement/neuromotor and cognitive functions, and olfaction. METHODS: In 2008, 26 welders (70% response rate) were retested using a similar methodology as at baseline (Bowler et al., 2007). A general linear model was used to estimate individual-specific endpoint differences over time. Mean age was 47 years, mean years of education 12.4, and mean total years of welding 16.9 years. Thirteen participants no longer welded. RESULTS: At follow-up, mean blood Mn concentration had decreased from 10.0 to 8.4 mug/L (p=0.002). Those still welding had higher blood Mn than those no longer welding (9.9 mug/L vs. 6.8 mug/L, p=0.002). Several domains of cognitive functioning improved substantially as shown by large effect sizes. Emotional disturbance improved only slightly clinically, but complaints of depression and anxiety persisted. Motor dexterity/tactile function and graphomotor tremor improved significantly, while psychomotor speed remained unchanged. The findings of the neurological examination (UPDRS) did not change compared to baseline, whereas rigidity, dominant postural hand tremor and body sway worsened. Olfactory test scores remained depressed. CONCLUSION: After 3.5 years of cessation of confined space welding, only cognitive function improved significantly, while olfactory, extrapyramidal, and mood disturbances remained constant or were exacerbated. This suggests differential intrinsic vulnerabilities of the brain loci involved with Mn exposure. As the Mn exposure of the Bay Bridge welders frequently exceeded the Cal-OSHA TLV of 0.2 mg Mn/m(3) at baseline, a more stringent preventive measure is recommended for confined space welding.

Bowler, R. M., et al. (2007). "Sequelae of fume exposure in confined space welding: a neurological and neuropsychological case series." Neurotoxicology 28(2): 298-311.

Welding fume contains manganese (Mn) which is known to be bio-available to and neurotoxic for the central nervous system. Although an essential metal, Mn overexposure may cause manganism, a parkinsonian syndrome. The present welder study sought to improve the clinical portrait of manganism and to determine dose-effect relationships. The welders were employed in the construction of the new Bay Bridge (San Francisco) and welded in confined spaces for up to 2 years with minimal protection and poor ventilation. Neurological, neuropsychological, neurophysiological,

and pulmonary examinations were given to 49 welders. Clinical cases were selected on the basis of apriori defined criteria pertaining to welding history and neurological/neuropsychological features. Among the 43 eligible welders, 11 cases of manganism were identified presenting with the following symptoms: sleep disturbance, mood changes, bradykinesia, headaches, sexual dysfunction, olfaction loss, muscular rigidity, tremors, hallucinations, slurred speech, postural instability, monotonous voice, and facial masking. Significant associations between outcome variables and cumulative exposure index (CEI) or blood Mn (MnB) were obtained with CEI for variables implicating attention and concentration, working and immediate memory, cognitive flexibility, and verbal learning; and with MnB for executive function, cognitive flexibility, visuo-spatial construction ability, and visual contrast sensitivity. This study strongly suggests that neuropsychological features contribute in a dose-effect related way to the portrait of manganism usually characterized by tremor, loss in balance, diminished cognitive performance, and signs and symptoms of parkinsonism.

Bowler, R. M., et al. (2007). "Dose-effect relationships between manganese exposure and neurological, neuropsychological and pulmonary function in confined space bridge welders." Occup Environ Med 64(3): 167-177.

BACKGROUND: Although adverse neuropsychological and neurological health effects are well known among workers with high manganese (Mn) exposures in mining, ore-processing and ferroalloy production, the risks among welders with lower exposures are less well understood. METHODS: Confined space welding in construction of a new span of the San Francisco-Oakland Bay Bridge without adequate protection was studied using a multidisciplinary method to identify the dose-effect relationship between adverse health effects and Mn in air or whole blood. Bridge welders (n = 43) with little or no personal protection equipment and exposed to a welding fume containing Mn, were administered neurological, neuropsychological, neurophysiological and pulmonary tests. Outcome variables were analysed in relation to whole blood Mn (MnB) and a Cumulative Exposure Index (CEI) based on Mn-air, duration and type of welding. Welders performed a mean of 16.5 months of welding on the bridge, were on average 43.8 years of age and had on average 12.6 years of education. RESULTS: The mean time weighted average of Mn-air ranged from 0.11-0.46 mg/m(3) (55% >0.20 mg/m(3)). MnB >10 microg/l was found in 43% of the workers, but the concentrations of Mn in urine, lead in blood and copper and iron in plasma were normal. Forced expiratory volume at 1s: forced vital capacity ratios (FEV(1)/FVC) were found to be abnormal in 33.3% of the welders after about 1.5 years of welding at the bridge. Mean scores of bradykinesia and Unified Parkinson Disease Rating Scale exceeded 4 and 6, respectively. Computer assisted tremor analysis system hand tremor and body sway tests, and University of Pennsylvania Smell Identification Test showed impairment in 38.5/61.5, 51.4 and 88% of the welders, respectively. Significant inverse dose-effect relationships with CEI and/or MnB were found for IQ ($p<or=0.05$), executive function ($p<or=0.03$), sustaining concentration and sequencing ($p<or=0.04$), verbal learning ($p<or=0.01$), working ($p<or=0.04$) and immediate memory ($p<or=0.02$), even when adjusted for demographics and years of welding before Bay Bridge. Symptoms reported by the welders while working were: tremors (41.9%); numbness (60.5%); excessive fatigue (65.1%); sleep disturbance (79.1%); sexual dysfunction (58.1%); toxic hallucinations (18.6%); depression (53.5%); and anxiety (39.5%). Dose-effect associations between CEI and sexual function ($p<0.05$), fatigue ($p<0.05$), depression ($p<0.01$) and headache ($p<0.05$) were statistically significant. CONCLUSIONS: Confined space welding was shown to be associated with neurological, neuropsychological and pulmonary adverse health effects. A careful enquiry of occupational histories is recommended for all welders presenting with neurological or pulmonary complaints, and a more stringent prevention strategy should be considered for Mn exposure due to inhalation of welding fume.

Calvert, G. M., et al. (2012). "Lung cancer risk among construction workers in California, 1988-2007." Am J Ind Med 55(5): 412-422.

BACKGROUND: Although lung cancer risks can vary by race/ethnicity and by construction occupation, these risks have not been examined extensively. METHODS: This study analyzed 110,937 lung cancer cases identified from the California Cancer Registry between 1988 and 2007. Mean age at diagnosis, proportion diagnosed at an advanced stage, and proportion with 3-year survival were calculated for lung cancer cases employed in the construction industry. Case-control methodology was also used to assess the risk of lung cancer. Morbidity odds ratios (MORs) were estimated by conditional logistic regression. RESULTS: Construction workers were found to have a significantly elevated risk for all lung cancer combined (MOR = 1.57) and for each lung cancer histologic subtype examined. All construction occupations, except managers/engineers and supervisors, had a significantly elevated risk for all lung cancer combined. Roofers and welders had the highest risks for total lung cancer and for each of the histologic subtypes. Construction workers in each of the four race/ethnicity groups also had significantly increased lung cancer risks. Compared to non-construction workers, construction workers were diagnosed at an earlier age, at a more advanced stage, and had significantly lower 3-year survival, though differences were modest. CONCLUSION: These findings justify additional reductions in carcinogenic exposures in construction, and increased support for smoking cessation programs at construction sites.

Cavallari, J. M., et al. (2007). "Night heart rate variability and particulate exposures among boilermaker construction workers." Environ Health Perspect 115(7): 1046-1051.

BACKGROUND: Although studies have documented the association between heart rate variability (HRV) and ambient particulate exposures, the association between HRV, especially at night, and metal-rich, occupational particulate exposures remains unclear. OBJECTIVE: Our goal in this study was to investigate the association between long-duration HRV, including nighttime HRV, and occupational PM(2.5) exposures. METHODS: We used 24-hr ambulatory electrocardiograms (ECGs) to monitor 36 male boilermaker welders (mean age of 41 years) over a workday and nonworkday. ECGs were analyzed for HRV in the time domain; rMSSD (square root of the mean squared differences of successive intervals), SDNN (SD of normal-to-normal intervals over entire recording), and SDNN(i) (SDNN for all 5-min segments) were summarized over 24-hr, day (0730-2130 hours), and night (0000-0700 hours) periods. PM(2.5) (particulate matter with an aerodynamic diameter </= 2.5 microm) exposures were monitored over the workday, and 8-hr time-weighted average concentrations were calculated. We used linear regression to assess the associations between HRV and workday particulate exposures. Matched measurements from a nonworkday were used to control for individual cardiac risk factors. RESULTS: Mean (+/- SD) PM(2.5) exposure was 0.73 +/- 0.50 mg/m(3) and ranged from 0.04 to 2.70 mg/m(3). We observed a consistent inverse exposure-response relationship, with a decrease in all HRV measures with increased PM(2.5) exposure. However, the decrease was most pronounced at night, where a 1-mg/m(3) increase in PM(2.5) was associated with a change of -8.32 [95% confidence interval (CI), -16.29 to -0.35] msec nighttime rMSSD, -14.77 (95% CI, -31.52 to 1.97) msec nighttime SDNN, and -8.37 (95% CI, -17.93 to 1.20) msec nighttime SDNN(i), after adjusting for nonworking nighttime HRV, age, and smoking. CONCLUSION: Metal-rich particulate exposures were associated with decreased long-duration HRV, especially at night. Further research is needed to elucidate which particulate metal constituent is responsible for decreased HRV.

Cavallari, J. M., et al. (2008). "PM2.5 metal exposures and nocturnal heart rate variability: a panel study of boilermaker construction workers." Environ Health 7: 36.

BACKGROUND: To better understand the mechanism(s) of particulate matter (PM) associated cardiovascular effects, research priorities include identifying the responsible PM characteristics.

Evidence suggests that metals play a role in the cardiotoxicity of fine PM (PM2.5) and in exposure-related decreases in heart rate variability (HRV). We examined the association between daytime exposure to the metal content of PM2.5 and night HRV in a panel study of boilermaker construction workers exposed to metal-rich welding fumes. METHODS: Twenty-six male workers were monitored by ambulatory electrocardiogram (ECG) on a workday while exposed to welding fume and a non-workday (baseline). From the ECG, rMSSD (square root of the mean squared differences of successive intervals) was summarized over the night (0:00-7:00). Workday, gravimetric PM2.5 samples were analyzed by x-ray fluorescence to determine metal content. We used linear mixed effects models to assess the associations between night rMSSD and PM2.5 metal exposures both with and without adjustment for total PM2.5. Matched ECG measurements from the non-workday were used to control for individual cardiac risk factors and models were also adjusted for smoking status. To address collinearity between PM2.5 and metal content, we used a two-step approach that treated the residuals from linear regression models of each metal on PM2.5 as surrogates for the differential effects of metal exposures in models for night rMSSD. RESULTS: The median PM2.5 exposure was 650 microg/m3; median metal exposures for iron, manganese, aluminum, copper, zinc, chromium, lead, and nickel ranged from 226 microg/m3 to non-detectable. We found inverse linear associations in exposure-response models with increased metal exposures associated with decreased night rMSSD. A statistically significant association for manganese was observed, with a decline of 0.130 msec (95% CI: -0.162, -0.098) in night rMSSD for every 1 microg/m3 increase in manganese. However, even after adjusting for individual metals, increases in total PM2.5 exposures were associated with declines in night rMSSD. CONCLUSION: These results support the cardiotoxicity of PM2.5 metal exposures, specifically manganese. However the metal component alone did not account for the observed declines in night HRV. Therefore, results suggest the importance of other PM elemental components.

Cavallari, J. M., et al. (2008). "Time course of heart rate variability decline following particulate matter exposures in an occupational cohort." Inhal Toxicol 20(4): 415-422.

Although research suggests that particles influence cardiac autonomic response as evidenced by decreases in heart rate variability (HRV), the time course of the response remains unclear. Using a crossover panel study, we monitored 36 male boilermaker welders, occupationally exposed to metal-rich particulate matter (PM) to investigate the temporal trend of hourly HRV subsequent to PM exposure. Ambulatory electrocardiograms were collected over work (exposure) and non-work (control) periods and the mean of the standard deviations of all normal-to-normal intervals for all 5-min segments (SDNN(i)) was calculated hourly for up to 14-hrs post-work. The exposure-response relationship was examined with linear mixed effects regression models to account for participants monitored over multiple occasions. Models were adjusted for non-work HRV to control for diurnal fluctuations and individual predictors of HRV. The mean (SD) work PM(2. 5) concentration was 1.12 (0.76) mg/m(3). Hourly SDNN(i) was consistently lower post-work as compared to the same time period on a non-work day. HRV was inversely associated with work PM(2. 5) exposures in each of the 14-hrs post-work. The hourly associations suggested an early and later phase response, with the largest regression coefficients observed 2-3 hrs (beta = -6.86 (95% CI: -11.91, -1.81) msec/1 mg/m(3) at 3-hrs), and then 9-13 hrs (beta = -8.60 (95% CI: -17.45, 0.24) msec/1 mg/m(3) at 11-hrs), after adjusting for non-work HRV, smoking status, and age. This investigation demonstrates declines in HRV for up to 14 hours following PM exposure and a multiphase cardiovascular autonomic response with immediate (2 hrs) and delayed (9-13 hrs) responses.

Cavallari, J. M., et al. (2010). "Circadian variation of heart rate variability among welders." Occup Environ Med 67(10): 717-719.

OBJECTIVE: To compare the circadian variation of hourly heart rate variability (HRV) on work and non-workdays among boilermaker construction workers. METHOD: A panel study of 18 males monitored by 24-h ambulatory ECG over 44 observation-days on paired work and non-workdays was conducted. ECGs were analysed and the SD of normal-to-normal beats index (SDNN(i)) was calculated from 5-min data and summarised hourly. SDNN(i)s over work and non-workdays were compared using linear mixed-effects models to account for repeated measures and harmonic regression to account for circadian variation. RESULTS: Both work and non-work hourly HRV exhibited circadian variation with an increase in the evening and a decrease in the afternoon. SDNN(i) was lower on workdays as compared with non-workdays with the largest, statistically significant differences observed between 10:00 and 16:00, during active working. Lower SDNN(i), albeit smaller yet statistically significant differences, was also observed in the evening hours following work (17:00-21:00) and early morning (4:00). In regression models using all time periods, an average workday SDNN(i) was 8.1 ms (95% CI -9.8 to -6.3) lower than non-workday SDNN(i). The circadian pattern of HRV exhibited two peaks which differed on work and non-workdays. CONCLUSION: While workday and non-workday HRV followed a circadian pattern, decreased HRV and variation of the circadian pattern were observed on workdays. Declines and changes in the circadian pattern of HRV is a concern among this exposed population.

Chen, J. C., et al. (2006). "Personal coronary risk profiles modify autonomic nervous system responses to air pollution." J Occup Environ Med 48(11): 1133-1142.

OBJECTIVE: We investigated whether PM2.5-mediated autonomic modulation depends on individual coronary risk profiles. METHODS: Five-minute average heart rate (HR) and heart rate variability (HRV, including standard deviation of normal-to-normal intervals [SDNN], square root of the mean squared differences of successive NN intervals [rMSSD], high frequency [HF]) were measured from 24-hour ambulatory electrocardiograms, and personal PM(2.5) exposures were monitored in a prospective study of 10 male boilermakers (aged 34.3 +/- 8.1 years). We used the Framingham score to classify individuals into low (score = 1-3) and high (score = 5-6) risk categories. Mixed-effect models were used for statistical analyses. RESULTS: Each 1-mg/m(3) increase in the preceding 4-hour moving average PM(2.5) was associated with HR increase (5.3 beats/min) and HRV reduction (11.7%, confidence interval [CI] = 6.2-17.1% for SDNN; 11.1%, CI = 3.1-19.1% for rMSSD; 16.6%, CI = 1.5-31.7% for HF). Greater responses (2- to 4-fold differences) were observed in high-risk subjects than in low-risk subjects. CONCLUSIONS: Our study suggests that adverse autonomic responses to metal particulate are aggravated in workers with higher coronary risk profiles.

Dement, J. M., et al. (2010). "Airways obstruction among older construction and trade workers at Department of Energy nuclear sites." Am J Ind Med 53(3): 224-240.

BACKGROUND: A study of chronic obstructive pulmonary disease (COPD) among 7,579 current and former workers participating in medical screening programs at Department of Energy (DOE) nuclear weapons facilities through September 2008 was undertaken. METHODS: Participants provided a detailed work and exposure history and underwent a respiratory examination that included a respiratory history, respiratory symptoms, a posterior-anterior (P-A) chest radiograph classified by International Labour Office (ILO) criteria, and spirometry. Statistical models were developed to generate group-level exposure estimates that were used in multivariate logistic regression analyses to explore the risk of COPD in relation to exposures to asbestos, silica, cement dust, welding, paints, solvents, and dusts/fumes from paint removal. Risk for COPD in the study population was compared to risk for COPD in the general US population as determined in National Health and Nutrition Examination Survey (NHANES III). RESULTS: The age-standardized prevalence ratio of COPD among DOE workers compared to all NHANES III data was 1.3. Internal analyses found the odds ratio of COPD to range from 1.6 to 3.1 by trade after adjustment for age, race, sex, smoking, and duration of DOE employment.

Statistically significant associations were observed for COPD and exposures to asbestos, silica, welding, cement dusts, and some tasks associated with exposures to paints, solvents, and removal of paints. CONCLUSIONS: Our study of construction workers employed at DOE sites demonstrated increased COPD risk due to occupational exposures and was able to identify specific exposures increasing risk. This study provides additional support for prevention of both smoking and occupational exposures to reduce the burden of COPD among construction workers.

Fethke, N. B., et al. (2016). "Reduction of Biomechanical and Welding Fume Exposures in Stud Welding." Ann Occup Hyg 60(3): 387-401.

The welding of shear stud connectors to structural steel in construction requires a prolonged stooped posture that exposes ironworkers to biomechanical and welding fume hazards. In this study, biomechanical and welding fume exposures during stud welding using conventional methods were compared to exposures associated with use of a prototype system that allowed participants to weld from an upright position. The effect of base material (i.e. bare structural beam versus galvanized decking) on welding fume concentration (particle number and mass), particle size distribution, and particle composition was also explored. Thirty participants completed a series of stud welding simulations in a local apprenticeship training facility. Use of the upright system was associated with substantial reductions in trunk inclination and the activity levels of several muscle groups. Inhalable mass concentrations of welding fume (averaged over ~18 min) when using conventional methods were high (18.2 mg m(-3) for bare beam; 65.7 mg m(-3) for through deck), with estimated mass concentrations of iron (7.8 mg m(-3) for bare beam; 15.8 mg m(-3) for through deck), zinc (0.2 mg m(-3) for bare beam; 15.8 mg m(-3) for through deck), and manganese (0.9 mg m(-3) for bare beam; 1.5 mg m(-3) for through deck) often exceeding the American Conference of Governmental Industrial Hygienists Threshold Limit Values (TLVs). Number and mass concentrations were substantially reduced when using the upright system, although the total inhalable mass concentration remained above the TLV when welding through decking. The average diameters of the welding fume particles for both bare beam (31+/-17 nm) through deck conditions (34+/-34 nm) and the chemical composition of the particles indicated the presence of metallic nanoparticles. Stud welding exposes ironworkers to potentially high levels of biomechanical loading (primarily to the low back) and welding fume. The upright system used in this study improved exposure levels during stud welding simulations, but further development is needed before field deployment is possible.

Flynn, M. R. and P. Susi (2009). "Neurological risks associated with manganese exposure from welding operations--a literature review." Int J Hyg Environ Health 212(5): 459-469.

Exposure to manganese dusts and fumes may cause a clinical neurological syndrome called manganism. Welders are frequently exposed to manganese-containing fumes generated by electric arcs and thermal torches. This paper reviews studies on the association between exposure to such welding fumes and neurological disease. Using the IRSST expert panel criteria, 78 cases of probable/possible, and 19 additional cases of possible occupational manganism were identified in the literature among manganese-exposed workers involved in welding processes. Epidemiological evidence linking welding exposures to Parkinson's disease is still controversial. Although more research is needed to clarify the risks of neurological impairment from welding, control measures including ventilation and adequate respiratory protection, should be implemented to minimize welding fume exposures. The significance of fume transport into the central nervous system via the olfactory nerve, which by-passes the blood-brain barrier, also needs to be assessed.

Flynn, M. R. and P. Susi (2010). "Manganese, iron, and total particulate exposures to welders." J Occup Environ Hyg 7(2): 115-126.

Welders are exposed to a variety of metal fumes, including manganese, that may elevate the risk for neurological disease. This study examines several large data sets to characterize manganese, iron, and total particulate mass exposures resulting from welding operations. The data sets contained covariates for a variety of exposure modifiers, including the presence of ventilation, the degree of confinement, and the location of the personal sampler (i.e., behind or in front of the welding helmet). The analysis suggests that exposures to manganese are frequently at or above the current ACGIH(R) threshold limit value of 0.2 mg/m(3). In addition, there is evidence that local exhaust ventilation can control the exposures to manganese and total fume but that mechanical ventilation may not. The data suggest that higher exposures are associated with a greater degree of enclosure, particularly when local exhaust ventilation is absent. Samples taken behind the helmet were, in general, lower than those measured outside of it. There were strong correlations among manganese, iron, and total particulate mass exposures, suggesting simple equations to estimate one fume component from any of the others.

Flynn, M. R. and P. Susi (2010). "Modeling mixed exposures: an application to welding fumes in the construction trades." Stochastic Environmental Research and Risk Assessment 24(3): 377-388.

Workers are often exposed to mixtures of airborne contaminants which may complicate health studies, risk assessments, and epidemiological investigations. In situations where these mixed exposures are correlated, multivariate probability distributions may serve as models suitable for description and subsequent inference. This paper presents a methodology for modeling correlated mixed exposures using the Johnson system of multivariate probability distributions. This system involves transformations to normality and includes the multivariate normal and lognormal distributions, among others. The technique is illustrated with manganese exposures for pipefitters and boilermakers conditioned upon a measurement of total particulate exposure. Applications involving compliance and risk assessment for mixed exposure problems are presented using the fitted distributions.

Flynn, M. R. and P. Susi (2012). "Local exhaust ventilation for the control of welding fumes in the construction industry--a literature review." Ann Occup Hyg 56(7): 764-776.

Arc welding is a common unit operation in the construction industry, where frequent changes in location and welding position make it more difficult to control fume exposures than in industries where fixed locations are the norm. Welders may be exposed to a variety of toxic airborne contaminants including manganese (Mn) and hexavalent chromium (CrVI). Local exhaust ventilation (LEV) is a well-known engineering control for welding fumes but has not been adopted widely in the construction industry. This literature review presents data on the performance of a variety of LEV systems for welding fume control from the construction (five references), shipyard (five references), and other industries. The studies indicate that LEV can reduce fume exposures to total particulate, Mn, and CrVI to levels below currently relevant standards. Field studies suggest that 40-50% or more reduction in exposure is possible with portable or fixed LEV systems relative to natural ventilation but that correct positioning of the hood and adequate exhaust flow rates are essential. Successful implementation of extraction guns for gas metal arc welding (GMAW) and flux core arc welding has been demonstrated, indicating that a successful balance between extraction airflow and shielding gas requirements is possible. Work practices are an important part of achieving successful control of fume exposures; in particular, positioning the hood close to the arc, checking exhaust flow rates, and avoiding the plume. Further research is needed on hood size effects for controlling welding fume with portable LEV systems and identifying and overcoming barriers to LEV use in construction.

Grashow, R., et al. (2014). "Toenail metal concentration as a biomarker of occupational welding fume exposure." J Occup Environ Hyg 11(6): 397-405.

In populations exposed to heavy metals, there are few biomarkers that capture intermediate exposure windows. We sought to determine the correlation between toenail metal concentrations and prior 12-month work activity in welders with variable, metal-rich, welding fume exposures. Forty-eight participants, recruited through a local union, provided 69 sets of toenail clippings. Union-supplied and worker-verified personal work histories were used to quantify hours welded and respirator use. Toenail samples were digested and analyzed for lead (Pb), manganese (Mn), cadmium (Cd), nickel (Ni), and arsenic (As) using ICP-MS. Spearman correlation coefficients were used to examine the correlation between toenail metal concentrations. Using mixed models to account for multiple participation times, we divided hours welded into three-month intervals and examined how weld hours correlated with log-transformed toenail Pb, Mn, Cd, Ni, and As concentrations. Highest concentrations were found for Ni, followed by Mn, Pb and As, and Cd. All the metals were significantly correlated with one another (rho range = 0.28-0.51), with the exception of Ni and As (rho = 0.20, p = 0.17). Using mixed models adjusted for age, respirator use, smoking status, and BMI, we found that Mn was associated with weld hours 7-9 months prior to clipping (p = 0.003), Pb was associated with weld hours 10-12 months prior to clipping (p = 0.03) and over the entire year (p = 0.04). Cd was associated with weld hours 10-12 months prior to clipping (p = 0.05), and also with the previous year's total hours welded (p = 0.02). The association between Ni and weld hours 7-9 months prior to clipping approached significance (p = 0.06). Toenail metal concentrations were not associated with the long-term exposure metric, years as a welder. Results suggest Mn, Pb, and Cd may have particular windows of relevant exposure that reflect work activity. In a population with variable exposure, toenails may serve as useful biomarkers for occupational metal fume exposures to Mn, Pb, and Cd during distinct periods over the year prior to sample collection.

Grashow, R., et al. (2014). "Inverse association between toenail arsenic and body mass index in a population of welders." Environ Res 131: 131-133.

Recent data show that arsenic may play a role in obesity-related diseases. However, urinary arsenic studies report an inverse association between arsenic level and body mass index (BMI). We explored whether toenail arsenic, a long-term exposure measure, was associated with BMI in 74 welders with known arsenic exposure. BMI showed significant inverse associations with toenail arsenic (p=0.01), which persisted in models adjusted for demographics, diet and work history. It is unclear whether low arsenic biomarker concentrations in high BMI subjects truly reflect lower exposures, or instead reflect internal or metabolic changes that alter arsenic metabolism and tissue deposition.

Hanley, K. W., et al. (2015). "Manganese Fractionation Using a Sequential Extraction Method to Evaluate Welders' Shielded Metal Arc Welding Exposures During Construction Projects in Oil Refineries." J Occup Environ Hyg 12(11): 774-784.

The National Institute for Occupational Safety and Health has conducted an occupational exposure assessment study of manganese (Mn) in welding fume of construction workers rebuilding tanks, piping, and process equipment at two oil refineries. The objective of this study was to evaluate exposures to different Mn fractions using a sequential extraction procedure. Seventy-two worker-days were monitored for either total or respirable Mn during stick welding and associated activities both within and outside of confined spaces. The samples were analyzed using an experimental method to separate different Mn fractions by valence states based on selective chemical solubility. The full-shift total particulate Mn time-weighted average (TWA) breathing zone concentrations ranged from 0.013-29 for soluble Mn in a mild ammonium acetate solution; from 0.26-250 for Mn(0,2+) in acetic acid; from non-detectable (ND) - 350 for Mn(3+,4+) in hydroxylamine-hydrochloride; and from ND - 39

micrograms per cubic meter (mug/m(3)) for insoluble Mn fractions in hydrochloric and nitric acid. The summation of all Mn fractions in total particulate TWA ranged from 0.52-470 mug/m(3). The range of respirable particulate Mn TWA concentrations were from 0.20-28 for soluble Mn; from 1.4-270 for Mn(0,2+); from 0.49-150 for Mn(3+,4+); from ND - 100 for insoluble Mn; and from 2.0-490 mug/m(3) for Mn (sum of fractions). For all jobs combined, total particulate TWA GM concentrations of the Mn(sum) were 99 (GSD = 3.35) and 8.7 (GSD = 3.54) mug/m(3) for workers inside and outside of confined spaces; respirable Mn also showed much higher levels for welders within confined spaces. Regardless of particle size and confined space work status, Mn(0,2+) fraction was the most abundant followed by Mn(3+,4+) fraction, typically >50% and approximately 30-40% of Mn(sum), respectively. Eighteen welders' exposures exceeded the ACGIH Threshold Limit Values for total Mn (100 mug/m(3)) and 25 exceeded the recently adopted respirable Mn TLV (20 mug/m(3)). This study shows that a welding fume exposure control and management program is warranted, especially for welding jobs in confined spaces.

Harezlak, J., et al. (2007). "Penalized solutions to functional regression problems." Comput Stat Data Anal 51(10): 4911-4925.

Recent technological advances in continuous biological monitoring and personal exposure assessment have led to the collection of subject-specific functional data. A primary goal in such studies is to assess the relationship between the functional predictors and the functional responses. The historical functional linear model (HFLM) can be used to model such dependencies of the response on the history of the predictor values. An estimation procedure for the regression coefficients that uses a variety of regularization techniques is proposed. An approximation of the regression surface relating the predictor to the outcome by a finite-dimensional basis expansion is used, followed by penalization of the coefficients of the neighboring basis functions by restricting the size of the coefficient differences to be small. Penalties based on the absolute values of the basis function coefficient differences (corresponding to the LASSO) and the squares of these differences (corresponding to the penalized spline methodology) are studied. The fits are compared using an extension of the Akaike Information Criterion that combines the error variance estimate, degrees of freedom of the fit and the norm of the bases function coefficients. The performance of the proposed methods is evaluated via simulations. The LASSO penalty applied to the linearly transformed coefficients yields sparser representations of the estimated regression surface, while the quadratic penalty provides solutions with the smallest L(2)-norm of the basis functions coefficients. Finally, the new estimation procedure is applied to the analysis of the effects of occupational particulate matter (PM) exposure on the heart rate variability (HRV) in a cohort of boilermaker workers. Results suggest that the strongest association between PM exposure and HRV in these workers occurs as a result of point exposures to the increased levels of particulate matter corresponding to smoking breaks.

Hong, O., et al. (2014). "The association between occupational exposures and cigarette smoking among operating engineers." Arch Environ Occup Health 69(3): 172-179.

The purpose of this study was to determine the relationship between occupational exposures and cigarette smoking among operating engineers. A cross-sectional survey was conducted with operating engineers (N =412) from a midwestern state in the United States. The survey included validated questions on cigarette smoking, occupational exposures, demographics, comorbidities, and health behaviors. About 35% were current smokers. Those exposed to asphalt fumes, heat stress, concrete dust, and welding fumes were less likely to smoke (odds ratio [OR] = .79, 95% confidence interval [CI]: .64-.98). Other factors associated with smoking included younger age (OR = .97, 95% CI: .94-.99), problem drinking (OR = 1.07, 95% CI: 1.03-1.12), lower Body Mass Index (OR = .95, 95% CI: .90-.99), and being separated/widowed/divorced (OR = 2.24, 95% CI: 1.19-4.20). Further investigation

is needed for better understanding about job-specific exposure patterns and their impact on cigarette smoking among operating engineers. © 2014 Taylor & Francis Group, LLC.

Hubbard, B. J. and B. Middaugh (2013). "Leveraging Bluetooth Consumer Electronics as Proximity Sensors to Construction Health Hazards." International Journal of Construction Education and Research 9(2): 117-131.

There are numerous hazards on construction sites. Significant research has focused on using advanced technologies to prevent collisions between moving construction equipment and workers. Relatively few studies have focused on advanced technologies to quantify worker exposure to long-term health hazards, such as noise, fumes, silica dust and other exposure hazards. One possible technology is wireless Bluetooth systems to quantify exposure risk. A series of tests was designed to investigate leveraging consumer Bluetooth enabled devices as a platform to determine the proximity of a construction worker to potential construction hazards. Bluetooth enabled devices were tested in controlled studies to determine the characteristics of the signal detection and signal strength. The controlled studies demonstrated the viability of estimating the distance between a Bluetooth receiver and emitting device. In a field test, the receiver system performed reasonably well and the system was able to determine when workers were within approximately 50 to 100 feet of the construction hazard. However, signal disruption between the emitter and the receiver due to obstructions was an issue. Based on this research, there is significant promise in utilizing Bluetooth to detect worker proximity to processes that represent exposure risks to long-term health hazards. © 2013 Copyright Associated Schools of Construction.

Kalil, A. J., et al. (2004). "Time variant exposure analysis (TVEA): a measurement tool for characterizing particulate exposure determinants in construction." J Occup Environ Hyg 1(12): 816-825.

A work sampling-based approach, time variant exposure analysis (TVEA), was developed for assessment of determinants for particulate air contaminants in dynamic construction environments. To use TVEA, the field researcher records observations at fixed intervals to systematically survey over 30 potential determinants that could affect exposure to three types of particulate matter: quartz-containing dusts, diesel exhaust, and a general grouping of "other particles" that includes welding fume and wood dust. Two field studies were conducted to address questions of inter-rater reliability (n = 20) and coding interval appropriateness (n = 21) for the TVEA method. At least substantial inter-rater agreement (kappa > 0.60) was obtained for the TVEA variables related to tool or machine use, process, material, source intensity, and source orientation. Kappa values for source direction (0.22-0.38) and number of sources (0.38-0.60) showed comparatively lower agreement for all particulate types. Observation interval appropriateness was analyzed using linear regression to compare a 5-min observation interval "gold standard" with alternate intervals. Regression statistics indicated that while 30 min is an acceptable interval for exposure assessment, 15 min optimizes precision and practicality by ensuring that 95% of all observations differ less than ten percentage points from the "true" values. TVEA is a useful exposure assessment tool for the dynamic construction environment. It is flexible in that only those determinants that are of interest need be coded and the coding interval can be adjusted to accommodate the level of precision desired.

Kile, M. L., et al. (2013). "A panel study of occupational exposure to fine particulate matter and changes in DNA methylation over a single workday and years worked in boilermaker welders." Environ Health 12(1).

Background: Exposure to pollutants including metals and particulate air pollution can alter DNA methylation. Yet little is known about intra-individual changes in DNA methylation over time in relationship to environmental exposures. Therefore, we evaluated the effects of acute- and chronic

metal-rich PM 2.5 exposures on DNA methylation. Methods. Thirty-eight male boilermaker welders participated in a panel study for a total of 54 person days. Whole blood was collected prior to any welding activities (pre-shift) and immediately after the exposure period (post-shift). The percentage of methylated cytosines (%mC) in LINE-1, Alu, and inducible nitric oxide synthase gene (iNOS) were quantified using pyrosequencing. Personal PM2.5 (particulate matter with an aerodynamic diameter ≤ 2.5 μm) was measured over the work-shift. A questionnaire assessed job history and years worked as a boilermaker. Linear mixed models with repeated measures evaluated associations between DNA methylation, PM2.5 concentration (acute exposure), and years worked as a boilermaker (chronic exposure). Results: PM2.5 exposure was associated with increased methylation in the promoter region of the iNOS gene (β = 0.25, SE: 0.11, p-value = 0.04). Additionally, the number of years worked as a boilermaker was associated with increased iNOS methylation (β = 0.03, SE: 0.01, p-value = 0.03). No associations were observed for Alu or LINE-1. Conclusions: Acute and chronic exposure to PM2.5 generated from welding activities was associated with a modest change in DNA methylation of the iNOS gene. Future studies are needed to confirm this association and determine if the observed small increase in iNOS methylation are associated with changes in NO production or any adverse health effect. © 2013 Kile et al.; licensee BioMed Central Ltd.

Kim, J. Y., et al. (2004). "Comparison of fine particle measurements from a direct-reading instrument and a gravimetric sampling method." J Occup Environ Hyg 1(11): 707-715.

Particulate air pollution, specifically the fine particle fraction (PM2.5), has been associated with increased cardiopulmonary morbidity and mortality in general population studies. Occupational exposure to fine particulate matter can exceed ambient levels by a large factor. Due to increased interest in the health effects of particulate matter, many particle sampling methods have been developed In this study, two such measurement methods were used simultaneously and compared. PM2.5 was sampled using a filter-based gravimetric sampling method and a direct-reading instrument, the TSI Inc. model 8520 DUSTTRAK aerosol monitor. Both sampling methods were used to determine the PM2.5 exposure in a group of boilermakers exposed to welding fumes and residual fuel oil ash. The geometric mean PM2.5 concentration was 0.30 mg/m3 (GSD 3.25) and 0.31 mg/m3 (GSD 2.90)from the DUSTTRAK and gravimetric method, respectively. The Spearman rank correlation coefficient for the gravimetric and DUSTTRAK PM2.5 concentrations was 0.68. Linear regression models indicated that log, DUSTTRAK PM2.5 concentrations significantly predicted loge gravimetric PM2.5 concentrations ($p < 0.01$). The association between log(e) DUSTTRAK and log, gravimetric PM2.5 concentrations was found to be modified by surrogate measures for seasonal variation and type of aerosol. PM2.5 measurements from the DUSTTRAK are well correlated and highly predictive of measurements from the gravimetric sampling method for the aerosols in these work environments. However, results from this study suggest that aerosol particle characteristics may affect the relationship between the gravimetric and DUSTTRAK PM2.5 measurements. Recalibration of the DUSTTRAK for the specific aerosol, as recommended by the manufacturer, may be necessary to produce valid measures of airborne particulate matter.

Kim, J. Y., et al. (2004). "Urinary 8-hydroxy-2'-deoxyguanosine as a biomarker of oxidative DNA damage in workers exposed to fine particulates." Environ Health Perspect 112(6): 666-671.

Residual oil fly ash (ROFA) is a chemically complex mixture of compounds, including metals that are potentially carcinogenic because of their ability to cause oxidative injury. In this study, we investigated the association between exposure to particulate matter with an aerodynamic mass median diameter <or= 2.5 micro m (PM2.5) and oxidative DNA damage and repair, as indicated by urinary 8-hydroxy-2'-deoxyguanosine (8-OHdG) concentrations, in a group of boilermakers exposed to ROFA and metal fumes. Twenty workers (50% smokers) were monitored for 5 days during an overhaul

of oil-fired boilers. The median occupational PM2.5 8-hr time-weighted average was 0.44 mg/m3 (25th-75th percentile, 0.29-0.76). The mean +/- SE creatinine-adjusted 8-OHdG levels were 13.26 +/- 1.04 micro g/g in urine samples collected pre-workshift and 15.22 +/- 0.99 micro g/g in the post-workshift samples. The urinary 8-OHdG levels were significantly greater in the post-workshift samples than in the pre-workshift samples (p = 0.02), after adjusting for urinary cotinine levels, chronic bronchitis status, and age. Linear mixed models indicated a significant exposure-response association between PM2.5 exposure and urinary 8-OHdG levels (p = 0.03). Each 1-mg/m3 incremental increase in PM2.5 exposure was associated with an increase of 1.67 micro g/g (95% confidence interval, 0.21-3.14) in 8-OHdG levels. PM2.5 vanadium, manganese, nickel, and lead exposures also were positively associated with 8-OHdG levels (p <or= 0.05). This study suggests that a relatively young and healthy cohort of boilermakers may experience an increased risk of developing oxidative DNA injury after exposure to high levels of metal-containing particulate matter.

Laohaudomchok, W., et al. (2010). "Assessment of occupational exposure to manganese and other metals in welding fumes by portable X-ray fluorescence spectrometer." J Occup Environ Hyg 7(8): 456-465.

Elemental analysis of welding fume samples can be done using several laboratory-based techniques. However, portable measurement techniques could offer several advantages. In this study, we sought to determine whether the portable X-ray fluorescence spectrometer (XRF) is suitable for analysis of five metals (manganese, iron, zinc, copper, and chromium) on 37-mm polytetrafluoroethylene filters. Using this filter fitted on a cyclone in line with a personal pump, gravimetric samples were collected from a group of boilermakers exposed to welding fumes. We assessed the assumption of uniform deposition of these metals on the filters, and the relationships between measurement results of each metal obtained from traditional laboratory-based XRF and the portable XRF. For all five metals of interest, repeated measurements with the portable XRF at the same filter area showed good consistency (reliability ratios are equal or close to 1.0 for almost all metals). The portable XRF readings taken from three different areas of each filter were not significantly different (p-values = 0.77 to 0.98). This suggested that the metal rich PM(2.5) deposits uniformly on the samples collected using this gravimetric method. For comparison of the two XRFs, the results from the portable XRF were well correlated and highly predictive of those from the laboratory XRF. The Spearman correlation coefficients were from 0.325 for chromium, to 0.995 for manganese and 0.998 for iron. The mean differences as a percent of the mean laboratory XRF readings were also small (<5%) for manganese, iron, and copper. The differences were greater for zinc and chromium, which were present at very low amounts in our samples and below the limits of detection of the portable XRF for many of the samples. These five metals were moderately to strongly correlated with the total fine particle fraction on filters (Spearman rho = 0.41 for zinc to 0.97 for iron). Such strong correlations and comparable results suggested that the portable XRF could be used as an effective and reliable tool for exposure assessment in many studies.

Laohaudomchok, W., et al. (2011). "Toenail, blood, and urine as biomarkers of manganese exposure." J Occup Environ Med 53(5): 506-510.

OBJECTIVE: This study examined the correlation between manganese exposure and manganese concentrations in different biomarkers. METHODS: Air measurement data and work histories were used to determine manganese exposure over a work shift and cumulative exposure. Toenail samples (n = 49), as well as blood and urine before (n = 27) and after (urine, n = 26; blood, n = 24) a work shift were collected. RESULTS: Toenail manganese, adjusted for age and dietary manganese, was significantly correlated with cumulative exposure in 7 to 9, 10 to 12, and 7 to 12 months before toenail clipping date, but not 1 to 6 months. Manganese exposure over a work shift was not correlated

with changes in blood nor urine manganese. CONCLUSIONS: Toenails appeared to be a valid measure of cumulative manganese exposure 7 to 12 months earlier. Neither change in blood nor urine manganese appeared to be suitable indicators of exposure over a typical work shift.

Liu, Y., et al. (2005). "Estimation of personal exposures to particulate matter and metals in boiler overhaul work." J Occup Environ Med 47(1): 68-78.

OBJECTIVE: We sought to develop an algorithm and estimate unmeasured exposures to particulate matter (PM) and metals in an epidemiologic study of boilermakers. METHODS: The algorithm was based on limited measurements and workers' task and time activity patterns. Half of the measurements were used to develop exposure estimates for unmeasured person days. The other half was used for method validation. RESULTS: The validation demonstrated good approximations of actual exposures with differences less than 5% for PM and vanadium (V). Average estimated exposures to PM (mg/m3) and V (microg/m3) were significantly higher for workers doing boiler repair than utility work (0.36 vs. 0.09 for PM and 5.99 vs. 0.38 for V). CONCLUSIONS: This algorithm provided reasonably accurate exposure indices for our epidemiologic study in this population. It also is likely applicable to similar exposure scenarios in other studies.

Liu, Y., et al. (2005). "Exposure to fuel-oil ash and welding emissions during the overhaul of an oil-fired boiler." J Occup Environ Hyg 2(9): 435-443.

The health effects of exposure to vanadium in fuel-oil ash are not well described at levels ranging from 10 to 500 microg/m(3). As part of a larger occupational epidemiologic study that assessed these effects during the overhaul of a large oil-fired boiler, this study was designed to quantify boilermakers' exposures to fuel-oil ash particles, metals, and welding gases, and to identify determinants of these exposures. Personal exposure measurements were conducted on 18 boilermakers and 11 utility workers (referents) before and during a 3-week overhaul. Ash particles < 10 microm in diameter (PM(10), mg/m(3)) were sampled over full work shifts using a one-stage personal size selective sampler containing a polytetrafluoroethylene filter. Filters were digested using the Parr bomb method and analyzed for the metals vanadium (V), nickel (Ni), iron (Fe), chromium (Cr), cadmium (Cd), lead (Pb), manganese (Mn), and arsenic (As) by inductively coupled plasma mass spectrometry. Nitrogen dioxide (NO(2)) was measured with an Ogawa passive badge-type sampler and ozone (O(3)) with a personal active pump sampler.Time-weighted average (TWA) exposures were significantly higher ($p < 0.05$) for boilermakers than for utility workers for PM(10) (geometric mean: 0.47 vs. 0.13 mg/m(3)), V (8.9 vs. 1.4 microg/m(3)), Ni (7.4 vs. 1.8 microg/m(3)) and Fe (56.2 vs. 11.2 microg/m(3)). Exposures were affected by overhaul time periods, tasks, and work locations. No significant increases were found for O(3) or NO(2) for boilermakers or utility workers regardless of overhaul period or task group. Fuel-oil ash was a major contributor to boilermakers' exposure to PM(10) and metals. Vanadium concentrations sometimes exceeded the 2003 American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value.

Meeker, J. D., et al. (2007). "Manganese and welding fume exposure and control in construction." J Occup Environ Hyg 4(12): 943-951.

Overexposure to welding fume constituents, particularly manganese, is of concern in the construction industry due to the prevalence of welding and the scarcity of engineering controls. The control effectiveness of a commercially available portable local exhaust ventilation (LEV) unit was assessed. It consisted of a portable vacuum and a small bell-shaped hood connected by a flexible 2 inch (50.8 mm) diameter hose, in both experimental and field settings. The experimental testing was done in a semienclosed booth at a pipefitter training facility. Five paired trials of LEV control vs. no control, each approximately 1 hr in duration and conducted during two successive welds of 6 inch (152.4 mm)

diameter carbon steel pipe were run in random order. Breathing zone samples were collected outside the welding hood during each trial. In the field scenario, full-shift breathing zone samples were collected from two pipefitters welding carbon steel pipe for a chiller installation on a commercial construction project. Eight days of full-shift sampling were conducted on both workers (n = 16), and the LEV was used by one of the two workers on an alternating basis for 7 of the days. All samples were collected with personal sample pumps calibrated at 2 L/min. Filter cassettes were analyzed for total particulate and manganese concentration by a certified laboratory. In the experimental setting, use of the portable LEV resulted in a 75% reduction in manganese exposure (mean 13 microg/m(3) vs. 51 microg/m(3); $p < 0.05$) and a 60% reduction in total particulate (mean 0.74 mg/m(3) vs. 1.83 mg/m(3); $p < 0.05$). In the field setting, LEV use resulted in a 53% reduction in manganese exposure (geometric mean 46 microg/m(3) vs. 97 microg/m(3); $p < 0.05$) but only a 10% reduction in total particulate (geometric mean 4.5 mg/m(3) vs. 5.0 mg/m(3); $p > 0.05$). These results demonstrate that LEV use can reduce manganese exposure associated with welding tasks in construction.

Meeker, J. D., et al. (2010). "Hexavalent chromium exposure and control in welding tasks." J Occup Environ Hyg 7(11): 607-615.

Studies of exposure to the lung carcinogen hexavalent chromium (CrVI) from welding tasks are limited, especially within the construction industry where overexposure may be common. In addition, despite the OSHA requirement that the use of engineering controls such as local exhaust ventilation (LEV) first be considered before relying on other strategies to reduce worker exposure to CrVI, data on the effectiveness of LEV to reduce CrVI exposures from welding are lacking. The goal of the present study was to characterize breathing zone air concentrations of CrVI during welding tasks and primary contributing factors in four datasets: (1) OSHA compliance data; (2) a publicly available database from The Welding Institute (TWI); (3) field survey data of construction welders collected by the Center for Construction Research and Training (CPWR); and (4) controlled welding trials conducted by CPWR to assess the effectiveness of a portable LEV unit to reduce CrVI exposure. In the OSHA (n = 181) and TWI (n = 124) datasets, which included very few samples from the construction industry, the OSHA permissible exposure level (PEL) for CrVI (5 mug/m(3)) was exceeded in 9% and 13% of samples, respectively. CrVI concentrations measured in the CPWR field surveys (n = 43) were considerably higher, and 25% of samples exceeded the PEL. In the TWI and CPWR datasets, base metal, welding process, and LEV use were important predictors of CrVI concentrations. Only weak-to-moderate correlations were found between total particulate matter and CrVI, suggesting that total particulate matter concentrations are not a good surrogate for CrVI exposure in retrospective studies. Finally, in the controlled welding trials, LEV reduced median CrVI concentrations by 68% ($p = 0.02$). In conclusion, overexposure to CrVI in stainless steel welding is likely widespread, especially in certain operations such as shielded metal arc welding, which is commonly used in construction. However, exposure could be substantially reduced with proper use of LEV.

Mills, J. B., et al. (2013). "Comparison of the DiSCmini aerosol monitor to a handheld condensation particle counter and a scanning mobility particle sizer for submicrometer sodium chloride and metal aerosols." J Occup Environ Hyg 10(5): 250-258.

We evaluated the robust, lightweight DiSCmini (DM) aerosol monitor for its ability to measure the concentration and mean diameter of submicrometer aerosols. Tests were conducted with monodispersed and polydispersed aerosols composed of two particle types (sodium chloride [NaCl] and spark-generated metal particles, which simulate particles found in welding fume) at three different steady-state concentration ranges (Low, <10(3); Medium, 10(3)-10(4); and High, >10(4) particles/cm(3)). Particle number concentration, lung deposited surface area (LDSA) concentration, and mean size measured with the DM were compared with those measured with reference instruments, a

scanning mobility particle sizer (SMPS), and a handheld condensation particle counter (CPC). Particle number concentrations measured with the DM were within 16% of those measured by the CPC for polydispersed aerosols. Poorer agreement was observed for monodispersed aerosols (+/-35% for most tests and +101% for 300-nm NaCl). LDSA concentrations measured by the DM were 96% to 155% of those estimated with the SMPS. The geometric mean diameters measured with the DM were within 30% of those measured with the SMPS for monodispersed aerosols and within 25% for polydispersed aerosols (except for the case when the aerosol contained a substantial number of particles larger than 300 nm). The accuracy of the DM is reasonable for particles smaller than 300 nm, but caution should be exercised when particles larger than 300 nm are present. [Supplementary materials are available for this article. Go to the publisher's online edition of the Journal of Occupational and Environmental Hygiene for the following free supplemental resources: manufacturer-reported capabilities of instruments used, and information from the SMPS measurements for polydispersed test particles.].

Mukherjee, S., et al. (2004). "Smoking status and occupational exposure affects oxidative DNA injury in boilermakers exposed to metal fume and residual oil fly ash." Cancer Epidemiol Biomarkers Prev 13(3): 454-460.

Epidemiologic studies demonstrate increased cancer incidence among workers exposed to polycyclic aromatic hydrocarbons (PAH) and metals, probably through cumulative oxidative DNA damage in response to carcinogens. Boilermakers are exposed to particulates of residual oil fly ash (ROFA) and metal fume that contain carcinogenic PAH and metals. We conducted a repeated-measures cohort study in boilermakers during the overhaul of an oil-fired boiler to determine a possible association between the level of 8-hydroxy-2'-deoxyguanosine (8-OH-dG; an oxidative injury biomarker) and biomarkers of PAH (1-hydroxypyrene; 1-OHP) and metal exposure. Preshift and postshift urine samples were analyzed for 8-OH-dG, cotinine, 1-OHP, and metals. Generalized estimating equations were used to model the multivariate relationship of 8-OH-dG to the explanatory variables of interest. Biomarker levels were determined for 181 urine samples from 20 male subjects (mean age 45 years, 50% smokers). Metal and 1-OHP levels increased cross-week and were affected by smoking status. Levels of 8-OH-dG were higher in nonsmokers at the start of the workweek yet declined after occupational exposure to similar levels as in smokers. Multivariate analysis indicated that metal x cotinine interaction terms for nickel, vanadium, chromium, and copper were significantly associated with the 8-OH-dG level, but there were differential effects depending on the metal. This study suggests that oxidative DNA damage in boilermakers is influenced by the interaction between occupational exposures and smoking status. In addition, boilermakers may have reduced ability to repair damaged DNA after ROFA and metal fume exposure. This finding has clinical relevance because these exposures may increase the cancer susceptibility of boilermakers.

Mukherjee, S., et al. (2005). "Urinary metal and polycyclic aromatic hydrocarbon biomarkers in boilermakers exposed to metal fume and residual oil fly ash." Am J Ind Med 47(6): 484-493.

BACKGROUND: Boilermakers are occupationally exposed to known carcinogens. METHODS: The association of urinary 1-hydroxy-pyrene (1-OHP), a biomarker of polycyclic aromatic hydrocarbon (PAH) exposure, with biomarkers of metal exposure (vanadium, chromium, manganese, nickel, copper, and lead) in boilermakers exposed to metal fume from welding and dust particulates from residual oil fly ash (ROFA) was examined. A repeated measures cohort study was conducted during the overhaul of an oil-fired boiler. Twice-daily urine samples were obtained for 5 days and analyzed for cotinine, 1-OHP, and metals. Generalized estimating equations (GEE) were used to model the multivariate relationship of 1-OHP to the explanatory variables. RESULTS: Metal and 1-OHP levels were determined for 165 urine samples from 20 boilermakers and these levels increased during the workweek. However, the 1-OHP level was not significantly associated with any individual metal level at any time point.

CONCLUSION: This suggests that boilermakers were occupationally exposed to PAH and metals, but 1-OHP as a PAH biomarker was unable to serve as a surrogate marker of metal exposure for the metals measured in this study.

Nuernberg, A. M., et al. (2008). "Urinary 8-isoprostane and 8-OHdG concentrations in boilermakers with welding exposure." J Occup Environ Med 50(2): 182-189.

OBJECTIVE: To investigate the association of exposure to fine particulate matter (PM2.5) with DNA damage and oxidative stress in boilermakers exposed to welding fumes. METHODS: Forty-one workers were monitored over 24 hours during which baseline, postshift, bedtime, and next morning measurements were collected. Twenty-two workers participated as controls. RESULTS: Linear regression was used to model pairwise change in u-8-isoprostane and u-8-OHdG: pre- to postshift, preshift to bedtime, postshift to bedtime, and postshift to next morning. In the models, pre- to postshift change in 8-OHdG was statistically significant, whereas postshift to bedtime change in 8-isoprostane showed an unexpected inverse relationship with PM2.5. CONCLUSIONS: Acute welding exposure is associated with a postshift blunting of systemic inflammation in chronically exposed boilermakers, as measured by 8-isoprostane. The level of oxidative DNA damage as measured by 8-OHdG is less clear.

Park, R. M., et al. (2006). "Issues in neurological risk assessment for occupational exposures: the Bay Bridge welders." Neurotoxicology 27(3): 373-384.

The goal of occupational risk assessment is often to estimate excess lifetime risk for some disabling or fatal health outcome in relation to a fixed workplace exposure lasting a working lifetime. For sub-chronic or sub-clinical health effects measured as continuous variables, the benchmark dose method can be applied, but poses issues in defining impairment and in specifying acceptable levels of excess risk. Such risks may also exhibit a dose-rate effect and partial reversibility such that effects depend on how the dose is distributed over time. Neurological deficits as measured by a variety of increasingly sensitive neurobehavioral tests represent one such outcome, and the development of a parkinsonian syndrome among welders exposed to manganese fume presents a specific instance. Welders employed in the construction of piers for a new San Francisco-Oakland Bay Bridge in San Francisco were previously evaluated using a broad spectrum of tests. Results for four of those tests (Rey-Osterrieth Complex Figure Test, Working Memory Index, Stroop Color Word Test and Auditory Consonant Trigrams Test) were used in the benchmark dose procedure. Across the four outcomes analyzed, benchmark dose estimates were generally within a factor of 2.0, and decreased as the percentile of normal performance defining impairment increased. Estimated excess prevalence of impairment, defined as performance below the 5th percentile of normal, after 2 years of exposure at the current California standard (0.2 mg/m3, 8 h TWA), ranged 15-32% for the outcomes studied. Because these exposures occurred over a 1-2-year period, generalization to lifetime excess risk requires further consideration of the form of the exposure response and whether short-term responses can be generalized to equivalent 45-year period. These results indicate unacceptable risks at the current OSHA PEL for manganese (5.0 mg/m3, 15 min) and likely at the Cal OSHA PEL as well.

Wang, Z., et al. (2005). "Global gene expression profiling in whole-blood samples from individuals exposed to metal fumes." Environ Health Perspect 113(2): 233-241.

Accumulating evidence demonstrates that particulate air pollutants can cause both pulmonary and airway inflammation. However, few data show that particulates can induce systemic inflammatory responses. We conducted an exploratory study using microarray techniques to analyze whole-blood total RNA in boilermakers before and after occupational exposure to metal fumes. A self-controlled study design was used to overcome the problems of larger between-individual variation interferences

with observations of relatively smaller changes caused by environmental exposure. Moreover, we incorporated the dichotomous data of absolute gene expression status in the microarray analyses. Compared with nonexposed controls, we observed that genes with altered expression in response to particulate exposure were clustered in biologic processes related to inflammatory response, oxidative stress, intracellular signal transduction, cell cycle, and programmed cell death. In particular, the preinflammatory cytokine interleukin 8 and one of its receptors, chemokine receptor 4, seemed to play important roles in early-stage response to heavy metal exposure and were down-regulated. Furthermore, most observed expression variations were from nonsmoking exposed individuals, suggesting that smoking profoundly affects whole-blood expression profiles. Our study is the first to demonstrate that with a paired sampling study design of pre- and postexposed individuals, small changes in gene expression profiling can be measured in whole-blood total RNA from a population-based study. This technique can be applied to evaluate the host response to other forms of environmental exposures.

Weisskopf, M. G., et al. (2005). "Prospective study of occupation and amyotrophic lateral sclerosis mortality." Am J Epidemiol 162(12): 1146-1152.

Occupational exposures are suspected of contributing to the risk of amyotrophic lateral sclerosis (ALS), but results of epidemiologic studies have been inconsistent. The authors prospectively assessed the relation between occupation and ALS mortality among more than 1 million participants in the Cancer Prevention Study II of the American Cancer Society. Follow-up from 1989 through 2002 identified 507 ALS deaths among men and 430 among women. Adjusted rate ratios were calculated by using Mantel-Haenszel weights and Cox proportional hazards. Among men, elevated ALS mortality was found for programmers (rate ratio = 4.55, 95% confidence interval: 1.46, 14.2; p = 0.009) and laboratory technicians (rate ratio = 1.96, 95% confidence interval: 1.04, 3.66; p = 0.04). Occupations previously associated with increased risk of ALS for which no increased risk was found included farmers, electricians, and welders, although the numbers of electricians (eight ALS deaths) and welders (two ALS deaths) were small. Among women, only machine assemblers had significantly increased ALS mortality (rate ratio = 2.81, 95% confidence interval: 1.05, 7.53; p = 0.04). Results, which suggest that male programmers and laboratory technicians and female machine assemblers may be at increased risk of death from ALS, should be interpreted cautiously, however, because they are based on small numbers.

Welch, L. S., et al. (2004). "Construction welding exposures to manganese likely to exceed proposed TLV." J Occup Environ Hyg 1(6): D63-65.

Column reviewing welding exposures to manganese in construction

Wong, J. Y. Y., et al. (2014). "The association between global DNA methylation and telomere length in a longitudinal study of boilermakers." Genetic Epidemiology 38(3): 254-264.

The objectives of this study were to determine if global DNA methylation, as reflected in LINE-1 and Alu elements, is associated with telomere length and whether it modifies the rate of telomeric change. A repeated-measures longitudinal study was performed with a panel of 87 boilermaker subjects. The follow-up period was 29 months. LINE-1 and Alu methylation was determined using pyrosequencing. Leukocyte relative telomere length was assessed via real-time qPCR. Linear-mixed models were used to estimate the association between DNA methylation and telomere length. A structural equation model (SEM) was used to explore the hypothesized relationship between DNA methylation, proxies of particulate matter exposure, and telomere length at baseline. There appeared to be a positive association between both LINE-1 and Alu methylation levels, and telomere length. For every incremental increase in LINE-1 methylation, there was a statistically significant 1.0 × 10-1 (95%

CI: 4.6 × 10-2, 1.5 × 10-1, P < 0.01) unit increase in relative telomere length, controlling for age at baseline, current and past smoking status, work history, BMI (log kg/m2) and leukocyte differentials. Furthermore, for every incremental increase in Alu methylation, there was a statistically significant 6.2 × 10-2 (95% CI: 1.0 × 10-2, 1.1 × 10-1, P = 0.02) unit increase in relative telomere length. The interaction between LINE-1 methylation and follow-up time was statistically significant with an estimate -9.8 × 10-3 (95% CI: -1.8 × 10-2, -1.9 × 10-3, P = 0.02); suggesting that the rate of telomeric change was modified by the degree of LINE-1 methylation. No statistically significant association was found between the cumulative PM exposure construct, with global DNA methylation and telomere length at baseline. © 2014 WILEY PERIODICALS, INC.

Woskie, S. R., et al. (2002). "Exposures to quartz, diesel, dust, and welding fumes during heavy and highway construction." J Occup Environ Hyg 63(4): 447-457.

Personal samples for exposure to dust, diesel exhaust, quartz, and welding fume were collected on heavy and highway construction workers. The respirable, thoracic, and inhalable fractions of dust and quartz exposures were estimated from 260 personal impactor samples. Respirable quartz exposures exceeded the National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) in 7-31% of cases for the trades sampled. More than 50% of the samples in the installation of drop ceilings and wall tiles and concrete finish operations exceeded the NIOSH REL for quartz. Thoracic exposures to quartz and dust exceeded respirable exposures by a factor of 4.5 and 2.8, respectively. Inhalable exposures to quartz and dust exceeded respirable exposures by a factor of 25.6 and 9.3, respectively. These findings are important due to the identification of quartz as a carcinogen by the National Toxicology Program and the International Agency for Research on Cancer. Fourteen percent of the personal samples for EC (n = 261), collected as a marker for diesel exhaust, exceeded the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) for diesel exhaust. Seventeen of the 22 (77%) samples taken during a partially enclosed welding operation reached or exceeded the ACGIH TLV of 5 mg/m3 for welding fume.

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