chamber walls. Subsequent re-emission from the glass walls to the air adds to the airborne concentration until equilibrium is established between adsorption onto and desorption from the sink. At this point the airborne concentration levels off.

Adsorption and apparent degradation of the active ingredient on the chamber walls results in equilibrium airborne concentrations that are about a third of those predicted without these mechanisms. It is anticipated that glass is not a very efficient sink. Tests with typical residential interior surfaces could render significantly more active ingredient going to sinks for longer periods with subsequently more degradation and lower airborne concentrations in the test chambers and real rooms.

Conceptual details of the model's construction, the use and value of simulation software and a predicting performance advantage over previous models are presented.

166

EVALUATION OF SOCIOECONOMIC FACTORS AFFECTING TIME SPENT IN INDOOR AND OUTDOOR MICROENVIRONMENTS BASED ON TEN TIME/ACTIVITY STUDIES. T.R. Johnson, J. Capel, and M. McCoy, International Technology Corporation, 3710 University Drive, Durham, NC 27514; W. Ollison, American Petroleum Institute, 1220 L Street, NW, Washington, DC 2000.

A number of computer-based exposure models have been developed which attempt to realistically simulate the movements of people through zones of varying air quality. Many of these models employ time/activity databases obtained from surveys in which subjects documented their activities in diaries. These surveys differ with respect to geographic location, local climate, diary recall approach (realtime versus retrospective), and demographic makeup of the sampled population. This paper presents results of a series of statistical analyses performed on ten time/activity databases to determine the significance of various predictive variables, with an emphasis on variables relating to gender, race, and income. The databases represent the activity patterns of residents of five cities (Cincinnati, OH; Denver, CO; Washington, DC; Los Angeles, CA; and Valdez, AK) and of the entire state of California. Results of the statistical analyses indicate that income, race, and gender significantly affect the average time spent in various indoor and outdoor microenvironments. For example, diary data obtained from a study of outdoor workers in Los Angeles indicate that subjects with incomes below $10,000 spent more time than the average subject in the indoors-residence and outdoors-roadside microenvironments (21 percent and 44 percent more time, respectively). This income group spent less time than the average subject in the indoors-other, outdoors-other, and motor vehicle microenvironments (64 percent, 73 percent, and 56 less time, respectively). These data also show that female subjects spent 30 percent less time in motor vehicles than male subjects. Such inter-group differences in time/activity patterns may significantly affect exposure to air pollution and should be considered explicitly in exposure modeling applications.

167

MODELING STRATEGIES FOR INDOOR AIR EXPOSURE ASSESSMENT. M.D. Koontz and H.E. Rector, GEOMET Technologies, Inc., 20251 Century Boulevard, Germantown, MD 20874.

Exposure assessments have been historically limited by insufficient and inadequate data; this is especially true for the indoor environment. Indoor air quality models offer the means to overcome some of these shortfalls by providing the means to: (1) understand existing data, (2) interpolate across data gaps, (3) extend available information to analogous scenarios, and (4) extrapolate to purely hypothetical conditions. Models for simulating indoor exposure are invariably based on mass-conservation principles that track the material balance for a defined airspace in terms of material gains and losses. Mass-balance relationships are specified through one or more differential equations where contaminant gain (transported input plus sources) and contaminant loss (transported output plus sinks) are stated as analytical functions or fixed constants. Dynamic submodels can be considered to incorporate important processes. Unlike many other areas of environmental modeling, however, indoor air models typically are not software products that can be purchased as "off-the-shelf" items. Rather, most existing software models are research tools that have been developed for specific purposes and are in a near-continual stage of development and refinement. This paper reviews the theoretical and practical framework for simulating indoor exposure scenarios and summarizes available software products. Among the modeling concepts and strategies to be discussed are alternative methods for characterizing mass balance parameters (including emissions, airflows and reversible/ irreversible sink effects) as well as potential advantages and pitfalls associated with the use of simplifying assumptions.

168

ESTIMATION OF WORKROOM EMISSIONS FROM ELECTROPLATING. R.A.Wadden, P.A. Scheff, J.E.Franke, L.M.Conroy, Environmental and Occupational Health Sciences, University of Illinois at Chicago, P.O.Box 6998, Chicago, IL 60680.

Effective control of emissions from electroplating is necessary to maintain a healthy workplace. However, in many cases the emission rates are not well characterized. Based on intensive testing of 8 plating operations during production we have developed a number of methods for estimating emissions of chromium, nickel, copper, and sulfur. For each test area concentrations were determined from particulate samples collected on open face filters using calibrated personnel pumps. The samples were collected hourly at several locations in the vicinity of each source. The filters were analyzed using PIXE (proton induced x-ray emission spectroscopy). In each case, measurements of area concentrations were transformed to emission rates by using appropriate mass balance models in conjunction with measured ventilation rates. In addition source activities such as area plated, amp hours consumed, and total power usage were recorded simultaneously with concentration measurements. Comparison of the emission rates with source activities often allowed us to determine emission factors as well as the emission rates. For example, the emission factor for hard and decorative chrome electroplating for three processes varied between 0.08 and 1.47 mg Cr/amp·hr. These results were consistent with limited data available from the California Air Resources Board (0.02 - 3 mg Cr/amp·hr depending on control system). The methods provide a first estimate for determining workroom emissions when no other data are available, and are a useful way to extend field test measurements. For systems with local exhaust ventilation the approach also allows determination of mass-based collection efficiency.

169

RAOULT'S LAW v HENRY'S LAW. CHOOSING ONE TO PREDICT EQUILIBRIUM VAPOR PRESSURES FOR COMPONENTS OF A LIQUID MIXTURE. J.C. Rock, Texas Occupational Health & Safety Institute, Texas A&M University, College Station, TX 77843-3133.

Industrial hygienists often need to estimate vapor concentrations resulting from liquid solutions under process conditions. Two tools available for this estimation problem are Raoult's Law and Henry's Law.

Raoult's Law describes the equilibrium conditions reached by ideal solutions. The equilibrium partial pressure of the vapor of the nth component of an ideal mixture is the product of the mole fraction of that component in the liquid phase and the equilibrium vapor pressure of that component over its pure liquid. The ideal solution assumption is violated by many real solutions. It is shown that Raoult's Law is appropriate for the solvent vapor in dilute solutions.

Henry's Law describes the equilibrium behavior of solutes in dilute solutions. The equilibrium partial pressure of the vapor of the nth solute in a dilute solution is the product of Henry's constant (empirically determined) and the equilibrium vapor pressure of that component as over its pure liquid. It is useful for all real solutions. The conditions necessary for its application are discussed and examples are provided of its utility in industrial hygiene situations.

In summary, both Raoult's Law and Henry's Law apply to real dilute solutions. Raoult's Law allows reasonable estimates of equilibrium solvent vapor concentrations and Henry's Law allows reasonable estimates of solute vapor concentrations at equilibrium. In solutions of molecules that behave ideally, Raoult's Law applies to all concentrations .

170

CHARACTERIZATION OF SOURCE ACTIVITY AND EMISSION FACTORS FOR A COPPER PLATING LINE. S.A. Milz, Naval Hospital, Occupational Health/Preventive Medicine Department, NH064, Great Lakes, IL 60088; R.A. Wadden, J.E. Franke, P.A. Scheff, and L.M. Conroy, University of Illinois at Chicago, Environmental and Occupational Health Sciences, 2121 W. Taylor, M/C 922, Chicago, IL 60612.

Emission rates and emission factors were developed for copper and sulfur based on data collected during production of an eleven-tank copper plating line at a semi-conductor manufacturing plant. Hourly air samples for particulate matter were collected on polycarbonate filters over a two-day period at five locations around the line. The particulate matter on the filters was analyzed for elemental composition using Proton Induced X-Ray Emission Spectroscopy. In addition, source activity data were recorded during the entire twelve-hour sampling period. The observations included board code, rack size, number of boards, tank number, plating current, and temperature of the plating bath.

The collected hourly concentration data and ventilation rates were used with mass balance models to calculate hourly emission rates. The average copper emission rate was 487 µg/min. The average sulfur emission rate varied from 983 µg/min to 1232 µg/min depending on the mass balance model.

Source activity variables were averaged (rack size, current, temperature) or totaled (number of boards) for each of the twelve sampling hours. In addition, three other activity variables were calculated for each sampling hour. These calculated activity variables included the total square inches of boards entering the plating baths each hour, the total square inches of boards being plated each hour, and the total effective energy each hour, which was calculated by multiply-

ing the current by the plating time. As expected, the area plated was highly correlated with the product of current and time interval in the plating bath.

Emission factors were then calculated for all four emission rate estimates. The resulting equations indicated that the total effective energy and the total square inches of boards entering the plating baths each best described the copper and sulfur emissions. These emission factors can then be used to estimate emissions for other copper plating lines in the semiconductor industry.

171

EVAPORATION RATE OF VOLATILE LIQUIDS. K.O. Braun, K.J. Caplan, RUST Environment &: Infrastructure, 3033 Campus Drive, Suite 175, Minneapolis, MN 55441.

The purpose of this presentation is to make available to the scientific community the results of quantitative research data on evaporation rate of volatile liquids. Technical literature review reveals a lack of quantitative evaporation rate data for volatile liquids. The objective of this research was to determine whether the evaporation rate of a volatile liquid could be adequately predicted from its common "handbook" properties over a range of conditions representative of the typical factory environment. The handbook properties included Reynolds No., Schmidt No., molecular weight, vapor pressure, surface tension, diffusion coefficient, latent heat, and viscosity.

A test apparatus was designed, built and used to make quantitative measurements of evaporation rate. The objective of the apparatus design was to provide a uniform and controlled profile of airflow at controlled temperatures passing over an exposed liquid surface in such a way that turbulent eddying currents over the liquid would be minimized and permit measurement of evaporation rate at equilibrium test conditions. Initial tests were conducted on a base set of three examples from each of four classes of organic liquids: aliphatic, aromatic, alcohols and ketones. Additional work was later conducted on water, n-butyl acetate and three low vapor pressure alcohols. The basic experimental protocol involved measuring liquid evaporation rate at three conditions of air velocity (100, 500, and 1,000 feet per minute) and three conditions of air temperature (45, 70 and 100 degrees fahrenheit). The apparatus consisted of a test duct and a specially designed test pan. Evaporation rate was determined by maintaining the liquid level in the test pan while monitoring the weight change of a liquid supply container which was suspended from a sensitive load cell. Provisions were made to minimize heat transfer between the evaporating liquid and the pan itself The objective was to avoid biasing any data concerning simultaneous heat and mass transfer at the liquid surface. Airflow was provided by a remotely located blower. Heating and cooling were provided by hot and chilled water coil systems. An IBM XT computer was used to control and record airflow, temperature, and evaporation rate.

This work has resulted in approximately 160 recorded evaporation rate measurements and a reasonably accurate correlation (generally above 0.95 multiple correlation coefficient) between evaporation rate and the physical properties of molecular weight, vapor pressure, and air velocity. Individual predictive evaporation rate equations for each chemical class as well as for the combination of all test chemicals was developed based on these parameters. The base set of evaporation rate data and predictive formulae have been useful for occupational exposure assessment, environmental emission estimation, ventilation design, pollution control equipment selection, emergency/spill response evaluation and reconstruction of potential historical exposures for epidemiology study. This work was performed for the Chemical Engineering Branch, Office of Toxic Substances, United States Environmental Protection Agency.

172

IMPORTANT ASPECTS OF EXPOSURE ASSESSMENT AND SAMPLING STRATEGY IN THE REINFORCED PLASTIC INDUSTRY. R. F. Malek, Rhone-Poulenc Inc., CN 5266, Princeton, NJ 08543, J. M. Daisey, Lawrence Berkeley Lab., One Cyclotron Road, Berkeley, CA 94720, and B. S. Cohen, NYU Medical Center, 550 Fifth Avenue, New York, NY 10016.

Airflow profiles and styrene breathing zone concentrations were investigated in the reinforced plastic industry. Numerous significant factors must be taken into considerations when conducting exposure assessment in that industry. This paper summarizes the results of our research:

- Sample stability: styrene vapors were collected on charcoal tubes from an exposure chamber to investigate sample stability. The results showed that styrene vapors collected on charcoal tubes were stable up to four weeks without effect due to catalysis, storage temperature or length of storage.
- The effect of styrene droplets on overall worker's exposure to styrene was investigated during spraying of unsaturated polyester resin solution. Styrene aerosol contributed 30% ± 3% of the total worker's exposure to styrene.
- Measurements of styrene air concentrations and air flow studies in the worker's breathing zone were conducted utilizing a mannequin in front of a spray booth. Turbulence and the distance between the worker and the contaminant source were the most controlling factors behind the breathing zone concentration variations. Also, a semi-empirical model was developed to predict the worker's inhalation exposure to styrene.
- An exposure assessment was conducted for 21 workers in a boat manufacturing plant to test the applicability of the developed model. The model predicted the worker's exposure to styrene within 10% of the measured breathing zone concentrations.

This research demonstrated the important factors that control worker's exposure to styrene in the reinforced plastic industry.

173

EVAPORATION OF A LIQUID IN A FLOWING AIR STREAM. A. A. Hummel, HIMONT R&D Center, 912 Appleton Rd., Elkton, MD 21921; K.O. Braun, PACE Laboratories , Inc., 1710 Douglas Drive North, Minneapolis, MN 55422; and M.C. Fehrenbacher, U.S. Environmental Protection Agency, Office of Pollution and Prevention and Toxics, 401 M St., S.W. (TS-779), Washington, DC 20460.

An equation was developed to estimate the evaporation rate of a volatile liquid in a flowing air stream, and tested against experimental data. The equation requires only the molecular weight, vapor pressure, air velocity, pool size, ambient pressure and temperature, or estimates of these quantities, to approximate the overall evaporation rate in mass/time/unit area. The equation was developed by solving the partial differential equations describing the mass balance of a differential element above the liquid, and include fits of the diffusion coefficient based on classical kinetic theory of gases. The experiments tested the evaporation rate of over 15 different compounds at different temperatures and air flow rates, and regression fits were made of the data. Both the regression fit and the theoretical equation fit the data well within an order of magnitude. The theoretical equation thus provides an approximation of the evaporation rate for low vapor pressure (below 35 torr) liquids with a minimum of information about the liquid.

Papers 174 - 182
Biological Monitoring/Dermal Absorbtion I

175

OCCUPATIONAL EXPOSURE TO o-TOLUIDINE AND ANILINE IN THE RUBBER AND DYE INDUSTRIES. J. Fajen, D. Roberts, A. Ruder, E. Ward, and K. Wallingford, The National Institute for Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, OH 45226.

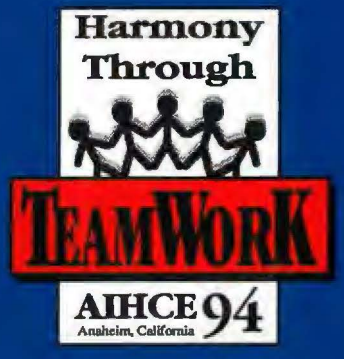
The National Institute for Occupational Safety and Health (NIOSH) conducted Health Hazard Evaluations (HHE) at two manufacturing plants that use o-toluidine and/or aniline to produce rubber antioxidants and accelerators at one facility and dyes at a second facility. The requests were initiated because eight cases of bladder cancer were reported between 1973 and 1988 at the plant that manufactures rubber antioxidants and accelerators. In addition, at the dye plant three cases of "bladder dysplasia" were diagnosed during annual bladder cytology examinations in 1990.

Personal air, urine, skin liquid contact indicator (dermal) badges, and glove samples were collected on workers to measure airborne exposure to o-toluidine and aniline and indicate potential dermal contact with these liquid chemicals. Area air and dermal badge samples were collected from representative locations to measure air exposure potential and evaluate the amount of passive absorption of chemicals from the air by dermal badges. Surface wipe samples and bulk samples were obtained. The data on urinary concentrations will not be presented in this paper.

At the plant that manufactured rubber chemicals, personal TWA air results for o-toluidine and aniline ranged from 87.4 to 1639 $\mu g/M^3$ and 53.9 to 726 $\mu g/M^3$ respectively. The area air sample results for o-toluidine and aniline ranged from 36.8 to 2,460 $\mu g/M^3$ and 3.9 to 1,440 $\mu g/M^3$, respectively. The personal glove sample results for o-toluidine and aniline ranged from non-detectable (ND) to 180 µg/set, and ND to 230 µg/set, respectively. The surface wipe sample results for o-toluidine ranged from ND to 50 µg/sample; no aniline was detected. Seven process bulk samples were analyzed for the presence of o-toluidine and aniline; four had detectable levels of o-toluidine, while aniline was detected in all seven. Trace amounts of the known human carcinogen, 4-aminobiphenyl, were detected in three of the nine bulk samples analyzed.

At the dye plant the personal TWA air samples ranged from less than 8.7 (limit of detection) to 164 µg/M3 o-toluidine and less than 1.3 to 25 $\mu g/M^3$ for aniline. The area TWA air o-toluidine concentrations ranged from 8.7 to 510 $\mu g/M^3$ and aniline concentrations ranged from less than 1.3 to 34 $\mu g/M^3$. The dermal badge sample results for o-toluidine ranged from less than 28 to 211 $\mu g/M^3$ and aniline concentrations ranged from less than 31 to 55 ~g/M^3. The personal glove samples were all non-detectable.

American Industrial Hygiene Conference & Exposition



Anaheim Convention Center
Anaheim, California
May 21 - 27, 1994

Abstracts

PDCs: May 21 - 22, 1994
Conference: May 21 - 27, 1994
Exposition: May 24 - 26, 1994

Cosponsored by
American Industrial Hygiene Association and American Conference of Governmental Industrial Hygienists