RESEARCH ARTICLE

Comparison of exposure measurements to near field–far field modeled results for benzene and base solvents during a cleaning process using plain or 0.1% benzene spiked toluene and xylene

It has been reported that the presence of ≤0.1% benzene in base solvents often used for cleaning is likely to result in exposure concentrations above the current OSHA PEL. This prediction was based upon calculations that depend largely on the concentration of benzene assumed to be present in a solvent mixture. Measurements of exposure during work simulations and more comprehensive modeling studies show that many factors other than the benzene content of the bulk solvent influence personal and area vapor concentrations. This study examines benzene exposure due to trace amounts of benzene in solvents available recently, and whether exposure in excess of the OSHA benzene standard occurs when 10 and 50 mL of base solvents containing up to 0.1% benzene are used during a manual cleaning process in a poorly ventilated room.

Breathing zone (BZ) concentrations were measured for benzene, toluene and xylene during repetitions of a cleaning procedure using a small cloth to wipe a metal paint tray with 10 and 50 mL of consumer-grade toluene and xylene alone and toluene spiked with 0.1% benzene. Air samples were collected in the breathing zone (BZ) for 15 min to determine the short-term exposure. Separate 2 hr samples were collected in the BZ and general area to obtain time-weighted average (TWA) exposure concentrations. All samples were analyzed with a GC–FID utilizing NIOSH Method 1501.

A near field–far field (NF–FF) model was used in conjunction with Monte Carlo simulation to predict airborne benzene, toluene, and xylene concentrations and to quantify uncertainty in the input parameters of the model. Variables including solvent evaporation time and air movement around the worker during the work activity were analyzed over a range of possible values. The result after 10^5 iterations of Monte Carlo simulation was a range of possible outcomes and the likelihood that each would occur; these outcomes are compared to the measured airborne concentrations.

Cleaning the metal pan with 10–50 mL of toluene or xylene with or without 0.1% benzene did not result in benzene exposures in excess of either the OSHA PEL 8-hr TWA (1.0 ppm) or action level (0.5 ppm). The ratio of predicted or modeled to measured benzene concentration ranged from 0.42 to 2.1. The ratio of predicted or modeled to measured xylene and toluene concentration ranged from 0.92 to 3.7. Application of the NF–FF model under the conditions studied indicates a reasonable degree of reliability in forecasting airborne solvent concentrations under the conditions studied.

1871-5532/$36.00
http://dx.doi.org/10.1016/j.jchas.2012.06.001

By Coreen A. Robbins, Michael W. Krause, Raja H. Atallah, Marc J. Plisko

INTRODUCTION

Benzene is found as an unintentional ingredient in solvents used by industry and consumers due to its ubiquitous presence in feedstock used to manufacture solvents; however, the level of benzene in such products has declined since the advent of the OSHA benzene standard. In 1977, OSHA published a proposed permanent standard of occupational exposure to benzene that required precautionary labeling on all containers of benzene and products containing benzene.[1] In 1978, OSHA amended the benzene standard by exempting from the labeling requirements liquid mixtures already packaged which contain 5.0% or less benzene, and exempt mixtures would be lowered to <0.1% benzene after three years.[2] Starting in 1983, the Hazard Communication standard required labeling of hazardous materials including those containing ≤0.1% of a suspected or confirmed carcinogen[3]; of which benzene was one.[4] Although the amount of benzene as a contaminant in solvents has been reduced over the years, questions have been raised about whether exposure to benzene occurs at or above the OSHA PEL when present at low (<0.1%) or trace concentrations (≤0.01%) in solvents. The 1987 and current OSHA benzene standards require that 8 hr time-weighted average (8 hr TWA) exposures and 15 min short term exposures (15 min STEL) be limited to 1.0 ppm and 5.0 ppm, respectively.[5]

It has been hypothesized that exposures to benzene are "much higher" than applicable standards and guidelines when solvents contain "much less" than 0.1% benzene; and further that a 1 hr TWA benzene concentration can be predicted for workers using benzene-containing solvents based solely on the percent benzene in the solvent being used.[6] This concept has been applied by Kopstein[6] to situations potentially involving similar exposure groups as previously described by Fedoruk et al.[7] However, no studies exist currently that contain measured exposure data that support this proposed relationship between solvent benzene content and resulting exposure. Unlike the exposure prediction technique proposed by Kopstein, exposure models such as the near field–far field (NF–FF) model consider factors besides solvent benzene content that are known to affect worker exposure to benzene (and exposure to solvents in general).[8] These exposure factors include worker distance from the solvent source, room ventilation rate, air mixing, solvent generation rate, and the overall presence of the worker.[9–12] Results of different work simulation studies using the NF–FF model have each found this model predicts reasonably well when compared to the measured solvent vapor concentrations, including benzene.

Recent simulation studies of exposure to solvents or benzene in solvents containing trace or higher levels of benzene have been of two general types. One type has examined benzene exposure during the use of solvent parts washing benches.[7,10,13–15] These operations involve substantial solvent volume (multiple liters or gallons) containing trace amounts of benzene (<0.01%). The other type, similar to our study, examines exposure to benzene through the use of smaller solvent volume (10–150 mL) containing trace or higher amounts of benzene that are sprayed or poured and then often manually wiped on metal parts or machinery to clean them.[16–18] Data from both types of studies have been analyzed or evaluated using the NF–FF model. All such studies indicate that factors influencing the airborne concentration of and exposure to benzene from trace to 0.1% benzene in solvent mixtures include the following: benzene content of the starting product, distance of the sampler/worker from the source, ventilation rate and room air mixing, and work practices and procedures. In the studies using smaller quantities of solvents (10–150 mL) the amount of starting solvent also influences the airborne benzene concentration, though not in direct proportion to starting amount; and while the concentration of benzene in the base solvent did influence the measured exposure concentrations, the results are not a simple or direct function of the benzene content of the solvent. Although none of the studies involving benzene in mixtures up to 0.1% reported measured benzene concentrations in excess of the current exposure limit, most of the currently available data are for studies of solvents that contain less than 0.1% benzene. However, one study did use solvents spiked with over 1% benzene.[18]

Our study was intended to assess benzene exposure during cleaning of a flat metal surface with different starting volumes (10 mL, 50 mL) of aromatic liquid solvents containing either trace (<0.01%) or spiked amounts (0.1%) of benzene; and to compare airborne concentrations of benzene as a function of benzene concentration in the solvent; and finally to assess the applicability of the NF–FF model to predict the concentration of benzene for this type of activity. The measurement of base solvent exposure is reported and results for these compounds are also compared to values obtained with the NF–FF model with

Coreen A. Robbins *is affiliated with Veritox,® Inc., 18372 Redmond-Fall City Rd., Redmond, WA 98052, United States (Tel.: +1 425 556 5555; fax: +1 425 556 5556; email: crobbins@veritox.com).*

Michael W. Krause *is affiliated with Veritox,® Inc., 18372 Redmond-Fall City Rd., Redmond, WA 98052, United States.*

Raja H. Atallah *is affiliated with Dade Moeller & Associates, 1835 Terminal Dr Ste 200, Richland, WA 99352, United States. This work by R. Atallah was completed during his tenure at Veritox,® Inc., DBA: GT Engineering, 18372 Redmond-Fall City Rd., Redmond, WA 98052, United States.*

Marc J. Plisko *is affiliated with Environmental Profiles, Inc., 8805 Columbia 100 Parkway, Columbia, MD 21045, United States.*