

Four volunteers were exposed on nine occasions. For eight of these exposures they wore air-fed half-masks to cut off the inhalation route. The "baseline" conditions were 25°C, 40% relative humidity, with volunteers wearing shorts and T-shirt. For each subsequent exposure, a single parameter was changed: humidity (60%, 30%), temperature (20°C, 30°C) and clothing (minimal, overalls). Finally, a "worst-case scenario" was conducted, combining the individual parameters that produced the highest dermal absorption.

Results show that baseline dermal absorption of 2-butoxyethanol vapor is, on average, 11% of the total absorbed dose. There is some indication that high temperature, high humidity, and minimal clothing might slightly increase absorption (means 14%, 13%, and 12%, respectively). The wearing of whole-body overalls did not attenuate absorption (mean 10%).

The work has shown that dermal absorption of vapors can be significant and that environmental conditions may possibly affect the absorption. Some types of protective clothing might not be suitable in significantly mitigating absorption. The possibility of dermal absorption of vapors should be considered particularly in high vapor concentration situations where control of exposure relies on respiratory protection.

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THE EFFECTS OF BENZO[A]PYRENE-INDUCED SKIN CYTOCHROME P450 ELEVATION ON 3,3',4,4'-TETRACHLOROBIPHENYL PERCUTANEOUS ABSORPTION AND TISSUE DISPOSITION. G. Qiao, NIOSH, Morgantown, WV; J. Riviere, North Carolina State University, Raleigh, NC

Skin metabolism has considerable impact on cutaneous and systemic risk of a topically exposed toxicant by changing its disposition and activity.

Workers could be exposed to both 3,3',4,4'-tetrachlorobiphenyl (TCB) and benzo[a]pyrene via the dermal route. To quantify skin cytochrome (Cyt) P450 induction effects on dermal absorption and local disposition, [<sup>14</sup>C]TCB was topically applied in vivo (n = 3), ex vivo (isolated perfused porcine skin flap, n = 4), and in vitro (flow-through diffusion cells, n = 6-9) to porcine models at 40 mg/cm<sup>2</sup> skin surface with or without Cyt P450 inducer benzo[a]pyrene pretreatment.

It was found that skin Cyt P450 induction enhanced <sup>14</sup>C absorption in all models tested. Total 8-hour ex vivo (0.11%-0.46%) and in vitro (0.21%-0.48%) <sup>14</sup>C absorption was increased 2-4 fold by skin P450 induction. The in vivo excretion via renal and fecal routes accounted for 5% and 9% of the doses. However, if the observation time was prolonged to 11 days as in the in vivo studies, the total absorption was 23%-30% regardless of skin Cyt P450 status, suggesting that the extended observation period may conceal the impact of modified skin metabolism on dermal absorption.

Skin Cyt P450 induction also changed label penetration depth and distribution pattern in local cutaneous tissues, suggesting that the enhanced cutaneous TCB metabolism may change the toxicity profile (cutaneous vs. systemic). On average, 82% of the topical doses were recovered.

It was concluded that the effects of cutaneous metabolism manipulation by pre-exposed or co-administered enzyme inducer(s) such as benzo[a]pyrene need to be taken into account for occupational and environmental dermal risk assessment. The mechanisms for such cutaneous Cyt P450

induction effects on total dermal absorption and disposition need to be further elucidated.

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A DERMAL SAMPLING METHOD FOR MEASURING SKIN EXPOSURE TO MULTIFUNCTIONAL ACRYLATES. L. Nylander-French, J. Surakka, University of North Carolina at Chapel Hill, Chapel Hill, NC

Dermal exposure to skin irritants and allergens, such as acrylates, is significant, but current methods for exposure assessment are insufficient. We have developed and tested a dermal sampling method for measuring skin exposure to a multifunctional acrylate using tape stripping of the nonviable epidermis (stratum corneum), extraction, and quantification by gas chromatography (GC).

We tested this method in 10 human volunteers exposed to 2.5 µL of neat tripropylene glycol diacrylate (TPGDA) or 2.5 µL of neat UV-curable acrylate coating containing TPGDA (UV-resin) at different sites on hands and arms. On average, the first tape stripping removed 94% of the theoretical quantity of TPGDA and 89% of the theoretical quantity of deposited TPGDA in the UV-resin after 30-minute exposures.

Two consecutive tape strippings removed 102% and 113%, of TPGDA or TPGDA in UV-resin, respectively. Coefficient of variation varied between 11% and 16% for all the sites and between 5% and 24% for the individual sites.

In general, recoveries for the first tape stripping were 10%-15% higher for TPGDA than for UV-resin, while the second tape stripping was 10%-15% lower for TPGDA than for UV-resin. However, when the average recoveries in the first tape stripping for TPGDA or TPGDA in UV-resin from the five different individual sites were compared, no significant difference was observed (p = 0.111 and p = 0.893, respectively).

No significant difference was observed in recovery between TPGDA and UV-resin for the first tape stripping when calculated as of percentage of the theoretical amount (p = 0.262). This tape-stripping method provides a simple and affordable noninvasive method for quantifying recent dermal exposures to multifunctional acrylates for exposure assessment.

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PREDICTING DERMAL EXPOSURE TO JET FUEL (NAPHTHALENE) USING AN ADHESIVE TAPE-STRIPPING METHOD. D. Mattorano, L. Nylander-French, University of North Carolina, Department of Environmental Sciences and Engineering, School of Public Health, Chapel Hill, NC

A noninvasive dermal sampling procedure was developed and tested to predict dermal exposure to jet fuel using tape-stripping of the nonviable epidermis (stratum corneum), extraction, and quantification by gas chromatography/mass spectrometry (GC/MS). Naphthalene was used as a marker for jet fuel (JP-8) exposure.

The method was tested in 20 human volunteers (10 male and 10 female) exposed to 25 µL of jet fuel (neat) at two sites on the ventral surface of each arm (four sites total). One additional site per arm was selected as an unexposed control area.

Jet fuel was applied by using an aluminum application chamber and a calibrated micropipette. Cover-Rollâ adhesive tape (BeiERSdorf AG, Germany), pre-cut in size to 2.5 cm × 4 cm, was applied to the exposed or unexposed site. After two minutes, the

Cover-Rollâ tape was removed carefully by pulling at an angle of 45° using clean forceps.

The samples were collected 5, 10, 15, or 20 minutes after fuel application. The tape-stripping samples were placed in vials containing 5 mL acetone and sealed for storage until analyzed. The data collected were fit to a second-order polynomial model. This model was able to predict the amount of jet fuel initially applied to skin when taking into account evaporation, perfusion away from the application site, and loss due to residual agent remaining on chamber walls after removal from the skin.

These results indicate that the tape-stripping technique developed can be used to predict dermal exposure to jet fuel.

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FACTORS INFLUENCING FILTER PENETRATION AND QUALITY. C. Chen, S. Huang, National Taiwan University, Taipei, Taiwan Republic of China; C. Chen, Institute of Occupational Safety and Health, CLA, Taipei, Taiwan Republic of China; Y. Huang, Center for Industrial Safety and Health Technology, ITRI, Hsinchu, Taiwan Republic of China

Air filtration is a complex process, so the establishment of an effectual filter test protocol is never an easy task. In the present study, a theoretical model is used to examine the factors that might affect the filtration characteristics of filters for respiratory protection.

The major operational parameters included face velocity, fiber diameter, packing density, filter thickness, and fiber charge density. The characteristics of the most penetrating size were demonstrated under the same ranges of operational parameters.

The results show that aerosol penetration through filter media increases with increasing face velocity or fiber diameter, and decreases as packing density, thickness, or fiber charge density decrease. The face velocity and fiber charge density have more significant effects on the filter quality than the other factors. The filter quality increases with decreasing face velocity or increasing fiber charge density.

For electret filters, the most penetrating size increases with increasing fiber diameter. The increase in packing density, thickness, and fiber charge density would cause the most penetrating size to decrease. The most penetrating size through electret filters increases with increasing filtration velocity or decreasing filter thickness, whereas for non-electret filter media the most penetrating size increases with decreasing face velocity and is not affected by the filter thickness.

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POWERED AIR-PURIFYING PARTICULATE RESPIRATOR FILTER PENETRATION BY DOP AEROSOL. S. Martin, E. Moyer, NIOSH, Morgantown, WV

With the inception of 42 CFR 84, the old 30 CFR 11 regulations for nonpowered, air-purifying particulate respirators were replaced with new, more demanding certification requirements. However, the updated 42 CFR 84 regulations only changed the requirements for negative-pressure particulate respirators. The certification requirements for powered air-purifying respirators (PAPRs), were copied directly from 30 CFR 11 without any major changes. PAPR filters are still certified based on their performance using the silica dust test.

An alternative testing protocol to the silica dust test was evaluated. Approved PAPR filters were tested against the updated 42 CFR 84 criteria to compare PAPR filter performance with that of newly approved negative-pressure particulate filters.

High-efficiency PAPR filters from different manufacturers were tested using a new TSI Model 8122 Automated Respirator Tester®. The 8122 tester produces a liquid dioctyl phthalate (DOP) aerosol that meets the requirements set forth in 42 CFR 84. New PAPR filters were tested against "neutralized" and "non-neutralized" DOP aerosols.

All of the tests were run eight hours a day for at least four days, and each test incorporated a weekend where the filter was untouched. Two manufacturers' filters never exceeded the 0.03% penetration threshold, while the third manufacturer's filters did exceed 0.03% penetration, but only after loadings of approximately 12,000 mg DOP.

The results from these tests were compared with new 42 CFR 84-certified P100 electrostatic filters that were tested on the TSI 8122 in the same fashion. When possible, these results were compared with results obtained from TSI 8110 and TSI 8130 instruments, which are used for 42 CFR 84 certification.

All PAPR filters certified by the silica dust test met the current requirements for P100 negative-pressure particulate filters and maintained a 99.97% filter efficiency level up to high DOP loads. Thus, this testing protocol may be an alternative to the current silica dust test.

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**COLLECTION EFFICIENCY COMPARISON OF DISPOSABLE ELECTROSTATIC RESPIRATORS SATURATED WITH ARTIFICIAL PERSPIRATION.** D. Larson, California State University, Sacramento, CA; A. Biermann, Lawrence Livermore National Laboratory, Livermore, CA; R. Buchan, Colorado State University, Fort Collins, CO

Electrostatic media are widely used in filtering facepiece respirators due to their economical cost, enhanced filtration efficiency, and reduced breathing resistance. These respirators, when worn in hot environments, can easily become saturated with the user's perspiration. Perspiration contains ions in solution that could potentially interact with the charge on the electrostatic filter media and reduce the respirator's collection efficiency.

Filtration efficiencies of five N95 filtering facepiece respirators were evaluated, one mechanical and four electrostatic. Collection efficiencies were determined by challenging the respirators with a dilute concentration of charge-neutralized sodium chloride aerosol meeting the criteria of 42 CFR 84. Penetration was measured with both a condensation nucleus counter (CNC) and a photometer.

After the respirator was sealed to its holder, it was submerged in a container filled with artificial perspiration, where it remained for 40 minutes. The wetted respirator was subsequently dried using HEPA-filtered air with a relative humidity (RH) of approximately 22%. Once the RH of the downstream air reached 25%, drying was terminated and respirator penetration was remeasured. Differences between the pre- and post-saturation penetration measurements were compared using a paired-t test.

The overall effect on the collection efficiencies of filtering facepiece respirators submerged in artificial perspiration followed by drying with HEPA-filtered air was unchanged. CNC-measured penetration for two electrostatic respirators improved significantly ( $p < 0.05$ ). Penetration, as measured by the pho-

tometer, was significantly decreased for the mechanical respirator, whereas the performance of one electrostatic respirator improved. The performance of filtering facepiece respirators that become damp from the user's perspiration would be expected to remain unchanged once the wetted respirator has been completely dried.

Work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

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**REVIEW OF AND PROPOSALS FOR CORRECTION FACTORS FOR ESTIMATES OF SERVICE LIVES OF ORGANIC VAPOR AIR-PURIFYING CARTRIDGES: I. RELATIVE HUMIDITIES.** G. Wood, Los Alamos National Laboratory, Los Alamos, NM

Service-life estimation models have received much attention since OSHA changed philosophy and regulations in 1998 to allow predictive models to be used in setting change-out schedules. Several manufacturers of respirator cartridges (and OSHA itself) have published website calculators or have distributed computer programs to implement the so-called "Wood Model." However, because of the theories and databases used, this model was originally limited to dry use (<50% relative humidity) conditions. Some of these model implementations include relative humidity (RH) correction factors. However, none of these correction factor schemes fully takes into account all the experimental data available.

A thorough review and analysis of RH effect data and models has been completed. This information has been used to derive a RH correction model that incorporates relative humidity, vapor concentration, vapor volatility, and duration of cartridge use.

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**REVIEW OF AND PROPOSALS FOR CORRECTION FACTORS FOR ESTIMATES OF SERVICE LIVES OF ORGANIC VAPOR AIR-PURIFYING CARTRIDGES: II. VAPOR MIXTURES.** G. Wood, Los Alamos National Laboratory, Los Alamos, NM

Since OSHA changed philosophy and regulations in 1998 to allow predictive models to be used in setting change-out schedules, service-life estimation models have received much attention. Several manufacturers of respirator cartridges (and OSHA itself) have published website calculators or have distributed computer programs to implement the so-called "Wood Model." However, this is currently a single-vapor service-life prediction model.

Some rules-of-thumb have been proposed to account for mixtures of vapors, but these have little theoretical or experimental basis. A large body of equilibrium adsorption capacity data and theories exists for mixtures. There are fewer studies of adsorption rates and breakthrough times of mixtures in air flowing through carbon beds (such as respirator cartridges).

All of the available data and theories have been reviewed and evaluated for usefulness in developing service-life correction factors for components of organic vapor mixtures. A model is proposed that takes into account vapor properties, vapor concentrations, and duration of cartridge use.

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**STUDY ON ACCURACY AND VALIDITY TESTS FOR VARIOUS PREDICTION MODELS FOR GAS AND VAPOR RESPIRATOR CARTRIDGE SERVICE LIVES.** D. Park, Hansung University, Seoul, Republic of Korea; J. Park, Seoul National University, Seoul, Republic of Korea

Most breakthrough tests are conducted at higher concentration levels compared with those in the field of air-purifying respirator applications. For example, typical challenge concentrations for breakthrough tests against carbon tetrachloride are ranged between 250 ppm and 1000 ppm, although the applicable concentration range for air-purifying cartridges is 5-50 ppm for carbon tetrachloride. However, no guarantee has been made that isotherms derived from the experiment at high challenge concentrations could estimate adsorption capacity at the lower concentration range where workers usually wear air-purifying respirators.

Three models of adsorption isotherms (Freundlich, Langmuir, and Dubinin/Radushkevich [D/R] isotherms) commonly applied for respirator cartridge testing were evaluated. Adsorption capacity at each challenge concentration was calculated from the Reaction Kinetic equation fitted for the breakthrough data. These data were used for derivation of three isotherms.

In general, the D/R isotherm has given the best agreement between estimated adsorption capacities and those experimentally measured. If the challenge concentration of 100 ppm is included for derivation of models, Freundlich and D/R models could successfully produce good estimations for adsorption capacities at the 50 ppm level.

Estimated adsorption capacities by both models ranged between 94% and 109% of those experimentally measured. However, the Langmuir model underestimates in all cases.

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**AN EVALUATION OF A QUALITATIVE FIT-TEST AGENT (BITREX) TO DETECT EXHALATION VALVE LEAKAGE IN FULL-FACEPIECE RESPIRATORS.** R. McKay, University of Cincinnati, Cincinnati, OH; C. Rodriguez, PDVSA Services Inc., Maturin, Estado Monagas, Venezuela

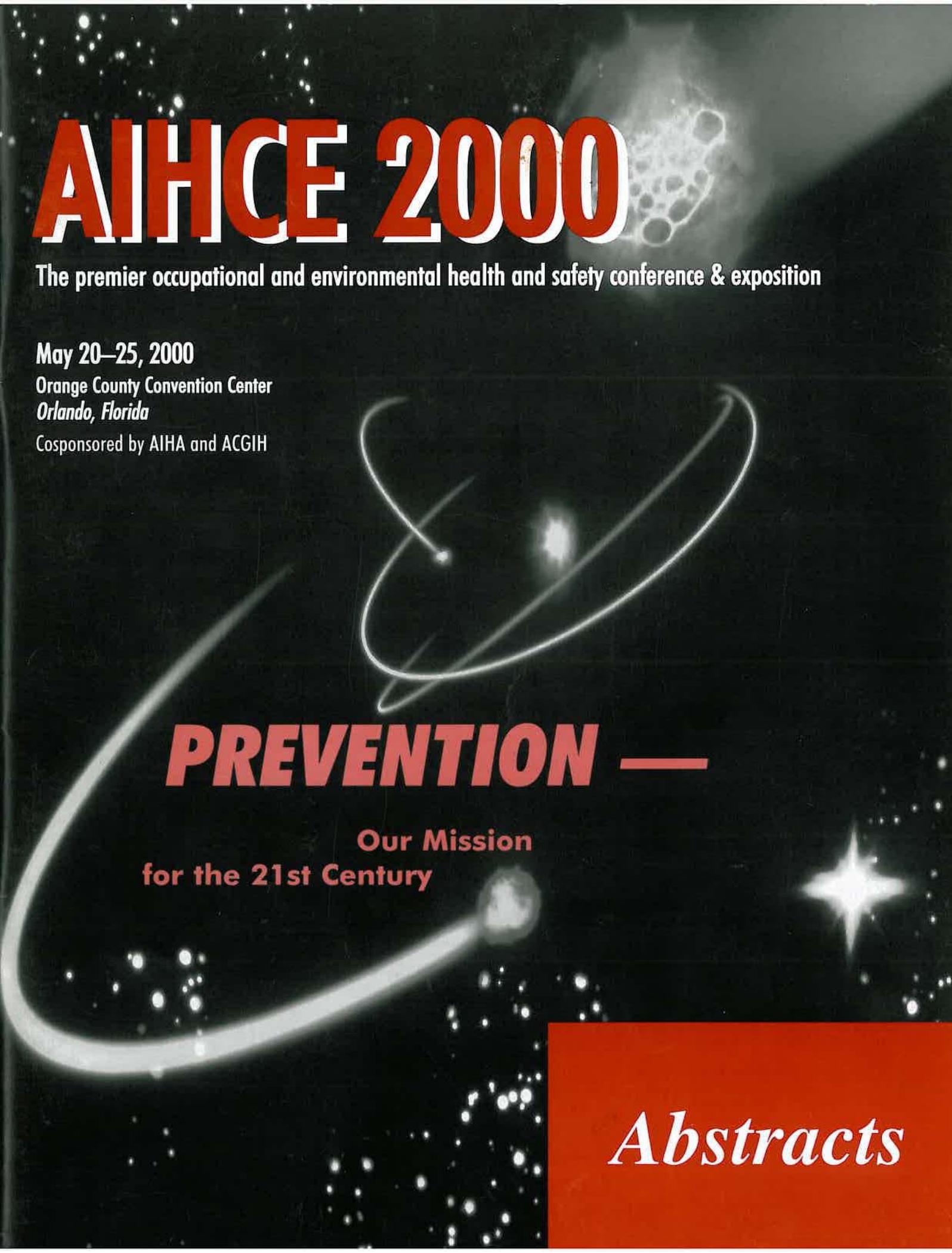
In this study, a qualitative fit-test agent (Bitrex) was evaluated for its ability to be detected by full-facepiece respirator wearers with leakage induced at the exhalation valve retainer. Prior to inducing leakage, 26 subjects wearing full-facepiece respirators were quantitatively fit-tested using controlled negative pressure (CNP) to verify successful fit.

The CNP leak rate for these 26 subjects was 40 ( $\pm 27$ ) mL/min, which is equivalent to a mean fit-factor of 11,072. Afterward, a controlled leak was induced by loosening (i.e., turning) the exhalation valve retainer until a nominal fit-factor between 60 and 100 was obtained by CNP.

This type of respirator leakage was selected because it had been observed in workers during field studies. The CNP leak rate for the "leaking" respirators was 1089 ( $\pm 128$ ) mL/min, which is equivalent to a fit-factor of 87. A qualitative fit-test using a commercial solution of Bitrex was then conducted following the OSHA protocol with the exception of substituting the head-straight-normal breathing maneuver for the entire protocol. This exception was made to prevent additional sources of unknown leakage that could possibly be introduced by different head and breathing maneuvers.

Results from these studies revealed that only 23% of the subjects were able to identify the taste of the

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