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Quantification of Perceptual Effects for Personal Protective Equipment

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Auditory-based measurement standards and specifications essential for quantifying the effects of personal protective equipment (PPE) on hearing are generally nonexistent. Quantification of perceptual effects on the auditory system is necessary to understand how wearing any given PPE can change awareness of one's environment. In many situations where PPE is worn, users must rely heavily on amplitude, pitch, and localization cues to avoid danger or harm. Methods were developed to characterize and measure important auditory parameters affected when PPE is worn. Parameters such as attenuation, head-related transfer functions, interaural level differences, interaural time differences, PPE-created noise, and speech transmission effects were evaluated and quantified for several PPE systems and subsystems. Theoretical relationships to human perceptions were also made using the above quantifications. From these measurements and characterizations, design suggestions are given that will enable manufacturers to develop PPE with improved auditory performance and fidelity. Additional efforts will provide practical PPE auditory measurement and performance standards, as well as ratings to increase the available database of auditory specifications.

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Derivation of Dermal Vapor Protection Factors for Chemical Warfare Agents: NFPA 1994 Class 2 Nonencapsulating (Level B) CBRN Chemical Protective Ensembles

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The U.S. Army operates and maintains storage and disposal facilities for chemical warfare agents (CWAs), including blister and nerve agents. Personal protective equipment worn by personnel performing CWA operations and maintenance activities include Level A and Level B military chemical protective ensembles (CPEs). CPEs are certified for use with chemical, biological, and radiological particulates (CBRN) under NFPA Standard 1994, "Protective Ensembles for First Responders to CBRN Terrorism Incidents." They include Class 1 CPEs (fully encapsulating suits with NIOSH-certified SCBAs, analogous to Level A) and Class 2 CPEs (chemical-resistant suits/hoods, gloves, and boots with NIOSH-certified SCBAs, which are similar to Level B). An evaluation was conducted to determine if certified NFPA 1994 Class 2 "nonencapsulating" CPEs could provide adequate dermal vapor protection at CWA levels above the two-hour maximum use concentrations (MUCs), which are used as guidance for upgrading to Level A protection. NFPA 1994 requires that CPEs meet various performance criteria, including a test protocol that utilizes a vapor simulant under laboratory conditions. This protocol was adopted from ASTM F 2588, "Standard Test Method for Man-In-Simulant Test (MIST) for Protective Ensembles." CPEs are tested in a chamber under dynamic conditions to assess the level of vapor penetration. Dosages are determined with personal adsorbent devices that are placed on the skin of human test subjects at specific locations on the body, while the subject performs physical exercises wearing the suit. The dosage data is used to calculate a series of local physiological dosage factors ($PPDF_i$) and a systemic physiological protective dosage factor ($PPDF_{sys}$) for the ensemble. $PPDF_i$ and $PPDF_{sys}$ values were back-calculated for selected CPEs, using two-hour exposure times (vs. the standard 30-minute MIST duration). Estimated protection factors were then derived and used to develop adjusted two-hour MUCs for dermal vapor protection against selected CWAs.

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An Improved Approach for Using Permeation Test Data in Glove Selection

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Relating laboratory glove permeation test results to practical real-world glove use recommendations has been problematic for industrial hygienists for many years. Glove users will often go to the manufacturers' glove selection charts and simply select a glove with the highest breakthrough time on the chart, adhering to the overly simplistic view that breakthrough time is the same as glove use time and is the primary factor when selecting a glove. We will report that a different approach has been developed that can better serve the practical needs of the end user. The approach is based on the concept that permeation test data are best used in the first step of selection to establish the set of glove materials that provide an adequate chemical barrier. The approach to be discussed involves a "weight of evidence" approach to evaluating glove materials. Instead of looking only at the breakthrough time for a particular make and model of glove, this new approach systematically generates a calculated index that takes into account the thickness-normalized breakthrough time and permeation rate data available for all gloves of a particular material. The result is, in effect, a property of the barrier material itself, instead of a property of a particular make and model of glove. To enlarge the data pool, the approach also facilitates the inclusion of data on chemicals of similar size and chemical functional group. We also will discuss how this approach has been used to produce glove material use statements for material safety data sheets.

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Critical Heat Stress Evaluation of Clothing Ensembles with Different Levels of Porosity

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Protective clothing is known to influence the level of heat stress experienced by the user. The progressive heat exposure protocol provides a method to estimate the critical WBGT above which thermal equilibrium is difficult to maintain and to estimate the apparent total evaporative resistance of the clothing ensemble. Both the WBGTcrit and the Re,T,a are useful for comparing the effects of protective clothing ensembles under heat stress conditions. The hypothesis of this study was that increases in air permeability through levels of porosity will influence the convective transfer of heat (convective mass transfer of water vapor instead of diffusive transfer). The prototype military protective clothing ensembles had six levels of porosity (0, 1, 2, 5, 10, 20%) and the control ensembles were work clothes and a typical military chemical protective ensemble. Six men wore each of the ensembles while walking at a metabolic rate of 160 W/m^2. There were no statistically different means of WBGTcrit (34°C-WBGT) and the Re,T,a (0.014 m^2 kPa/W) for the prototype coveralls with 2% or more porosity and work clothes. Likewise, the Saratoga and prototype with no porosity were not different (31°C-WBGT and 0.022 m2 kPa/W). While not statistically significant, there was good evidence that the prototype with 1% porosity performed at an intermediate level (33°C-WBGT and 0.016 m^2 kPa/W). Thus, there was a progression of lower heat stress with increasing porosity, but the level of porosity reaches diminishing returns above 2%.

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Whole-Glove Permeation Testing of Disposable Gloves with Simulated Movement

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According to NIOSH, more than 13 million workers are exposed to chemicals that can be absorbed through the skin. In addition, about 2.9 million workers suffer from dermatitis each year in the United States. One critical gap in knowledge is the protection afforded by chemical protective clothing under worker-use conditions. The aim of this study was to develop a method to conduct whole-glove chemical permeation testing with simulated movement. First, a novel method was developed to measure bi-directional stretching at the different regions of the glove. Measurements were taken on gloved hands with both extension and flexion hand postures. The gloves were then inflated using pressures ranging from 0.06 to 0.12 inches of water to determine the optimal pressure that would simulate the hand postures. A three-inch outer collar was used at the cuff to restrict inflation in this region. Inflation and deflation of the glove were controlled using an available pneumatic controller. Permeation testing of disposable nitrile gloves was conducted using ethanol. Continuous monitoring was performed with a photoionization detector in a closed loop. The normalized breakthrough time (NBT) was 12.5 ± 1.9 min with movement and 14.6 ± 2.2 min without ($p \leq 0.05$). The steady-state permeation rate was 10.5 ± 1.6 $\mu g/cm^2/min$ with movement and 8.7 ± 1.1 $\mu g/cm^2/min$ without ($p \leq 0.05$). Overall, whole-glove movement decreased the NBT by more than 14%, and increased chemical permeation by greater than 20%. For a 30-minute exposure, the average permeation rate with movement (2.6 ± 1.3 $\mu g/cm^2/min$) was twice ($p \leq 0.05$) that without movement (1.3 ± 0.7 $\mu g/cm^2/min$). Simulated hand movement significantly affected the permeation of ethanol through a disposable nitrile glove. The methods developed in this study can be used to evaluate whole-glove performance and the influence of hand movement on chemical permeation.

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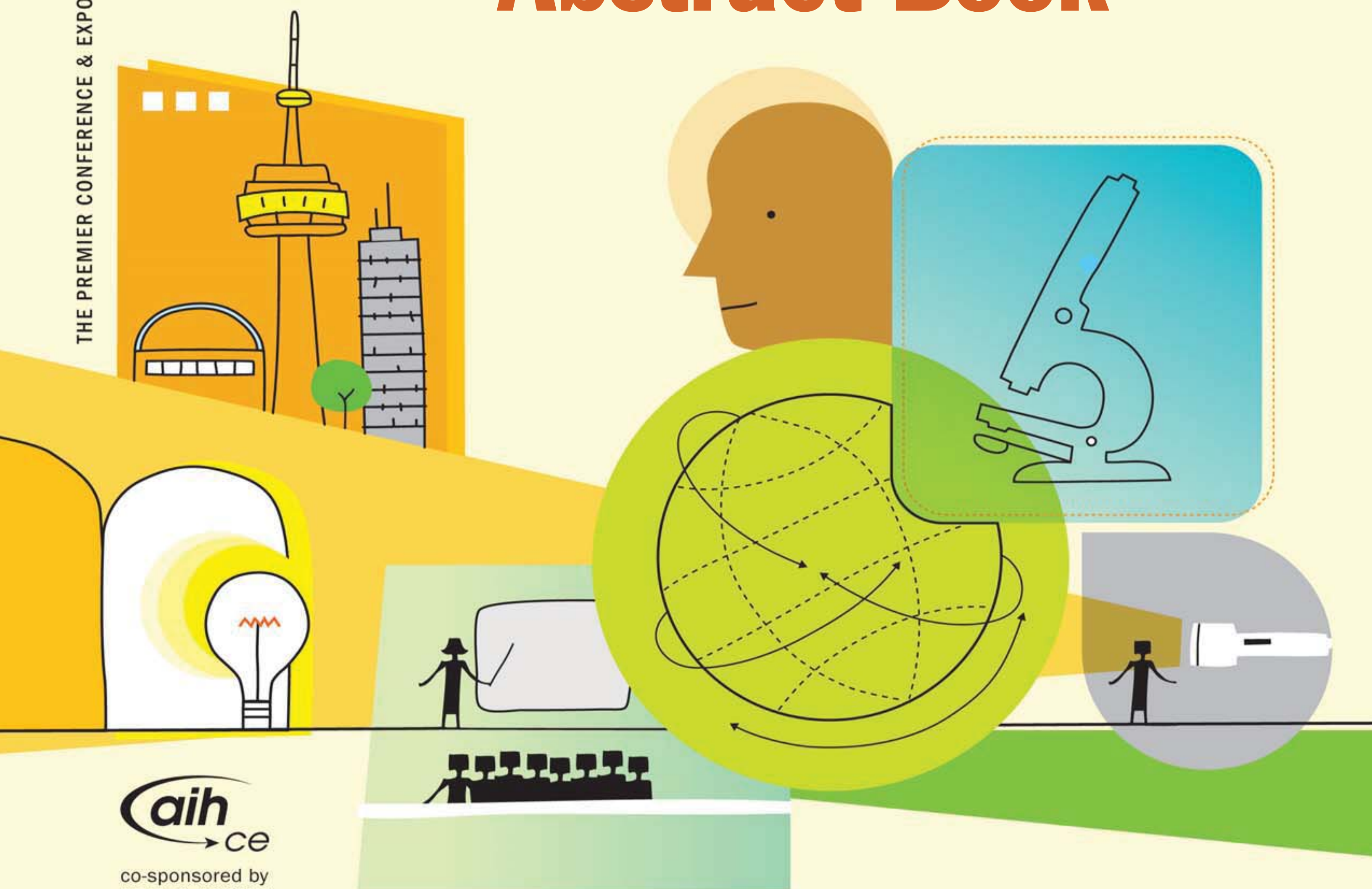

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