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Applied Occupational and Environmental Hygiene

ISSN: 1047-322X (Print) 1521-0898 (Online) Journal homepage: https://www.tandfonline.com/loi/uaoh20

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Thomas D. Klingner & Mark F. Boeniger

To cite this article: Thomas D. Klingner & Mark F. Boeniger (2002) A Critique of Assumptions About Selecting Chemical-Resistant Gloves: A Case for Workplace Evaluation of Glove Efficacy, Applied Occupational and Environmental Hygiene, 17:5, 360-367, DOI: 10.1080/10473220252864969

To link to this article: https://doi.org/10.1080/10473220252864969

Published online: 30 Nov 2010.

Applied Occupational and Environmental Hygiene
Volume 17(5): 360–367, 2002
1047-322X/02 $12.00 + .00

A Critique of Assumptions About Selecting Chemical-Resistant Gloves: A Case for Workplace Evaluation of Glove Efficacy

Thomas D. Klingner[1] and Mark F. Boeniger[2]
[1]Colormetric Laboratories, Inc., Des Plaines, Illinois; [2]National Institute for Occupational Safety and Health, Cincinnati, Ohio

Wearing chemical-resistant gloves and clothing is the primary method used to prevent skin exposure to toxic chemicals in the workplace. The process for selecting gloves is usually based on manufacturers' laboratory-generated chemical permeation data. However, such data may not reflect conditions in the workplace where many variables are encountered (e.g., elevated temperature, flexing, pressure, and product variation between suppliers). Thus, the reliance on this selection process is questionable. Variables that may influence the performance of chemical-resistant gloves are identified and discussed. Passive dermal monitoring is recommended to evaluate glove performance under actual-use conditions and can bridge the gap between laboratory data and real-world performance.

Keywords Occupational, Glove Performance, Chemical Protection, Skin Protection, Chemical-Resistant Gloves

Selecting chemical protective clothing (CPC), especially chemical-resistant gloves, can be a complex process of weighing and optimizing many variables. The foremost consideration for the occupational hygienist should be the efficacy of the selected CPC in protecting the worker under a particular condition of use. The selection process becomes complicated when multiple solvents and chemicals are used, environmental conditions are unusual, or the task performed induces unusual stress on the protective barrier. Evaluation of laboratory-generated chemical permeation data is a useful first step in the selection process, but it is often limited to common toxic chemicals encountered in the workplace. Even when such data are available, they may be of marginal use when needing to determine the duration of use before hazardous overexposure occurs.

A common shortcoming among those who are responsible for selecting CPC is that only breakthrough time and permeation rate might be considered. These kinetic data do not take into account the toxic effects of the compound on the body or the skin. Considering the toxicity of the potential exposure is a critical aspect of any hazard assessment.

As complex as the decision can be for selecting the glove with the best chemical barrier properties, this is only one factor that must be considered. Cost is always a consideration. The expense of CPC varies significantly depending on the material and the manufacturer. The purchase of inferior barrier materials may produce short-term cost savings, but it may result in higher, long-term costs if injuries and illnesses result. Worker productivity and comfort must also be considered. Workers on the plant floor will avoid gloves or clothes that are uncomfortable or too bulky. Efficacy, cost, productivity, user comfort, and the type of hazard involved must all be considered in CPC selection.

The purpose of this article is to highlight factors that could affect the performance of CPC and to use these concerns to support the proposition that in-use testing is needed to verify performance assumptions. The promise of this approach is that actual performance can then be weighed against cost to achieve the most appropriate health and economic benefit. Without in-use testing, workers could be poorly protected and both workers and employers subject to the consequences of exposures that could have been prevented.

SIGNIFICANCE OF THE PROBLEM

The idea that permeation is an important factor when determining the adequacy of CPC should be tempered by the realization that the skin is insensitive to detect subtle glove breakthrough during the use of the glove. Unlike airborne exposures, which may have an odor to warn of exposure, immediate sensation is not associated with most skin exposures, especially if occurring because of molecular permeation or liquid penetration through gloves. Use of chemical protective gloves typically cause the hands to perspire, masking the sensation of chemical exposures. Often a glove will not display physical signs of breakthrough, such as puckering or degradation, even after permeation occurs. Thus, except for corrosives or primary irritants, the human skin is ill-equipped to detect skin exposures when wearing gloves. Objective means of doing so are needed.

Chemical protective gloves and clothing are necessary when chemical exposure to the skin would otherwise result in adverse health effects, namely irritant dermatitis, allergic sensitization, or systemic toxicity. Since hands often contact hazardous chemicals and contaminated surfaces, gloves are second only to safety shoes as the most frequently required protective equipment.[1]

In recognition of the importance of this problem, several performance standard organizations, such as the American Society for Testing and Materials (ASTM), the European Committee on Standardization (CEN), and the International Standards Organization (ISO), have formed long-standing technical committees to assess and improve the glove selection process. In the United States, chemically resistant gloves are typically selected based on laboratory permeation testing following ASTM Method F 739.[2] Permeation is defined as the molecular diffusion of chemicals through a medium—in the case of CPC, the medium is the polymeric matrix. The purpose of this method is to determine the relative resistance of a material (chemical protection) to permeation of selected chemicals. This method does not consider the toxicity of chemicals or other factors of performance.

Skin Notations

Several recognized organizations have provided skin hazard designations to warn against the potential for increased risk of systemic toxicity due to skin permeation. These designations are assigned to certain compounds for which inhalation exposure limits have been established. The American Conference of Governmental Industrial Hygienists (ACGIH®) lists more than 170 chemicals with a skin hazard designation that supplements the threshold limit values (TLVs®) for inhalation concentration; the United States Occupational Safety and Health Administration (OSHA) listed 147 skin notations on the 1989 permissible exposure limit (PEL) tables. About 13.2 million workers in the United States are potentially exposed to chemicals with the OSHA skin notation.[3] By comparison, a European Economic Commission–sponsored survey in 1990 identified 275 chemicals listed by various countries as skin absorption hazards.[4]

In the United States the number of compounds with the potential to cause skin damage or systemic toxicity and used in the workplace may far exceed the number indicated by skin notations. This is illustrated by an evaluation of 132 chemicals with a TLV; 92 percent were calculated to be capable of significant dermal absorption and toxicity based on their skin permeation potential, but only 35 percent of the 132 chemicals carried a skin notation.[5]

The *NIOSH Pocket Guide to Chemical Hazards* recommends protecting the skin on about 450 of the organic chemicals listed. However, compounds that are hazards to the skin (chemical irritants or allergic sensitizers) are generally not assigned a skin notation in the United States or Europe. Yet the effect of skin exposure to irritants and sensitizers found in the workplace can be significant in terms of personal discomfort and lost income as well as reduced productivity and profit to the employer.[6]

Occupational Skin Disorders

The problem of dermatitis is widespread in many occupations. The incidence of new dermatitis cases in some occupations (such as hairdressers) is reported to be as high as 25 per 1000 workers per year, and the prevalence of cases may be 20 percent to 50 percent or more in medical, nursing, and professional cleaning occupations.[7–9] Given the large number of commercial products identified as potential irritants or sensitizers, the contribution of chemical exposures to occupational dermatoses should not be surprising. For instance, a recent search by the authors of more than 77,000 material safety data sheets (MSDSs) found reference to skin irritancy or skin sensitization in about 50 percent of the records. The Finnish Ministry of Labour lists some 3500 products containing potential skin sensitizers and 35,000 products that may cause skin irritation among a total of 97,000 products registered in that country.

The National Institute for Occupational Safety and Health (NIOSH) has included allergic and irritant dermatitis as a priority research item for the next decade. NIOSH estimates that skin disease accounts for 15 percent to 20 percent of all reported occupational disease. From 1983 to 1994, the rate of occupational skin diseases increased from 64 to 81 cases per 100,000 workers with an estimated annual cost of $1 billion.[10] According to the latest available data, dermatitis is the third most common cause of compensable temporary disability and the sixth most common cause of permanent partial disability in the United States.[11] To what extent skin absorption contributes to other possible causes of disability such as nervous system disorders, ill-defined conditions, and systemic poisoning is unknown. A full understanding of the health significance of skin exposure leading to systemic toxicity is far less clear because of the difficulty in objectively determining cause and effect, the chronic nature of many occupational diseases, and possibly the reluctance of employers to publish cases of illness that resulted from inadequately identifying and preventing chemical overexposures.

Despite recognition of the problem and the efforts to test protective clothing, approximately 2.9 million U.S. workers experience occupationally induced allergic and irritant dermatitis each year.[10] England's Health and Safety Executive reported from their 1990 Labour Force Survey that, of the estimated 85,000 skin disease cases, 54,000 (64%) were believed to be caused by work and 30,000 cases were made worse by work.[12] The number of cases qualifying for disability benefits has steadily increased in the past several years. During the period 1979–1989 in Denmark, occupational dermatitis accounted for 41 percent of all occupational diseases recognized by the National Board of Industrial Injuries. Of those cases, 64 percent received compensation for permanent injury, and 11 percent received compensation for loss of earning capacity.[13]

Controlling Skin Exposures in the Workplace

CPC should not be the first or sole approach considered for controlling chemical exposures to the skin, but, instead, the last option after process design and engineering controls prove not to protect workers adequately. Improper use of even properly selected CPC carries risks of increasing exposure if the skin is already contaminated, as well as risks of potential irritant response from chronic occlusion and allergic response from chemicals used to produce the CPC. These inherent risks from using CPC (along with worker discomfort, reduced productivity, donning and doffing time, generation of contaminated solid wastes, and costs of replacement) should be carefully considered before requiring CPC as part of the standard operating procedures. These costs of CPC should be weighed against the opposing risks of not using CPC. Although the risk analysis and decision process is very important, it has been discussed by others elsewhere and is not the focus of this article.[14] Rather, this article suggests possible approaches for verifying the in-use performance of CPC that could optimize the resources expended on CPC and maximize its protective function. For the sake of simplicity, this article focuses on evaluating the performance of chemical resistant gloves since they are the most common type of CPC.

GLOVE SELECTION INFORMATION AND PROCEDURES

Glove Performance Data

Numerous studies have been published reporting chemical permeation rates through various types of glove materials. Glove manufacturers often supply permeation data charts to aid in the glove selection decision. In spite of this effort, in 1989 a comprehensive review of existing performance data on chemicals listed by OSHA with a "skin" designation revealed that glove permeation testing data was reported for only 40 percent of these chemicals.[15] For 60 percent of these chemicals, no published permeation test data existed at that time.

A perusal by the authors of a 1998 compilation of the glove permeation data indicated that there continue to be limited test data for some major compounds and, in several cases (e.g., piperazine), the data indicate unacceptability of all the glove materials tested.[17] Of the approximately 450 organic chemicals listed in the 1997 *NIOSH Pocket Guide to Chemical Hazards* where it is recommended to protect the skin, a recommendation for specific glove material could be provided for only 39 percent.[17] For those compounds where a glove type was recommended, 47 percent of the recommendations for glove material were for PE/EVAL colaminate (e.g., 4H or Silver Shield) or Teflon polymers. Unfortunately, these latter materials are either uncomfortable to wear, lack good tactility, are expensive, or (as in the case of Teflon) are presently difficult to purchase. Thus, for less than 21 percent of the organic chemicals listed in the *Pocket Guide* where preventing skin contact is recommended is a glove such as natural rubber, polyvinyl chloride, butyl rubber, nitrile, or neoprene recommended. Another problem with the published kinetic data is that great inconsistencies in glove performance are sometimes reported for compounds with similar chemical properties (e.g., dimethylamine, diethylamine), and a wide range of test values may be reported by different laboratories for similar glove materials. In such cases, the person responsible for selecting the appropriate glove would find it difficult to make a decision on the basis of the available information.

The lack of glove material recommendations for the majority of chemicals reflects the lack of a standard method for testing breakthrough and permeation of chemicals with low vapor pressures. The ASTM Method F 739 works only with liquids and gaseous compounds. Water may be used as the receptor fluid but the permeants must be appropriately soluble in water to be collected for analysis. A common misconception is that dry materials (e.g., powders, flakes, etc.) cannot permeate polymeric barriers. However, testing of dry powders against common polymers indicated that compounds such as benzoquinone, dinitrocresol, naphthalene, dichlorobenzene, p-nitrotoluene, and phenol can be detected permeating common gloves made of natural rubber, polyvinyl chloride, polyurethane, or neoprene in as few as four minutes. In few cases were any of the tested gloves able to prevent breakthrough for more than one hour.[18] A more accurate understanding is that the permeation of low volatility, nonliquid chemicals has not been adequately tested.

Glove Selection Guidance

In the United States, there are regulatory requirements for selecting appropriate CPC. The recently revised OSHA personal protective equipment standard briefly addresses the important issue of CPC selection. This standard requires selection of appropriate CPC based on the results of a hazard assessment that includes consideration of "the task(s) to be performed, conditions present, duration of use, and the hazards and potential hazards identified."[19]

OSHA's hazard communication standard requires chemical suppliers to provide an MSDS with all purchases of chemical products.[20] MSDSs are required to indicate the need for appropriate personal protective equipment to protect workers from potentially adverse effects of working with the product when the effects are known. The often-stated requirement for "use of impervious gloves" is of little assistance to the customer. However, chemical suppliers cannot always know what other chemicals or environmental conditions will be present that could affect the performance of gloves, so they may be justified in not specifying the type of glove material to be used. For chemical suppliers, recommending a generic glove type could be a mistake that could adversely affect the health of the glove user. Therefore, the burden of selection is ultimately placed on the customer, who is most familiar with the conditions in which chemicals are used. As will be seen in the following section, there are many conditions that may potentially affect the performance of gloves and confound the interpretations drawn from laboratory testing.

CONFOUNDING FACTORS TO LABORATORY TESTING DATA

ASTM permeation test data supplied by the glove manufacturer typically forms the basis for glove selection and estimated duration of use before permeation occurs. Careful examination of published literature brings into question the adequacy of this selection process due to several potential variables encountered in the workplace that can influence glove performance.

Mixtures

Most published glove permeation results are based on tests performed with a single chemical. However, many job-related activities involve the use of multiple chemicals or mixtures. Laboratory test data performed with binary mixtures of solvents showed that breakthrough times depended on the solvent component that most readily permeated the glove.[(20)] Mickelson et al. demonstrated "an increase in employee risk resulting from early mixture breakthrough time and enhanced permeation rate over that of the pure chemicals."[(21)] Because of the varying degree in which cosolvent interactions occurred, permeation of a mixture could not be predicted from the results of the pure components. Thus, the adequacy of glove selection becomes more uncertain in any workplace not using a pure chemical.

In some instances, the presence of some chemicals may cause partial degradation of the polymeric barrier and have adverse effects on permeation resistance. For example, water effectively degrades polyvinyl alcohol (PVA) gloves that otherwise offer excellent resistance to nonpolar solvents. Laboratory breakthrough time for nonpolar solvents and PVA gloves is usually several hours, such as for toluene $\geq$ 6 hours. However, in the presence of slight amounts of water, or some polar organic solvents such as methanol or acetone the breakthrough time may be only several minutes. These gloves are usually manufactured with a heavy flock liner to absorb perspiration, but their performance in actual use remains undocumented.

Laboratory studies demonstrated greatly reduced breakthrough time for pesticides when used with solvents that permeate the glove.[(22–27)] The United States Environmental Protection Agency (EPA) has recognized the hazards involved with such vehicle effects under the Significant New Use Rule. As one of three options for evaluation, the rule requires testing to establish that "the chemical protective clothing will be impervious to the chemical substance alone and in combination with other chemical substances in the work area."[(28)] This is an important requirement that is difficult to establish on the basis of laboratory data alone.

Temperature

The EPA standard for new chemical use also requires that "testing must subject the chemical protective clothing to the expected conditions of exposure."[(28)] Both the solubility and diffusion coefficients of compounds through polymeric films vary exponentially with temperature.[(29)] A recent study tested the effect of increased temperatures on the permeation of N-methylpyrrolidone in gloves.[(30)] This solvent is commonly used at elevated temperatures in industry; therefore, ASTM permeation test data were obtained at four temperatures ranging from 25°C to 50°C. The authors developed a temperature-dependent model for glove permeation that has potential for broad application to other combinations of solvent, glove, and polymer. This study demonstrated an approximate 3-fold decrease in breakthrough time and a 2.5-fold increase in steady-state permeation rate between testing at 25°C and 37°C. At 50°C, the breakthrough time decreased 9-fold and the steady-state permeation rate increased 6-fold. Standard ASTM testing is performed at 25°C; body temperature is 37°C. Clearly, the decreased protection afforded by gloves at body temperature and in hot environments is another variable that needs to be considered when estimating the duration of effective glove protection.

Physical Stress

Pressure, stretching, and abrasion are also expected conditions of use. A practical study comparing laboratory and workplace permeation of an aromatic amine epoxy resin demonstrated the importance of these considerations in glove selection. Laboratory glove tests performed under static conditions did not detect amine breakthrough for more than 1 week. Actual workplace testing of glove performance showed significant breakthrough of amine after 20 minutes using an amine-contaminated screwdriver with normal exertion.

The authors concluded: "This represents a decrease in breakthrough time, which is two orders of magnitude different from that obtained in the laboratory test."[(31)] This was the first published study of this nature. Since then, additional studies have attempted to evaluate the effect of actual use and flexing on glove permeation.[(32)] In one pair of studies, laboratory tests indicated breakthrough time of 45 minutes, 8 hours, and more than 8 hours for three chemotherapeutic drugs through surgical latex gloves. In the field study, breakthrough was detected in the gloves worn by pharmacists preparing these same three drugs in 10, 37, and 62 minutes, respectively.[(33,34)] Differences between the manufacturers' brand of glove and the analytical detection limits prevent strict comparison of the two studies, but the results suggest the necessity of real-world testing.

Reuse

The permeation of chemicals through gloves does not cease when the gloves are removed from the hands and set aside. Very limited data exist on the effect of intermittent exposures but for some compounds the breakthrough time is the same for cumulative intermittent exposure as for continuous exposure. Continued permeation through gloves has been measured for as long as 70 hours after ending a 4-hour exposure test.[(35)] Thus, the reuse of seemingly impermeable gloves over a period of days, even with brief contact, would seem to assure that the inside of the glove will eventually become contaminated.

Product Variation

All gloves are not created equal. Mickelsen and Hall demonstrated a tenfold difference in protection factors for generically equivalent gloves from different manufacturers.[36] Differences in raw materials, their content in the finished product, and the degree of cross-bonding may account for these differences. This is seen even in lot-to-lot variation from the same manufacturer, presumably due to insufficient quality control. Perkins and Pool concluded that the published permeation values should be a guideline and should only used as relative measures for selecting one glove over others.[37] In other words, published permeation data should be used only as a starting point, not the conclusion of the selection and validation process.

Other Issues—The Human Factor

In addition to the adequacy of gloves as a barrier, the selection and appropriate use of gloves must also consider factors related to work practices, the need for dexterity and tactility, and training of workers and supervisors on proper glove use. Worker acceptance of gloves is a key to compliance with any safety program. The selection of gloves is often made by a professional responsible for worker protection who may wish to be risk-conservative by introducing gloves that will afford extra protection, such as extra-heavy gloves. This decision, made in exclusion of the "human factor," may be a mistake. Requiring the use of gloves that are bulky or uncomfortable is a prescription for problems because worker comfort and convenience are important in determining workers' use of gloves.[38] Groth reported an example of such a problem involving methylenedianiline (MDA).[39] Cured (dry) MDA composites were handled alternately with aliphatic naptha. Different gloves were specified for the two different tasks. Initial testing using biological monitoring (of urine) showed significant exposures among several of the workers. In follow-up interviews, these workers admitted to wearing the most comfortable glove for all the processes. Not switching to the more appropriate glove resulted in exposure. After the need was emphasized to follow the prescribed procedures for glove use, urine monitoring demonstrated significant exposure reductions.

Another study of glove selection considerations further illustrates the importance of considering the human element in glove selection.[40] Workers at a company using MDA had been using a 0.475 mm- (19 mil)-thick natural rubber glove to protect against dermal exposures. These gloves were often worn for many hours without being changed. Employee exposure was again documented by urine monitoring. The inability to detect the analyte in air indicated that exposure was almost exclusively by the skin. A series of alternative glove choices were field tested using thin cotton gloves worn under new chemical resistant gloves to monitor potential skin exposure under the gloves.

Alternative glove choices included 0.75 mm- (30 mil)-thick natural rubber (NR) gloves, several butyl gloves (including epichlorohydrin [ECO] treated), copolymer laminate (4H) and 0.475 mm- (19 mil)-natural rubber double glove combination, and the originally chosen natural rubber glove. For up to 4 hours, workers wore the copolymer-laminate and latex glove combination because laboratory testing had shown the copolymer glove could resist permeation of MDA in methylethylketone or methanol for well over 4 hours. The natural rubber and butyl gloves were worn for up to 2 hours. Analysis of the cotton glove monitoring data showed that the alternative glove choices selected to provide increased protection often resulted in higher exposures.

Figure 1 summarizes the results of this study and suggests no advantage in using the copolymer glove instead of the thinner latex glove. This result is surprising considering the superior laboratory performance of the copolymer glove. Interviews with workers revealed that workers often removed gloves that

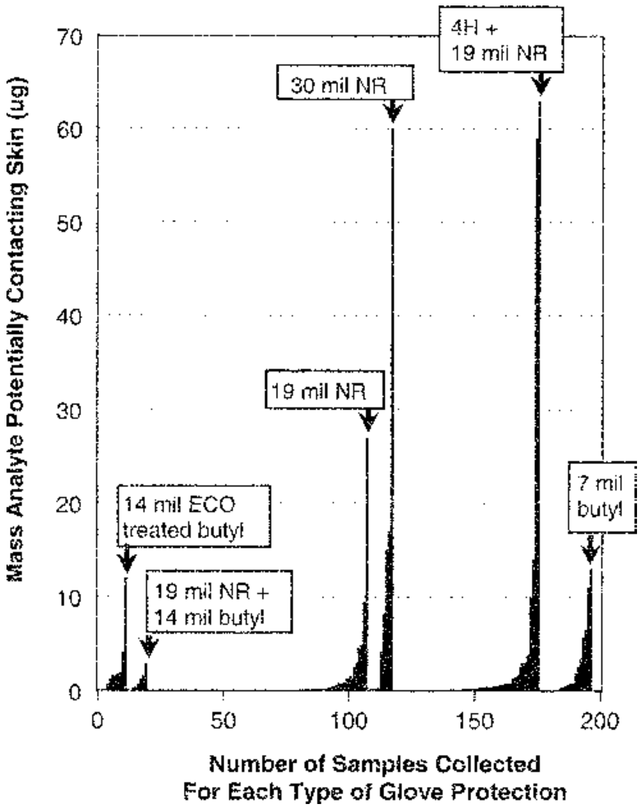

FIGURE 1

Field use testing of six types and combinations of gloves. The prevalence of detectable samples and the mass of analyte found underneath different gloves indicate the ability of each glove type or glove combination to protect the hands from contamination in this work setting. These results probably reflect poor work practices more than chemical permeation, as more impermeable gloves appear not to produce less hand contamination than more comfortable, yet more permeable gloves. NR = natural rubber; 4H = colaminate; ECO = epichlorohydrin treated. See text for discussion. Data from reference 40.

afforded less tactility to accomplish work tasks that required manual dexterity. Workers probably contaminated their hands when the gloves were removed and transferred MDA to the insides of the gloves on reuse.

Workers were informed of the findings and training was implemented to emphasize the importance of wearing gloves whenever working in a potentially contaminated area. To promote this practice, the practice of double gloving using the copolymer (outer) and 19-mil natural rubber (inner) glove combination was implemented. When tasks required greater tactility, as when performing paperwork, the outer glove was removed but the inner glove always remained on when in the contaminated work area. Subsequently, improvements in work practices and the decision to use the double glove combination reduced urinary MDA concentrations by an average of 80 percent.

A single glove might have been more comfortable and might have been effective if it were worn continuously but for a shorter period. However, this approach depends on worker replacement at the appropriate time, which may not be reliable. The investigation was very effective because field monitoring of glove efficacy (using cotton liners as dosimeters) and exposure assessment (using urine monitoring) validated anticipated glove performance. This resulted in the selection of a superior glove barrier and development of a strategy for its use that was emphasized through employee training.

These studies illustrate the value of in-use workplace performance monitoring to measure compliance with CPC use requirements. Although biological monitoring can be indispensable to revealing unexpected exposure, direct means of detecting exposure, such as under glove dosimetry, are also needed to identify exposure when the source is not obvious.

ADDITIONAL CONCERNS SUPPORTING TESTING

Studies with therapeutic agents indicate that occlusion may be the single most effective method to increase percutaneous absorption of topically applied compounds.[41] Protective gloves or clothing create an ideal occlusive barrier. If chemical breakthrough occurs, skin permeability of many chemicals may increase by a factor of 5- to 10-fold if the site of exposure is occluded.[42] The situation described below illustrates this concern.

Aprea et al. evaluated the influence of protective measures to reduce worker exposures during manual field activities with crops previously treated with insecticides.[43] These researchers used urine monitoring to quantify the effect of various approaches to prevent exposure. Workers were assigned to one of three groups where each performed the same tasks. Group 1 workers were provided neoprene or butyl rubber gloves, group 2 wore waterproofed cotton gloves, and group 3 wore cotton gloves. The workers in each of these groups were also provided with felt face masks to reduce respiratory exposure.

Alcohol hand washing was used to assess the pesticide exposures on workers' hands. The median pesticide levels recovered from hand washes of the three groups were 11.7 nmol, 729.6 nmol, and 542.2 nmol, respectively. The median increases in pesticide detected in workers' urine from the basal levels were 129 percent, 79 percent, and 13 percent, respectively, over the next 6 days.

Group 1 workers showed the largest absorption increase despite the assumed highest level of protection and the lowest measured hand wash results. A possible explanation is that the pesticide to which workers were exposed may be poorly absorbed through dry skin. The occlusive nature of the rubber gloves used in Group 1 may have increased skin absorption so that even minor contamination on hands led to the highest urine concentrations in this study. The interpretation of the results from this study must be tempered by the small size of each group; nevertheless, the study was exceptional in the use of objective means of ascertaining absorbed exposure. Presently, a surprising paucity of such field use performance information is in the literature.

Incidental dermal exposure to volatile solvents may result in very limited absorption. The majority of the exposure may simply evaporate.[44] However, the occlusive nature of gloves and protective clothing will prevent evaporation of any chemical that breaches the protective barrier, thus the chemical will be kept in contact with the skin with enhanced absorption. Such exposures through pinhole-sized damage to the CPC will usually go undetected unless a monitoring program is in place.

Wearing gloves for long periods can also damage the skin barrier.[45] The addition of glove powders can irritate the skin, also making the skin more permeable. Finally, the increasing use of skin creams may present an unrecognized hazard for skin exposure. The transfer of potentially allergenic proteins from natural rubber gloves was facilitated in one study after workers applied protective skin products with a petrolatum base.[46] Aloe vera and other lipophilic moisturizers may enhance cutaneous drug absorption as well and could possibly be incompatible with certain glove types.[47] The use of these types of products in combination with gloves deserves more attention, and only additional testing will determine the effects on glove performance and workers' exposures.

CONCLUSION

As demonstrated by the reviewed literature, many physical and chemical variables can affect the field performance of gloves. Most of these variables are difficult or impossible to replicate in controlled laboratory experiments. Furthermore, worker behaviors such as improper glove use or reuse, transfer of contamination to the inside of gloves, and general reluctance by workers to use gloves complicates the assessment of glove performance in relation to a workplace setting. Therefore, workplace monitoring should be conducted to determine the efficacy of glove performance and worker exposures during actual use situations.

Biological monitoring has proven an effective tool in assessing the efficacy of glove performance assumptions and the significance of skin exposures. The use of biological assessments in the workplace should be encouraged; however, biological monitoring is limited to verifying that exposure has occurred—it does not by itself indicate by what process exposure occurred. Therefore, the continued development of field methods to test the efficacy of glove performance is also needed. Finally, toxicologically based skin evaluation criteria are needed to compare the test results of CPC field performance studies. A discussion about available in-use sampling techniques and the development of toxicologically based comparison criteria is the subject of a companion article.[48]

Unfortunately, detailed studies that evaluate the actual performance of glove use in workplaces and the way some of the variables mentioned affect the performance are virtually nonexistent. The available field studies evaluated only a small number of workers and present a mixed picture of success and failure related to the use of CPC. These studies are generally performed without an in-depth understanding of important influential variables and therefore failed to document or to control these variables and demonstrate their contribution to the results. Sound recommendations based on objective field testing, integrating strategies for selecting CPC, use of CPC, personal hygiene practices, and the compatibility of CPC with certain skin care products cannot be offered at the present time. These studies are needed and could be performed using available test methods that could reduce the incidence of irritant and allergic dermatitis and systemic illnesses that are caused by chemical exposures to the skin.

REFERENCES

1. Occupational Safety and Health Administration: Personal Protective Equipment for General Industry, Final Rule. CFR 59, No. 66, pp. 16334–16364, Wednesday, April 6. U.S. Government Printing Office, Washington, DC (1994).
2. American Society for Testing and Materials: Standard Test Method for Resistance of Protective Materials to Permeation by Liquids and Gases Under Conditions of Continuous Contact (ASTM Method F739-99). ASTM, West Conshohocken, PA (1999).
3. NIOSH, National Occupational Exposure Survey, 1981–1983. DHHS (NIOSH) Publication No. 88-106. Special Data Analysis (1988).
4. Grandjean, P.; Berlin, A.; Gilbert, M.; et al.: Preventing Percutaneous Absorption of Industrial Chemicals: The "Skin" Denotation. Am J Indus Med 14:97–107 (1988).
5. Fiserova-Bergerova, V.; Pierce, J.T.; Droz, P.O.: Dermal Absorption Potential of Industrial Chemicals: Criteria for Skin Notation. Am J Indus Med 17:617–635 (1990).
6. Mathias, C.G.T.: The Cost of Occupational Skin Diseases. Arch Dermatol 121:332–334 (1985).
7. Smit, H.; Coenraads, P.J.; Emmett, E.: Dermatoses. In: Epidemiology of Work Related Diseases, C. McDonald, Ed., pp. 143–164. BMJ Publishing, London, UK (1995).
8. Van der Walle, H.B.; Brunsveld, V.M.: Dermatitis in Hair Dressers (1). The Experience of the Past 4 Years. Contact Dermatitis 30:217–221 (1994).
9. Forrester, B.G.; Roth, V.S.: Hand Dermatitis in Intensive Care Units. J Occup Env Med 40:881–885 (1998).
10. Lushniak, B.D.: Epidemiology of Occupational Contact Dermatitis. Dermatol Clinics 13:671–680 (1995).
11. Leigh, J.P.; Miller, T.R.: Job-Related Diseases and Occupations Within a Large Workers' Compensation Data Set. Am J Indus Med 33:197–211 (1998).
12. Health and Safety Commission: Health and Safety Statistics 1996/97. Government Statistical Service, HSE Books, Suffolk, UK (1997).
13. Halkier-Sorenson, L.: Notified Occupational Skin Diseases in Denmark: Important Exposure Sources, Occupations and Trades. The Course from Notification to Compensation and Socio-Economical Aspects, Occupational Skin Diseases. Contact Dermatitis 35 (Suppl 1):1–44 (1996).
14. Schwope, A.D.; Renard, E.P.: Estimation of the Cost of Using Chemical Protective Clothing. In: Performance of Protective Clothing, J.P. McBriarty; N.W. Henry, Eds., vol. 4, ASTM STP 1133. American Society for Testing and Materials, Philadelphia (1992).
15. Gillen, M.; Schneider, S.: Testimony on Behalf of the Occupational Health Foundation on OSHA's Re-Opening of the Proposed Rule for Personal Protective Equipment for General Industry. Occupational Health Foundation, Washington, DC (1992).
16. Forsberg, K.; Keith, L.H.: Instant Gloves + CPC, Database Version 2.0. Instant Reference Sources, Inc., Blacksburg, VA (1999).
17. Mansdorf, S.Z.: Recommendations for Chemical Protective Clothing, A Companion to the NIOSH Pocket Guide to Chemical Hazards. Report prepared for the National Institute for Occupational Health, NTIS No. PB 98-137730. NIOSH, Cincinnati, OH (1998).
18. Fricker, C.; Hardy, J.K.: Protective Glove Material Permeation by Organic Solids. Am Indus Hyg Assoc J 53:745–750 (1992).
19. Department of Labor, Occupational Safety and Health Administration: Personal Protective Equipment for General Industry, 29 CFR Part 1910.138—Hand Protection. (See also Federal Register, Vol. 59, No. 66, pp. 16334–16364, 1994, for preamble).
20. Department of Labor, Occupational Safety and Health Administration: 29 CFR Part 1910.1200, Hazard Communication.
21. Lara, J.; Ketelson, H.: Permeation of Binary Mixtures of Chemicals Through Neoprene and Nitrile Materials. Comparison Between Experimental Results and Theoretical Predictions. Abstracts of the American Industrial Hygiene Conference, ACGIH, AIHA, Boston (1992).
22. Mickelson, R.L.; Roder, M.M.; Berardinelli, S.P.: Permeation of Chemical Protective Clothing by Three Solvent Mixtures. Am Indus Hyg Assoc J 47:236–240 (1986).
23. Ehntholt, D.; Bodek, I.; Valentine, J.R.: The Effects of Solvent Type and Concentration on the Permeation of Pesticide Formulations Through Chemical Protective Glove Materials. In: Chemical Protective Clothing Performance in Chemical Emergency Response, J.L. Perkins; J.O. Stull, Eds., ASTM STP 1037. American Society for Testing and Materials, Philadelphia (1989).
24. Schwope, A.D.; Goydan, R.E.D.; Frank, U.; Nielsen, A.: Permeation Resistance of Glove Materials to Agricultural Operations. Am Indus Hyg Assoc J 53:352–361 (1992).
25. Ehntholt, D.; Almeida, R.F.; Beltis, K.J.; et al.: A Test Method for the Evaluation of Protective Glove Materials Used in Agricultural Operations. Am Indus Hyg Assoc J 5:462–468 (1990).

26. Nelson, G.O.; Lum, B.Y.; Carlson, G.J.; Wong, C.M.; Johnson, J.S.: Glove Permeation by Organic Solvents. Am Indus Hyg Assoc J 42:217–225 (1981).
27. Que Hee, S.: Permeation of Some Pesticidal Formulations Through Glove Materials. In: Chemical Protective Clothing Performance in Chemical Emergency Response; J.L. Perkins; J.O. Stull, Eds., ASTM STP 1037. American Society for Testing and Materials, Philadelphia (1989).
28. U.S. Environmental Protection Agency: Significant New Use Rules for Chemical Substances, Title 40 CFR Part 721.
29. Vahdat, N.; Bush, M.: Modeling the Temperature on the Permeation Properties of Protective Clothing Materials. In: Chemical Protective Clothing Performance in Chemical Emergency Response, J.L. Perkins; J.O. Stull, Eds., ASTM STP 1037. American Society Testing and Materials, Philadelphia (1993).
30. Zellers, E.; Sulewski, R.: Modeling the Temperature Dependence of N-methylpyrrolidone Permeation Through Butyl and Natural Rubber Gloves. Am Indus Hyg Assoc J 54:465–479 (1993).
31. Gunderson, E.C.; Kingsley, B.A.; Witham, C.L.; et al.: A Practical Study in Laboratory and Workplace Permeation Testing. Appl Indus Hyg 4:324–329 (1989).
32. Perkins, J.L.; Vesical, K.: The Effect of Glove Flexure on Permeation Parameters. Appl Occup Environ Hyg 12:206–210 (1997).
33. Colligan, S.A.; Horstman, S.W.: Permeation of Cancer Chemotherapeutic Drugs Through Glove Materials Under Static and Flexed Conditions. Appl Occup Environ Hyg 5:48–52 (1990).
34. Sessink, P.J.M.; Van de Kerkhof, M.C.A.; Anzion, R.B.M.; et al.: Environmental Contamination and Assessment of Exposure to Anti-Neoplastic Agents by Determination of Cyclophosphamide in Urine of Exposed Pharmacy Technicians: Is Skin Absorption an Important Exposure Route? Arch Environ Health 49:65–169 (1994).
35. Goydan, R.; Schwope, A.D.: Should Protective Gloves Be Reused? An Analysis of the Potential for Residual Permeation During Repeated Use. Abstracts of the American Industrial Hygiene Conference and Exposition, Boston (1992).
36. Mickelsen, R.L.; Hall R.C.: A Breakthrough Time Comparison of Nitrile and Neoprene Glove Materials Produced by Different Glove Manufacturers. Am Indus Hyg Assoc J 48:941–947 (1987).
37. Perkins, J.L.; Pool, B.: Batch Lot Variability in Permeation Through Nitrile Gloves. Am Indus Hyg Assoc J 58:474–479 (1997).
38. Kusters, E.: Biological Monitoring of MDA. Br J Indus Med 49:72 (1991).
39. Groth, K.: Assessment of Dermal Exposures to 4,4′ Methylene Dianiline in Aircraft Maintenance Operation Involving Advanced Technology Materials. Proceedings of the Conference on Advanced Composites, pp. 113–118, American Conference of Governmental Industrial Hygienists, Cincinnati, OH (1992).
40. Boeniger, M.: Technical Assistance Support to Brunswick Defense, Lincoln, NB (TA 90-313) Hazard Evaluation and Technical Assistance Branch. National Institute for Occupational Safety and Health, Cincinnati, OH (1991).
41. Scheuplein, R.J.: Permeability of the Skin: A Review of Major Concepts. Curr Prob Dermatol 7:172–186 (1978).
42. Grandjean, P.: Skin Penetration: Hazardous Chemicals at Work, pp. 18–29. Taylor and Francis, Inc., Bristol PA (1990).
43. Aprea, C.; Sciarra, G.; Sartorelli, P.; et al.: Biological Monitoring of Exposure to Organophosphorus Insecticides by Assay of Urinary Alkylphosphates: Influence of Protective Measures During Manual Operations with Treated Plants. Int Arch Occup Environ Health 66:333–338 (1994).
44. Reifenrath, W.G.; Spencer, T.S.: Evaporation and Penetration from Skin. In: Percutaneous Absorption: Mechanisms-Methodology-Drug Deliver, R.L. Bronaugh; H.I. Maibach, Eds., 2nd ed. Marcel Dekker, Inc., New York and Basel (1989).
45. Ramsing, D.W.; Agner, T.: Effect of Glove Occlusion on Human Skin (II): Long-Term Experimental Exposure. Contact Dermatitis 34:258–262 (1996).
46. Beezhold, D.H.; Kostyal, D.A.; Wiseman, J.: The Transfer of Protein Allergens from Latex Gloves. AORNJ 59:605–613 (1994).
47. Davis, R.H.; Parker, W.L.; Murdoch, D.P.: Aloe Vera As a Biologically Active Vehicle for Hydrocortisone Acetate. J Am Pod Med Assoc 81:1–4 (1991).
48. Boeniger, M.; Klingner, T.: In-Use Testing and Interpretation of Chemical Resistant Glove Performance. Appl Occup Environ Hyg 17(5):368–378 (2002).