

# A Rational Approach to Skin Decontamination

T.J. Buckley, A. Sapkota, N. Cardello  
Johns Hopkins University School of Hygiene and  
Public Health

M.J. Dellarco  
U.S. EPA National Center for Environmental  
Assessment

Thomas D. Klingner  
Colormetric Laboratories, Inc.

## Introduction / Background

In its National Occupational Research Agenda for the Next Century, NIOSH targeted a reduction in irritant and allergic dermatitis as a top priority. Skin disease accounts for 15 - 20% of all occupational diseases and reported incidence has increased by over 25% during the past 10 years. The standard recommended practice of using soap and water to cleanse the skin may contribute to the cycle of occupational dermatitis.

Among healthcare workers, numerous studies have demonstrated that frequent washings of skin with detergent cleansers are a major risk factor in the development of chronic irritant contact dermatitis of the hands.<sup>1</sup> Irritant response of the skin to anionic surfactants, such as sodium lauryl sulfate<sup>2</sup> (SLS) can produce long lasting (up to four weeks) damage to the normal barrier function of the skin.<sup>3</sup> That damage as measured by increased trans-epidural water loss (TEWL) is exacerbated by occlusion occurring with the use of protective gloves.

The incidence of occupational hand dermatitis in the hospital setting is significantly higher than in the general population. Frequent hand washing with disinfectant skin cleansers increases dermatitis (69.7 % of ICU4 workers) and sensitivity to disinfectants (30% of health service workers).<sup>5</sup> Disruption of the skin barrier also appears to play a role in the development of allergic latex sensitization.

Among industrial workers, the use of soap and water wash has been shown to enhance the percutaneous absorption of lipophilic chemicals.<sup>6</sup> Disrupting the stratum corneum significantly increases the percutaneous absorption of chemical exposure thereby contributing to the development of irritant or allergic dermatitis. Thus the use of harsh detergent cleansers increases the potential for skin absorption of chemical exposure.

Besides the physical damage to the barrier integrity of the skin, the addition of cosmetic emollients and “moisturizers” can further promote chemical exposures. Commonly used

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## References

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- <sup>2</sup> Pieter G.M. Van der Valk and Howard Maibach, Department of Dermatology, University of California, San Francisco, CA, USA, *Post-application occlusion substantially increases the irritant response of the skin to repeated short-term sodium lauryl sulfate (SLS) exposure*. CONTACT DERMATITIS, June 1989
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additives, such as aloe vera<sup>7</sup> and isopropyl myristate are rapidly absorbed into the stratum corneum. Moreover, these additives have been proven to be effective vehicles to enhance the absorption efficacy of lipophilic drugs. D-limonene, widely employed in citrus-based skin cleansers, has been shown to be among the most effective penetration enhancers for dermal drug delivery.<sup>8</sup> Clearly, for the occupational health practitioner, a more thoughtful, safer and more effective approach for dermal decontamination of chemical exposure is required.

OSHA in its methylene dianiline (MDA) standard, Federal Register, Vol. 57, No. 154, August 1992, recognized that the use of solvents may enhance absorption of MDA and that washing with soap and water is minimally effective. Nonetheless, OSHA requires “that workers subject to dermal exposure be instructed to immediately wash the exposed areas with soap and water or any media which does not increase the absorption properties of MDA”.

A new and more rationale approach to skin decontamination is warranted. This approach is designed to promote the skin's barrier function while optimizing the contaminant's removal based on its solubility in the decontamination solvent. This can be accomplished by the use of high molecular weight (HMW) solvents in a cleanser that rinses with water. These HMW components do not defat the skin or disrupt the barrier function of the stratum corneum.

Presently, evaluation procedures to determine the efficacy of skin cleansers rely on in-vivo or in-vitro testing. Because these methods are costly and time consuming, the occupational health professional has limited data on which to base the selection of decontamination products and procedures. Material Safety Data Sheets (MSDS) routinely recommend flushing the skin with copious amounts of water or using soap and water.

It has long been conventional wisdom to avoid the use of solvents to cleanse the skin. Low molecular weight solvents such as acetone, alcohols and paint thinners, etc. readily penetrate the skin and are likely to increase dermal penetration. Use of pumice or grit containing harsh detergents and degreasers severely damages the skin's barrier properties and can result in dermatitis and increased penetration.

The rate-limiting step in the process of dermal absorption is the partitioning of a chemical into the stratum corneum. The rate of dermal penetration (flux,  $K_p$ ) is primarily dependent on two physical properties: octanol/water solubility and molecular volume/weight. In general, lipophilic chemicals penetrate the skin more readily than do water-soluble chemicals<sup>9</sup> and as the molecular weight increases, the ability of chemicals to diffuse through the stratum corneum is reduced. Chemicals with a molecular weight above 350 are relatively poorly absorbed through the skin.

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<sup>7</sup> Robert H. Davis, Ph.D., William L. Parker, Douglas P. Murdoch, *Aloe Vera as a Biologically Active Vehicle for Hydrocortisone Acetate*, JOURNAL OF AMERICAN PODIATRIC MEDICAL ASSOC., Vol. 81, No. 1, January 1991

<sup>8</sup> Hideaki Okabe and Kozo Takayama, *Effects of limonene and related compounds on the percutaneous absorption of indomethacin*. DRUG DESIGN AND DELIVERY, 1989, Vol. 4

<sup>9</sup> Bronaugh, R.L. and Maibach, H.I., *Percutaneous Absorption: In Vitro Techniques*, Marcel Dekker, New York, 1989

Less recognized is the effect of solubility on the partitioning or flux into the skin. Chemicals tend to diffuse from a region of low solubility to that of high solubility. Thus, a water-soluble chemical applied to the skin with an oil based carrier or vehicle will be preferentially more soluble in the skin and its flux rate will increase 5 – 10 fold. The reverse is true where water is applied to remove a lipophilic (oil based) chemical; the resultant preferential solubility of the chemical in the skin will result in increased dermal absorption.<sup>10</sup> The co-solubility effect of the contaminant and the removal agent on skin decontamination efficacy was recently demonstrated. Isocyanate (lipophilic) was removed 5-10 fold more effectively with polyglycol or corn oil than with water or a soap and water wash.<sup>11</sup>

Simplified protocols for selecting the most effective means of decontamination are needed to better protect workers from percutaneous absorption from toxic chemical exposures. Recent in-vivo and in-vitro dermal exposure data support the conclusion that the solubility of a chemical in the removal agent is directly related to the decontamination effectiveness. This study presents data obtained using two simple protocols for selection of an optimum skin cleansing formula. Several chemicals of toxicological concern (pesticides, aromatic amines, and PNAs) with skin notations were selected to represent a broad range of chemical solubility characteristics (hydrophilic to lipophilic). All selected chemicals carried manufacturers' MSDS recommendations to wash skin exposures with soap and water. The goal of the current study is to evaluate the effectiveness of different decontamination solutions by examining their ability to solubilize various skin hazards.

Methods

Four different contaminants spanning a range of octanol water partition coefficients (See Table 1) were tested in four different decontamination solutions including water, 10% ivory soap, a polyethylene glycol based cleanser, and an oil based cleanser.

**Table 1. Test Contaminants**

<b>Contaminant</b>	<b>Log K o/w</b>
<b>Methylenedianiline</b>	<b>1.6</b>
<b>Chlorpyrophos</b>	<b>4.7</b>
<b>Pentachlorophenol</b>	<b>5.9</b>
<b>Benzo[a]pyrene</b>	<b>6.1</b>

Two approaches were used in order to evaluate solubility. The first was quantitative; the second was semi-quantitative. The quantitative method was conducted by analyzing the resulting concentration of the test contaminant in the decontamination solvent after adding 50 mg of the test chemical to 5 ml of decontamination agent. The solutions were gently agitated for 15 minutes at 30° C and an aliquot of decontamination agent quantitatively analyzed using HPLC with UV detection.

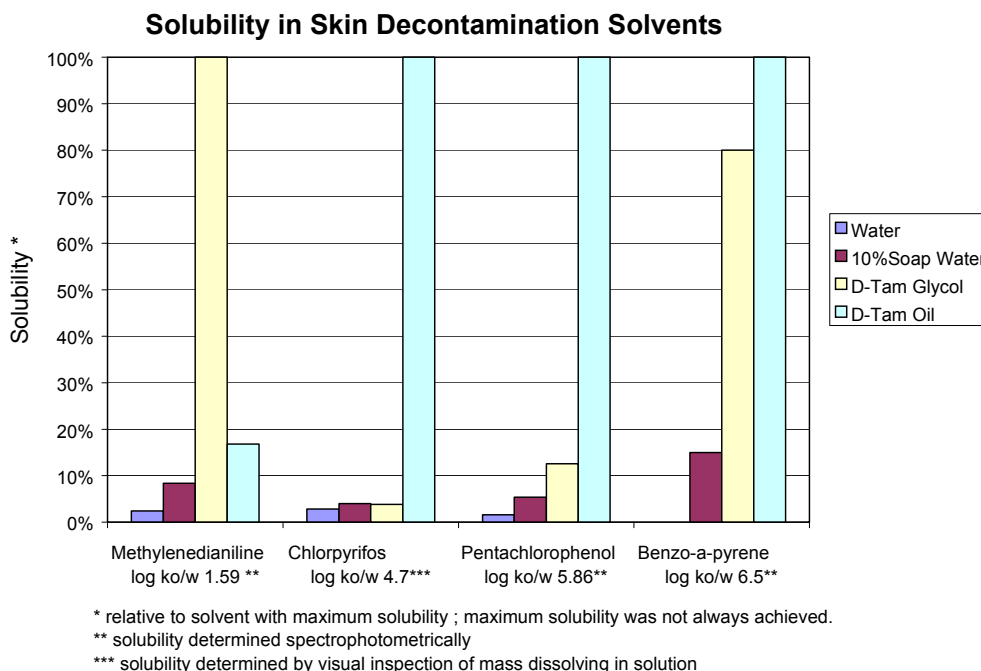
<sup>10</sup> Bucks, D.A.W., et al.; *In vitro percutaneous absorption and stratum corneum binding of alachlor: effect of formulation dilution with water*. TOXICOL. APPL. PHARMACOL. 100:417, 1989

<sup>11</sup> Ronald C. Wester, et al: *In vivo evaluation of MDI skin decontamination procedures*. Sponsored by the International Isocyanate Institute. Presented September 1998, Polyurethane Expo.

The semi-quantitative method entailed the sequential addition of 5 mg of the test chemical to 5 ml of each of the four decontamination solutions. The solutions were sonicated for 5 minutes at 35°C (approximate skin temperature) after each addition and saturation solubility was visually determined.

## Results

The relative solubility of the various contaminants in the decontamination solvents is shown in Figure 1.



## Discussion

This study investigated the solubility of four common skin contaminants in various skin decontamination solvents in order to evaluate a new science-based approach of dermal decontamination. This approach is based on the solubility of the contaminant in the decontamination solution. Our results indicate large differences in solubility suggesting that different skin decontamination solutions will have very different efficiencies for different contaminants. These results are supported by previous in vivo studies where corn oil (control) and a polyglycol-based cleaner (D-TAM®) were more effective than water or soap and water in limiting the transfer of MDI into the skin.

## Conclusion:

A new paradigm for the selection of dermal decontamination agents based on the octanol/water solubility of chemicals is proposed as an improvement in choosing dermal decontamination protocols (see Figure 2). Planned future research will compare the current

study results to standard in-vivo and in-vitro methods in order to validate a simplified protocol for the selection of the optimum decontamination procedure.

The use of water or soap and water is ineffective and may actually increase exposure when used to decontaminate skin of chemicals that are more lipophilic than hydrophilic. Common solvents or harsh degreasing agents such as limonene may substantially increase exposures due to their rapid absorption into the skin.

High molecular weight (>350) solvents (polyglycol or plant oils) are proven safe and effective for the dermal decontamination of chemicals that are poorly soluble in water. The choice of a decontamination agent should be based on the solubility characteristics of the chemical exposure.

Figure 2. Solubility-Based Skin Decontamination Solvents

Log K <sub>ow</sub> 0		3.5		8.0	
Water and Soap For use with chemicals soluble in water.		D-TAM™ Skin Cleanser For use with chemicals slightly soluble in water. (semi-polar)		D-TAM™ Safe Solvent For use with chemicals NOT soluble in water. (lipophilic)	
formaldehyde	acrylonitrile	phenol;1	aniline	aldrin	TDI benzo-a-pyrene MDI
propanol			di-nitro-toluene	lindane	
	acetone		nitro-aniline	malathion	pentachlorophenol parathion
ethyl carbonate			trinitrobenzene		PCB
hydrazine					DDT
		dichlorethane			diesel oil
		captan			
		MDA			toluene
		MBOCA			benzene

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