The influence of cosmetics on the skin absorption of chemicals amongst female workers

Dr. Sharyn Gaskin

Occupational & Environmental Hygiene, Public Health, School of Population Health,

University of Adelaide

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SAFEWORK SA AUGUSTA ZADOW SCHOLARSHIP

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Project Summary & Recommendations

Female susceptibility to chemicals in the workplace and the potential role of products worn on the skin has not previously been explored. In the workplace, there is little or no guidance on the issue of personal care products for workers handling chemicals, e.g. cleaning agents. This scholarship aimed to make a significant workplace health and safety improvement for women through a three-stage research program:

1. Review of current knowledge relating to female susceptibility to chemical exposure in the workplace, and the modifying effects of products worn on the skin such as sunscreen, facial products, cosmetics etc;
2. A visit to the Occupational Dermatology Research and Education Centre (Victoria) which is recognised as the leading Australian research and education group in occupational related skin disease. This will serve as a professional development visit, but will assist in knowledge transfer for South Australian workers;
3. Targeted laboratory experiments using female donor skin (from cosmetic reduction surgery) and representative personal care products and a workplace chemical to assess the influences on chemical absorption and penetration.

Conclusions & recommendations from review:

The role of cosmetics in enhancing, attenuating or altering the penetration or toxic effects of chemicals encountered in workplaces has not been thoroughly investigated. Personal products applied to the skin may or may not enhance the barrier protection provided by naked skin. The passage of some chemicals into the skin may be assisted by sunscreen or other cosmetics. In contrast, the barrier effectiveness provided by some cosmetics (e.g. oil-based sunscreen) can be quite marked for hydrophilic substances. More research is needed to clarify the role of personal items applied to the skin on dermal absorption of chemicals, and specific high risk industries and interactions should be highlighted as priority research targets.

The benefits of the professional development visit to ODREC were:

- Assistance in knowledge transfer from Victorian data and education programs for South Australian working women,

- An understanding of the common occupations where women are highly represented and have an increased incidence of skin allergies/sensitisation (e.g. hairdressers, health care providers),
- Improved awareness of chemicals in the workplace associated with contact dermatitis,
- Potential further collaboration in research with Prof Rosemary Nixon regarding skin exposure to chemicals and education programs targeting (in particular) young workers.

Conclusions/Recommendations to be made from these limited experiments using workplace chemicals (formaldehyde, ammonia, chlorine) include:

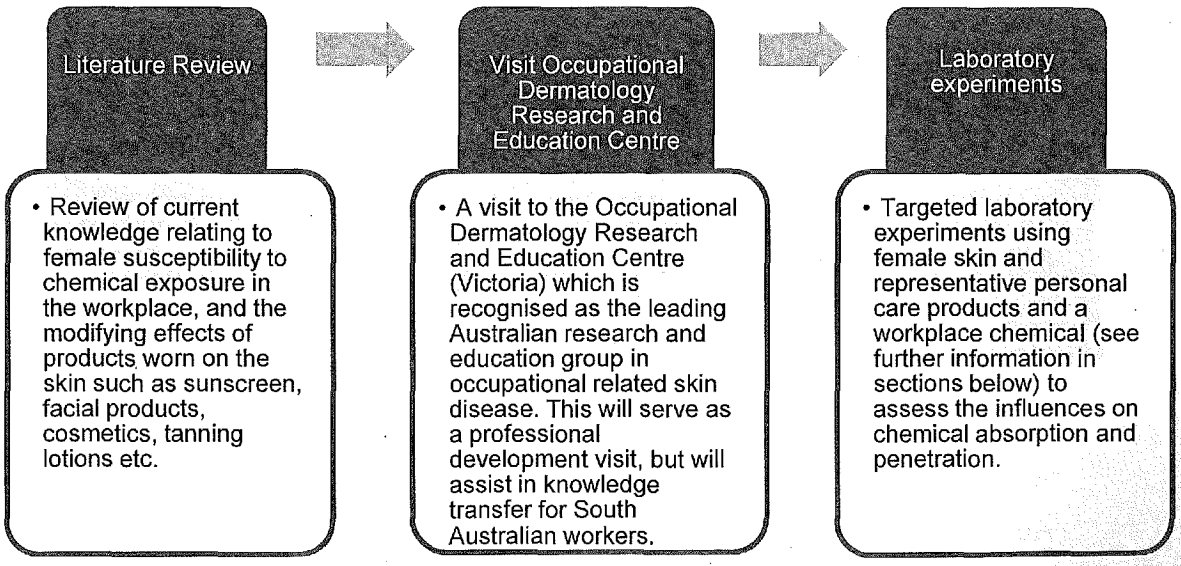
- Limiting skin contact time with the chemical for individuals using the substance in workplace environments.
- Wearing appropriate personal protective equipment (e.g. gloves) when handling chemicals in the workplace.
- Outcomes may help to inform workplace practices such as handling of new stock in the retail industry, guidance on the use of personal care products for workers handling cleaning chemicals, and other initiatives in relevant occupational settings.
- Conclusions able to be drawn from the barrier effectiveness of sunscreen (and other cosmetics) found for tested chemicals are limited, except where we may be dealing with hydrophobic contaminants, where physical removal of sunscreen is likely to be beneficial following exposure.
- More research is needed to clarify the role of personal items applied to the skin on dermal absorption of chemicals.
- This work will hopefully contribute to a better understanding of the issue for occupational hygienists and other OHS professionals who may be called upon to provide advice and assistance on these issues.

Aim and Scope

Many factors can influence the extent of dermal absorption of chemicals (e.g. age, gender, ethnicity, anatomical site of exposure). Gender differences in susceptibility to toxic industrial chemicals have been hotly debated in the literature (Calabrese 1986; Arbuckle 2006; Vahter et al 2007) but the general consensus is that more empirical data are needed. Skin irritation to chemicals has been shown to be more prevalent in women (Friedmann & Pickard 2010) possibly due to previous exposure from cosmetics worn on the skin.

However, in the workplace, there is little or no guidance on the issue of personal care products for workers handling chemicals, e.g. cleaning agents.

The scholarship aimed to make a significant workplace health and safety improvement for women through a three-stage research program:



Information generated from the work will provide new knowledge addressing some gaps and questions highlighted in the literature related to female susceptibility to chemicals in the workplace and the potential role of products worn on the skin. Information will be consolidated and made accessible to women in the workplace and key stakeholders (e.g. Unions, Employers, SafeWork SA Inspectors, OHS professionals, etc).

Results – Literature Review

AIM: Review of current knowledge relating to female susceptibility to chemical exposure in the workplace, and the modifying effects of products worn on the skin such as sunscreen, facial products, cosmetics, tanning lotions etc.

Introduction

Workers across a broad range of industries are frequently exposed to biologically-active and often toxic chemicals. The handling of these chemicals and the required personal protective equipment (PPE) is mandatorily documented in the form of standard operating procedures (SOPs), material data safety sheets (MSDS) and risk assessments (RA) in order to mitigate any potential hazards to workers. Whilst RAs, SOPs and MSDS provide an indication of the potential hazards of each compound, they rarely if ever describe any chemical interactions which may occur between workplace chemicals and common topical cosmetics or personal care products. Furthermore, they rarely describe any gender differences in susceptibility to potential toxic effects. Whilst there is some evidence that specifically demonstrates gender based toxicity effects and interactions with cosmetics and personal care products, there is generally a knowledge gap of direct research addressing these issues.

Exposure to chemicals in predominantly female workforces

A review of occupational contact dermatitis has recently been published (SafeWork Australia, 2012) outlining 18 years of data collection from occupational dermatology clinics in Australia. The demographic profile of patients from the review show 44.4% were female (n=1287). In female workers, the study reported that the most common causes of irritant contact dermatitis were: water and wet work (60.5%), soap and detergents (48.0%), heat and sweating (16.2%). Women were reported to be significantly more likely to have soaps/detergents and water/wet work as causes of their dermatitis compared with men (more likely oils/coolants and solvent exposures as causes). Cleaners were reported to have relative rates of occupational skin disease

(Victorian population) of 6.1 cases per 100,000 workers per year. This compares to 69.8 cases per 100,000 workers per year for hair and beauty therapists, and 20.6 cases per 100,000 workers per year for health care workers, all of which have predominantly female workforces.

International studies reporting the gender distribution within various industries highlights occupations with a strong female representation in the workforce, and allows an overview of potential industries most likely to involve exposure to hazardous chemicals. These studies indicate that in terms of a predominantly female workforce and moderate/high chemical exposure risk or incidence of workplace related illnesses includes; dental and surgical nurses (Alanko et al., 2004, Newman and Kachuba, 1992), cleaners and maids (Bello et al., 2009, Flyvholm, 1993, Lynde et al., 2009), beauticians and hairdressers (Lysdal et al., 2012, Ronda et al., 2009, Tennstedt, 2007, Kanerva et al., 1996, Thu et al., 2011, Tosti et al., 1993) and cooks/caterers and kitchen staff (Cherry et al., 2000, Karadzinska-Bislimovska et al., 2007, Warshaw et al., 2007) .

Whilst there are some semi-ubiquitous environmental and occupational chemicals (e.g. detergents for hand washing), within specific industries there are frequently reported chemicals of concern with associated illnesses. Hair dressers are exposed to a range of occupational chemicals as well as perfumes and dyes from clients. Workers in hair dressing salons frequently utilise solvents (Bradshaw et al., 2011), hair dyes containing p-phenylenediamine and aminophenol isomers (Lee and Lin, 2009) and phthalates (Vrijheid et al., 2003) which have been linked to dermatitis and rhinitis (Bradshaw et al., 2011, Khumalo et al., 2006) still births, low birth weight and a suggested link of oral cleft formation and hypospadias in foetuses (Rylander and Källén, 2005).

Surgical and dental nurses are often in near constant contact with natural rubber latex and starch powder in protective gloves which has been frequently cited as a cause of allergic contact dermatitis (Alanko et al., 2004, Cherry et al., 2000, Stingni et al., 1995). The health care industry relies on frequent sanitization of both surfaces and hands presenting a large exposure to soaps and disinfectants such as chlorhexidine gluconate (Stingni et al., 1995) causing an increased incidence of skin irritation and sensitization. Surgical and pathology nurses receive increased exposures to aldehydes

(gluteraldehyde and formaldehyde) (Newman and Kachuba, 1992) which have been linked to eczema, skin irritation and reduced fertility (Cronin, 1991, Taskinen et al., 1999). Dental nurses specifically are exposed to (meth)acrylate plastics used in dental restoration procedures (Alanko et al., 2004, Cherry et al., 2000) which have also been linked to allergic skin conditions. Similarly, beautician and nail technicians are also exposed to (meth)acrylates as well as toluene sulfonamide-formaldehyde resins from artificial nails and solvents such as toluene and acetone (Kanerva et al., 1996, LoSasso et al., 2001, Tosti et al., 1993) causing both skin sensitization and neurocognitive damage (LoSasso et al., 2002).

Cleaners are exposed to surfactants and disinfectants comprising quaternary ammonium compound formulations, 2-butoxyethanol, and ethanolamines, both dermally (primarily the hands) and respiratorily by vapours (Bello et al., 2009) causing dermatitis, skin irritation and asthma (Lynde et al., 2009). Additionally, cleaners are exposed to a range of volatile organic compounds (VOC) such as benzene, toluene, limonene, ethanol, acetone which have been implicated in the development and/or exacerbation of asthma, dermatitis and have been identified as carcinogens (Wolkoff et al., 1998, Bello et al., 2009).

Gender specific toxicity effects in females

There are specific physiological differences between men and women which alter the absorption, metabolism, storage and excretion of chemical compounds due to gender differences in behaviour, body composition and size, metabolism and endocrine function (Arbuckle, 2006).

Work by Smith et al. (1997) reported an increased risk of infertility among women exposed to volatile organic solvents (odds ratio [OR], 1.74; 95% confidence interval [CI], 1.11 to 2.71), chemical dusts (OR. 2.66; CI, 1.17 to 6.05) pesticides (OR, 3.02; CI, 1.10 to 8.29) and solvents (OR, 1.95; CI, 1.08 to 3.52). Exposure to solvents and chemical dusts also were associated with endometriosis (solvents: OR, 2.13; CI, 0.96 to 4.72; dusts: OR, 3.63; CI, 0.99 to 13.28). Similarly, exposure to formaldehyde has been linked to reduced fertility (specifically an increased time required to conceive) and an increase in the incidence of endometriosis and spontaneous abortion (Taskinen

et al., 1999). Studies of hairdressers have demonstrated a greater incidence of intrauterine growth-retardation, leading to low birth weights in infants (Rylander and Källén, 2005) and foetal malformations including oral cleft formation due to exposure to endocrine disruptors and solvents (Rylander and Källén, 2005, Vrijheid et al., 2003).

Experimental work has demonstrated that physiological gender differences result in women metabolizing 23–26% more benzene than men when exposed under the same conditions, due to difference in body composition and metabolism (Brown et al., 1998, Wolkoff et al., 1998). This suggests that chemical exposure standards calculated for male workers may not be protective of female workers under the same conditions.

Metal exposure is related to a range of industries, including mining and smelting, manufacturing industries and jewellery trades. There is a markedly higher prevalence of nickel-induced allergy and hand eczema in women compared to men (15–20% of women and 2–5% of men), mainly due to differences in exposure particularly from wearing jewellery (Meding et al., 2001, Nielsen et al., 2002). Lead and mercury are relatively common metal contaminants and are capable of being transferred from the mother to the foetus (Vahter et al., 2007) particularly as skeletal lead stores are mobilized during periods of increased bone turnover, e.g., pregnancy and lactation (Gulson et al., 1998).

Some specific gender based behavioural trends may influence the formation of workplace related illnesses. Women tend to report more frequent hand washing than male workers (OR 1.97, 95% CI 1.49–2.61) (Keegel et al., 2012), which may alternately lead to reduced chemical exposure but a higher rate of hand dermatitis, particularly in occupations such as healthcare and food preparation where hand washing may occur in excess of 100 times a day (Keegel et al., 2012).

Altered chemical toxicity and penetrance by cosmetics

Approximately 80% of occupational contact dermatitis involves the hands, and 10% the face (Belsito, 2005). These are the areas where cosmetics and personal care

products are most frequently applied in the form of makeup, moisturisers, sunscreen, lipsticks and lip glosses as well as hair creams, gels or sprays. These compounds have the potential to alter the absorbance and/or toxicity of chemicals contacting the skin, may act as chemical reservoirs or may in their own right become irritants or act as sensitisers after chemical exposure.

Although these products are used by male workers, the majority of personal care product and cosmetic consumers are women. Women tend to have a higher rate of allergic contact dermatitis than men working in similar industries and an associated higher immune response to allergens, possibly due to previous exposure from cosmetics worn on the skin (Kwangsukstith and Maibach, 1995, Friedmann and Pickard, 2010).

An emerging area of research is the potential for penetration-enhancing effects of cosmetic products on the absorption of component chemicals (Api et al., 2008, Loretz et al., 2006, Loretz et al., 2008, Wang et al., 2009). Most studies discussing the absorption of chemicals through the skin in relation to cosmetics focuses on the chemicals contained in the product, rather than interactions with exogenous chemicals (Api et al., 2008, Loretz et al., 2006, Loretz et al., 2008, Wang et al., 2009).

As many cosmetics are specifically designed to be easily absorbed by the skin (e.g. moisturiser, sunscreen), they contain chemical agents which act as skin penetration enhancers. Surfactants (e.g. sodium dodecyl sulphate, SDS), fatty acids (e.g. oleic acid) and essential oils (e.g. eucalyptus oil) are added to moisturisers and topical creams to increase the solubility of a wide range of lipophilic and hydrophilic chemicals. Alcohols, glycols and sulphoxides (e.g. dimethylsulphoxide, DMSO) act as solvents and thus increase the permeation of otherwise insoluble chemicals residing on the skin, such as powders (Williams and Barry, 2004). These penetration enhancers may additionally enhance the toxic potential of workplace chemicals by a similar mode of action, e.g. by increasing chemical penetration and solubility, leading to enhanced skin absorption of toxic compounds.

Agricultural and outdoor workers are encouraged to frequently apply sunscreen to decrease the risk of UV-related skin cancer. However, within this context sunscreen

use has been demonstrated to enhance the penetration of potentially harmful agricultural chemicals, specifically pesticides (Pont et al., 2004, Brand et al., 2007). Lipophilic pesticides present a specific hazard as oil-based sunscreens can enhance dermal penetration, and subsequently be excreted via breast milk leading to secondary exposure to infants (Siddiqui and Saxena, 1985). In practice, the protective benefits of sunscreen for UV cancer risk in occupational settings will continue to outweigh the potential added risk associated with its use.

There are some studies on the influence of skin absorption of sunscreen with vehicles. With hairless mouse skin (Brand *et al*, 2002; Pont *et al*, 2004), the active ingredients of sunscreen formulations (i.e. the UV absorbing components and insect repellents for the sunscreen/bug repellent combinations) on the skin significantly enhanced skin absorption of a herbicide, 2,4-dichlorophenoxyacetic acid within 24 hours, compared the control where sunscreen was not applied (Brand et al., 2007, Pont et al., 2004).

Cosmetics contain a range of preservatives and antimicrobials, such isothiazolinone, quaternary ammonium compounds and formaldehyde releasing agents in order to increase product life. These compounds in their own right have been demonstrated to act as sensitizers or to cause occupational asthma and dermatitis (De Groot and Herxheimer, 1989, Purohit et al., 2000) with quarternium-15 being the one the most common causes of allergic dermatitis of the hands and responsible for 16.5% of cases (Warshaw et al., 2007). Subsequent occupational exposure to these chemicals may heighten any pre-existing allergic responses and eventually lead to allergies to previously tolerable cosmetics.

Potential protective effects

In some occupations, the use of barrier creams or emollients is recommended to reduce exposure to hazardous or irritant chemicals (Goh and Gan, 1994, Halkiersorensen and Thestruppedersen, 1993, Simpson et al., 2010). In some cases the use of personal care products, such as moisturiser may in fact have a protective effect. As discussed earlier, hydrophilic compounds and some solvents, such as quaternary ammonium compounds or ethanol would have their dermal absorbance reduced by a

lipid rich topical cosmetic such as sunscreen or moisturiser, as well as increasing skin hydration and repair after exposure (Halkiersorensen and Thestruppedersen, 1993).

Conclusions & Recommendations from review

The role of cosmetics in enhancing, attenuating or altering the penetration or toxic effects of chemicals encountered in workplaces has not been thoroughly investigated. Personal products applied to the skin may or may not enhance the barrier protection provided by naked skin. The passage of some chemicals into the skin may be assisted by sunscreen. For other hydrophilic substances, the barrier effectiveness provided by oil-based sunscreens can be quite marked. More research is needed to clarify the role of personal items applied to the skin on dermal absorption of chemicals, and specific high risk industries and interactions should be highlighted as priority research targets.

Results – Professional Development Visit to Occupational Dermatology Research & Education Centre

AIM: A visit to the Occupational Dermatology Research and Education Centre (Victoria) which is recognised as the leading Australian research and education group in occupational related skin disease. This will serve as a professional development visit, but will assist in knowledge transfer for South Australian workers.

The visit component was undertaken over the period 22th June – 30 June 2012 at the Occupational Dermatology Research and Education Centre (ODREC) (under Prof Rosemary Nixon's supervision) at Carlton South, Victoria. The purpose of the visit was to gain a better understanding of the clinical aspects of women's susceptibility to chemicals in the workplace. This visit included a two-day workshop and participation and observation of a Patch Test Clinic Cycle.

The skin patch test clinic included approximately 8-10 patients who attended on the Monday AM, Wednesday AM and Friday PM of the same week. The presenting workers were from various occupations including building construction (cement worker), hospitality (chef), health care workers, and were seeking treatment for a range of skin issues. Patch testing is a diagnostic process undertaken over five days to detect the presence of delayed hypersensitivity reactions involving the skin. It involves exposing the skin of the back to a set of common allergens and to other allergens likely to be encountered through work, in order to reproduce allergic contact dermatitis or another form of skin allergy known as urticaria. Attendance in the clinic cycle was valuable to gain a better understanding of the process of skin disease assessment and treatment for occupational exposures. It also aided in identifying potential 'high risk' occupations, especially where female workers predominate (e.g. health care workers, hairdressers).

Also attendance at presentations and discussions with the group and Prof Dino Pisaniello (via phone link) regarding what research and education is relevant to women in the workplace took place on the Mon and Wed afternoons following the clinic. Discussions of ODREC recent directions, as well as current and future interest

in research regarding uptake of chemicals and female susceptibility was conducted. In addition, a review of resources (e.g. datasets such as PATCHDERM) available at ODREC regarding skin research relevant to women in the workplace was performed. ODREC have also developed a training package called RASH (Resources About Skin Health) designed to educate the workplace, and students attending training institutions, about occupational contact dermatitis. Information to accompany the program is available at www.rashprevention.com.au . The industries targeted are those commonly affected by work-related skin problems, including:

- Construction
- Food handling
- Hair and beauty
- Healthcare
- Mechanical and metal working.

The RASH resource is a "train-the-trainer" style education package, aimed at raising awareness about appropriate ways skin conditions can be prevented. RASH can be used as a training tool in workplaces, e.g. short 15 minute 'toolbox' talks or training sessions of about 30 minutes, or for induction training, for self-paced learning, or included in OH&S units at training institutions. The resource materials include a reference guide with industry specific sections, CD ROM containing all training materials, posters to advertise and reinforce important workplace messages, and information cards (wallet size) for participants to take away.

The benefits of the professional development visit were:

- Assistance in knowledge transfer from Victorian data and education programs for South Australian working women,
- An understanding of the common occupations where women are highly represented and have an increased incidence of skin allergies/sensitisation (e.g. hairdressers, health care providers),
- Improved awareness of chemicals in the workplace associated with contact dermatitis,
- Potential further collaboration in research with Prof Rosemary Nixon regarding skin exposure to chemicals and education programs targeting (in particular) young workers.

Results – Laboratory experiments

AIM: Targeted laboratory experiments using female donor skin (from cosmetic reduction surgery*) and representative personal care products and a workplace chemical to assess the influences on chemical absorption and penetration.

The aim of the experimental skin studies was using female door skin and representative relevant workplace chemical/s (e.g. formaldehyde, ammonia, chlorine) to assess the influences on chemical absorption and penetration.

Formaldehyde is a chemical with widespread use in varied occupational settings including:

- Cleaning industry (direct or indirect exposure, e.g. generated from citrus cleaning agents);
- Retail industry, for crease resistance in new (imported) garments and textiles;
- Industries which use synthetic mineral fibres (e.g. as packaging for whitegoods);
- Pathology/histology laboratories for clinical services;
- Mortuaries;
- Wood processing industry.

These industries are varied in terms of personal protective equipment required (e.g. gloves) and knowledge of occupational exposure to chemicals. For example, in the cleaning industry chemical exposure can be via direct contact, or by indirect aerosol deposition of a chemical on the neck/face. Female workers are also highly represented in many of these occupational settings (Stewart & Blair 1994).

Experiments were performed using different concentrations of formaldehyde solution on to the skin, with assessment of breakthrough time and absorbed concentration (results shown below). This provides a basis against which further work using cosmetic products on the skin can be compared.

* Ongoing ethics approval has been obtained from Southern Adelaide Health Service Clinical Research Ethics Committee as part of our laboratory's ongoing skin research activities. Excised skin is obtained (with written consent) from individuals undergoing cosmetic reduction surgery.

As Figure 1 shows, an increase in exposure time to the chemical resulted in a greater concentration penetrating through the skin. The total percentage of applied dose that penetrated the skin was low (< 0.2%).

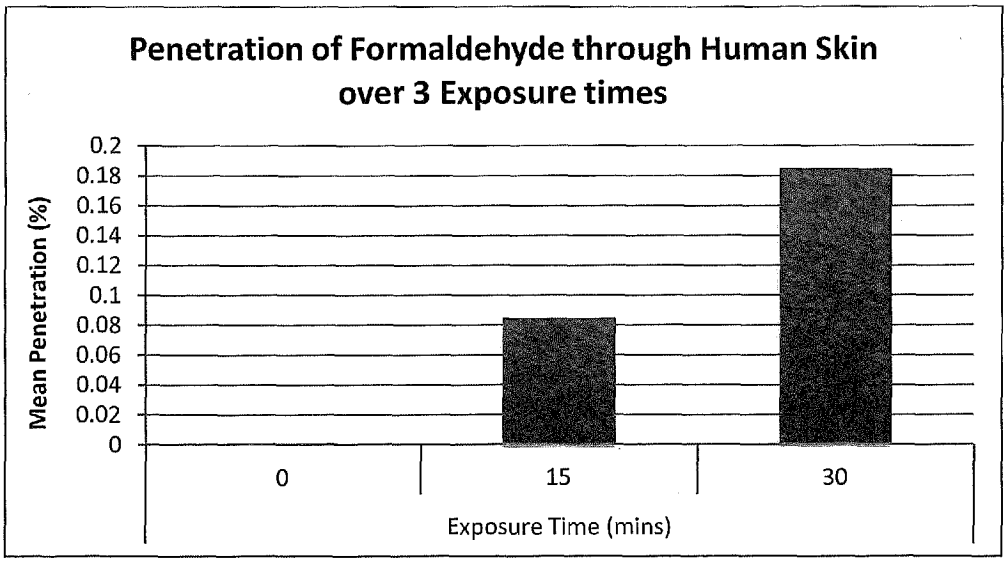


Figure 1: Penetration over time of formaldehyde solution applied (at 4%) to excised female abdominal skin.

Figure 2 demonstrates that increased applied dose of formaldehyde solution for thirty minute exposures resulted in increased penetration through the skin (i.e. higher applied dose = greater penetration concentration).

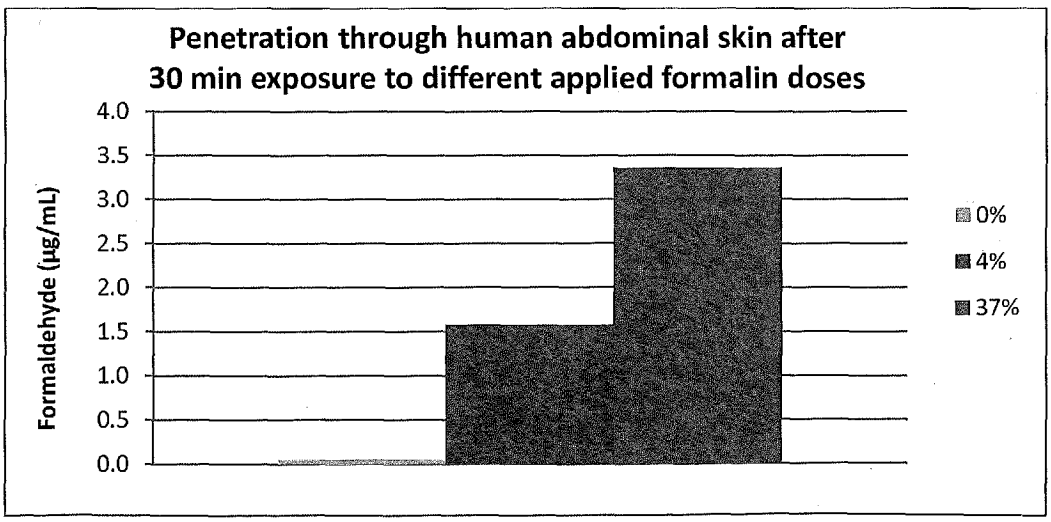


Figure 2: Penetration of formaldehyde solution at different test concentrations through excised female abdominal skin.

Conclusions/Recommendations to be made from these limited experiments using formaldehyde include:

- Limiting skin contact time with the chemical for individuals using the substance in workplace environments.
- Minimising as much as practicable the concentration of formaldehyde in cleaning agents and other workplace chemicals.
- Wearing appropriate personal protective equipment (e.g. gloves) when handling chemicals in the workplace which contain formaldehyde/formalin.
- The influencing effect of personal products worn on the skin (e.g. foundation, moisturiser) on formaldehyde absorption and penetration is still to be assessed.
- Eventual outcomes may help to inform workplace practices such as handling of new stock in the retail industry, guidance on the use of personal care products for workers handling cleaning chemicals, and other initiatives in relevant occupational settings.

Ammonia is extensively used in the food-manufacturing and agricultural industries and is one of the most commonly spilled chemicals in occupational settings (Makarovsky et al., 2008). **Chlorine** is one of the most commonly manufactured chemicals and is widely used:

- as a bleaching agent in the manufacture of pulp and paper and textiles
- to make pesticides, herbicides, refrigerants, propellants, household and commercial bleaches, detergents for dishwashers, antifreeze, antiknock compounds, plastics, synthetic rubbers, adhesives and pharmaceuticals
- for drinking and swimming water purification
- for sanitation of industrial wastes and sewage
- in the degassing of aluminium metal.

These two chemicals (as gases) were separately applied to human abdominal skin for short durations (up to 30 mins) in the presence and absence of an oil-based sunscreen to determine the influence of cosmetics on absorption and penetration of the chemical/s. Results of chemical penetration of ammonia are shown in Figure 3, and chlorine in Figure 4.

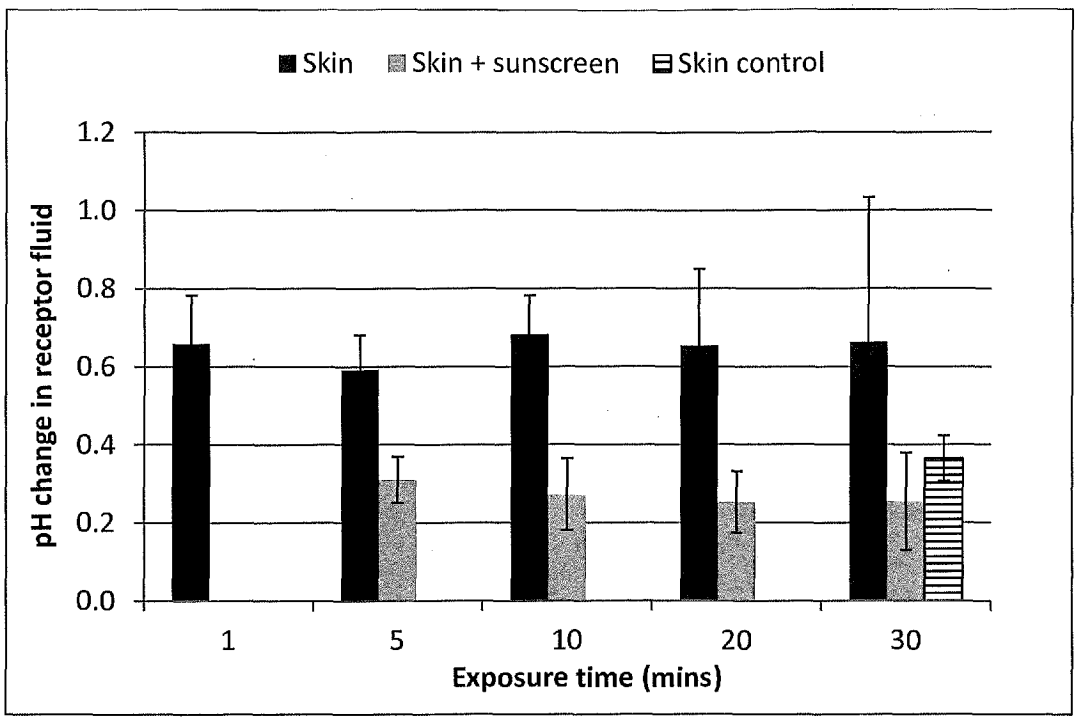


Figure 3: Penetration through human abdominal skin exposed to 2000 ppm ammonia gas with and without sunscreen applied. 'Skin control' is pH change in solution in the absence of ammonia exposure.

Results for ammonia show minimal penetration through skin ($p = 0.006$) in the absence of sunscreen which was not exposure-time dependent. The application of oil-based sunscreen onto skin was shown to effectively inhibit and eliminate ammonia penetration through skin across all exposure times ($p \leq 0.03$).

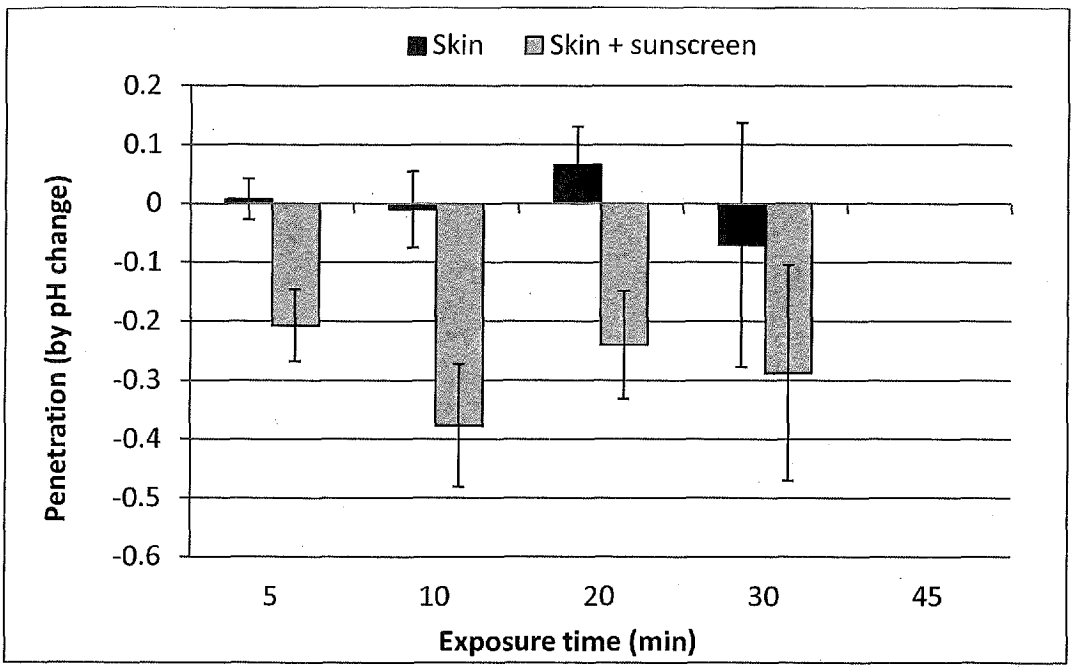


Figure 4: Penetration through human abdominal skin exposed to 500 ppm chlorine gas with and without sunscreen applied.

Results for chlorine show no significant penetration through skin across all exposure times (without sunscreen), however the application of an oil-based sunscreen onto skin facilitated penetration ($p < 0.0001$) for all exposure times.

Conclusions/Recommendations to be made from these limited experiments using ammonia and chlorine include:

- Conclusions able to be drawn from the sunscreen barrier effectiveness outcomes for tested chemicals are limited, except where we may be dealing with hydrophobic contaminants, where physical removal of sunscreen is likely to be beneficial following exposure.
- More research is needed to clarify the role of personal items applied to the skin on dermal absorption of chemicals.
- This work will hopefully contribute to a better understanding of the issue for occupational hygienists and other OHS professionals who may be called upon to provide advice and assistance on these issues.

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