Effect of Skin Protection and Skin Irritation on the Internal Exposure to Carbon Disulfide in Employees of the Viscose Industry

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ABSTRACT

Introduction: Occupational exposure to carbon disulfide (CS2) leads to inhalative and dermal uptake and thereby to internal exposure. In order to prevent occupational contact dermatitis, gloves and skin protection creams are used at the workplace. The aim of the study was the evaluation of the influence of personal skin protection and irritation on the internal exposure to CS2 of employees in the viscose industry.

Methods: One hundred and eighty-two male CS2-exposed employees were included in the study and were examined regarding working conditions, use of personal protective measures and skin status. Personal air monitoring and biological monitoring was performed and the 'relative internal exposure' (RIE, internal exposure in relation to external exposure) calculated. A multiple regression analysis calculated the influence of skin protection and irritation on CS2 uptake.

Results: Usage of skin protection creams and gloves (and both in combination) while working was associated with a significantly higher RIE indicating a higher dermal penetration of CS2. Equally, irritated skin and younger age was associated with a higher internal burden.

Conclusions: Gloves and skin protection creams are useful for preventing occupational skin diseases. However, when handling skin-resorptive substances like CS2, they can increase internal exposure or skin irritation. Therefore, we recommend the careful consideration of benefits and risks of protective creams and gloves at the workplace.

KEYWORDS: biomonitoring; carbon disulfide; dermal uptake; exposure assessment; gloves; skin protection; skin protection creams

INTRODUCTION

Since 1892 the chemical agent carbon disulfide (CS2) is used as an essential reactant in the production of viscose fibres. CS2 is known as a toxic substance in particular for the nervous system and the cardiovascular system (National Institute for Occupational
Safety and Health [NIOSH], 1996; Deutsche Forschungsgemeinschaft [DFG], 2005). Local contact can result in erythema, blisters and ulcers, aggravated by co-exposure to other substances such as hydrogen sulfide (Hueper, 1936; NIOSH, 1996).

Generally, the strategies to avoid or reduce the health risk from CS₂ exposure mainly focus on the inhalative uptake. However, the dermal uptake of CS₂ is also considered to be a relevant route of CS₂ absorption into the organism (Dutkiewicz and Baranowska, 1967; Drexler et al., 1995). Dutkiewicz and Baranowska (1967) determined dermal resorption of CS₂ from aqueous solutions with different methods. Their test results emphasize the high relevance of the dermal uptake of CS₂ for the internal exposure of workers in the viscose industry. In addition, Drexler et al. (1995) showed that pathological skin conditions cause an increase in the dermal uptake of CS₂.

Due to improved working conditions in the viscose producing industry, the exposure of employees via the workplace air has been distinctly reduced (Gelbke et al., 2009). Nevertheless, in the production of viscose, CS₂ is a reactant that cannot be substituted by a less toxic one. Thus, exposure to CS₂ and consequently its impact on the employees' health still exists today. In order to prevent adverse dermal effects and dermal absorption of CS₂, the contact to the agent should be avoided or minimized first and foremost by technical and organizational means. If these measures alone do not suffice, individual protection measures shall be applied to further reduce dermal contact to chemical agents (European Community [EU], 1998). The employees are requested to use personal protective equipment like gloves and skin protection creams, often referred to as skin barrier creams. Thereby, direct dermal contact to CS₂ should be reduced, if not completely prevented. Depending on the operating conditions and possible interactions between skin protection creams and gloves, attention should be paid to select appropriate gloves and skin protection creams (European Agency for Safety and Health at Work [EU OSHA], 2008). The benefit of skin protection measures for preventing skin diseases is well documented (Elsner, 2007; Kütting et al., 2010; Schliemann et al., 2014). On the other hand, many studies demonstrated that the efficiency of skin protection measures is questionable regarding a reduced dermal uptake of hazardous chemicals. A penetration enhancement effect by the creams itself, particular ingredients of the creams or irritations of the skin (following long-term use of gloves) are discussed (Lodén, 1986; Boman and Mellström, 1989; Korinth et al., 2003a, 2007a, 2008; Bock et al., 2009). Thus, the impact of skin protection measures, especially the combination of gloves and skin protection creams on the dermal penetration of hazardous substances at the workplace is of great interest for occupational safety and preventive medicine.

In this study, we investigated the impact of personal skin protective measures (use of gloves and application of skin barrier creams) and pathological skin conditions on the dermal absorption of CS₂ in employees in a viscose producing factory. For this purpose the individual exposure to CS₂ in the air at the workplace and the internal exposure of the employees were assessed. To evaluate the impact of factors which potentially interfere with the uptake of CS₂ the relative internal exposure (RIE) approach was applied. This ratio can be used as the 'measure of the internal exposure related to the individual (external) exposure'. It allows us 'to compare the individual relationships of internal to external exposure' (Drexler et al. 1995).

A higher RIE means a higher internal exposure as expected from external exposure. Due to this standardization the RIE allows us to estimate the influence factors such as physical work load or dermal resorption on the employees’ internal exposure.

MATERIALS AND METHODS

Study design and subjects

From a cross-section of 289 CS₂-exposed employees from different departments of a viscose production plant (Göen et al., 2014) have been studied. Due to operational process conditions, we have not been able to obtain either CS₂ or 2-thiothiazolidine-4-carboxylic acid (TTCA) values from 79 or 74 workers, respectively. Only ~8% (n = 24) of the TTCA-values and <1% (n = 2) of the CS₂ values have not been detectable. One hundred and eighty-two male individuals, who showed both CS₂ air concentration and urinary TTCA levels above the detection limits, were included in the study. The age of the employees ranged from 24 to 63 years. Personal sampling of CS₂ in the workplace air was performed during the whole shift. Urine samples were taken at the end of the same shift and analysed for TTCA, a specific metabolite of CS₂. Moreover, personal information on life-style, medical history, working history, and occupational
hygiene behaviour was recorded using a standardized, computer-processible questionnaire. The workers were asked about skin irritation and the frequency of occurrence. The current skin status of forearms and hands was recorded. In addition, they were asked in particular about individual working conditions considering direct dermal contact to wet spinning spools that can cause skin damage and the use of personal protective equipment like gloves and skin protection creams before, during and after work. Working conditions and work processes are described elsewhere (Drexler et al., 1994; Göen et al., 2014). Written informed consent was obtained from each participant.

The study was approved by the local Ethics Committee of the University of Erlangen-Nuremberg.

**Personal air monitoring and biological monitoring**

Personal air monitoring of CS$_2$ was carried out using diffusive sampling with charcoal tubes (ORSA S, Draeger, Lübeck, Germany) for the total length of a shift. The quantification of CS$_2$ was carried out after liquid extraction with toluene by gas chromatography as described elsewhere (Göen et al. 2002). The limit of quantification (LOQ) was 0.20 ppm. For analysis of the CS$_2$-metabolite TTCA in urine a procedure published by the Deutsche Forschungsgemeinschaft was used (Eben et al., 1994). In brief, TTCA was extracted from the urine by liquid extraction with diethyl ether and was determined by high-performance liquid chromatography and UV absorption. The LOQ of the procedure was 0.10 mg l$^{-1}$ urine. The accuracy of the biomonitoring method was controlled by the successful participation in the German External Quality Assessment Scheme (www.g-equas.de).

The RIE was calculated as described by Drexler et al. (1995):

$$RIE = \frac{C_{TTCA}}{C_{CS2}}$$

$C_{TTCA}$ represents the concentration of TTCA related to creatinine in the post-shift urine sample (in mg g$^{-1}$ creatinine) and $C_{CS2}$ represents the individual exposure to CS$_2$ in air during the shift (in ppm).

**Statistics**

The statistical data analysis was performed using IBM SPSS 21.0 for Windows (IBM Co., Armonk, NY, USA). The Kolmogorov–Smirnov test was carried out to examine normal distribution ($P < 0.05$, the K–S test shows a significant deviation from normality). If not normally distributed, the non-parametric Mann–Whitney $U$ test and the Spearman’s correlation coefficient were used to compare different groups. If data were normally distributed, the Student’s $t$-test was performed. The level of significance was 5% ($P \leq 0.05$). If not stated otherwise, data are represented as median (range). With respect to ambient CS$_2$ concentrations, age and length of employment, the workers were divided according to the tertiles of the empirical distribution to control the confounding of these parameters with other RIE influencing factors. Inflammatory changes of skin can still be on a merely sub-clinical level. To account for this, we included all workers who complained about skin irritations (regardless of frequency and severity of occurrence) in one subgroup.

A multiple linear regression analysis (CS$_2$ air-level, age, skin contact with wet spinning spools, use of gloves, frequency of using skin protection creams, irritation of the skin and length of employment, the workers were divided according to the tertiles of the empirical distribution to control the confounding of these parameters with other RIE influencing factors. Inflammatory changes of skin can still be on a merely sub-clinical level. To account for this, we included all workers who complained about skin irritations (regardless of frequency and severity of occurrence) in one subgroup. A multiple linear regression analysis (CS$_2$ air-level, age, skin contact with wet spinning spools, use of gloves, frequency of using skin protection creams, irritation of the skin and length of employment, the workers were divided according to the tertiles of the empirical distribution to control the confounding of these parameters with other RIE influencing factors. Inflammatory changes of skin can still be on a merely sub-clinical level. To account for this, we included all workers who complained about skin irritations (regardless of frequency and severity of occurrence) in one subgroup.

**RESULTS**

The results of personal air monitoring and biological monitoring are as follows: The median external exposure to CS$_2$ in the ambient air of all employees was 2.77 ppm (range 0.46–20.87 ppm). The median internal exposure of the employees was 0.93 mg g$^{-1}$ creatinine TTCA in the urine (0.16–5.27 mg g$^{-1}$). Statistical comparison did not reveal any difference in TTCA values between workers on Day 1 or 2 of their working week ($P = 0.61$). There was a significant positive correlation between the concentration of airborne CS$_2$ and TTCA in urine (Spearman’s correlation coefficient = 0.79, $P < 0.001$). From this data a median RIE of 0.33 mg ppm$^{-1}$ g$^{-1}$ (0.12–0.90) was derived. A decrease in RIE was seen at higher personal CS$_2$-levels (Fig. 1A). This effect was mostly pronounced in the young and
According to the company’s occupational hygiene officer gloves were used for ~2–3 h per shift (occasionally up to 8 h per shift). The use of industrial grade gloves resistant to the chemicals was mandatory with certain types of work or handled materials and regulated by the factory’s skin protection plan. For instance, gloves made of natural latex were used in the presence of sulphuric acid (e.g. spinning bath) and gloves made of nitrile in the presence of alkaline liquids (e.g. rayon aging).

The worker used, depending on the work place situation, a water-in-oil-in-water emulsion (W/O/W emulsion; recommended against water-based workplace substances, e.g. acids or bases), an oil-in-water emulsion (O/W emulsion ; recommended against skin softening, e.g. frequent gloves use or mechanical strain) and an oil-free suspension (recommended against oily and water-insoluble workplace substances) for skin protection, all according to recommendations by the manufacturer of the creams.

Additionally, a solvent-free suspension and a solvent-free paste for skin cleaning and an O/W emulsion for skin care at the end of work were recommended. For evaluation of the effects of personal skin protection (gloves, skin protection creams) on RIE individuals who used skin protection creams before and during work were summarized in the same subgroup. Eight employees who stated to use skin protection creams only at home have been excluded from the analyses. Sixteen workers (8.8%) used neither protection creams nor gloves at work whereas 75 (41.2%) of the employees used both. Solely usage of gloves was stated by 52 individuals (28.6%) and solely usage of protection creams by 31 individuals (17.0%). The median RIE of individuals, who did not apply skin protection creams at all nor used gloves, was 0.26 (0.17–0.61). The sole use of skin protection creams was associated with a significantly higher RIE \[0.36 (0.19–0.87); P = 0.014\]. Similarly, in employees who solely used gloves, a significantly higher RIE was found \[0.33 (0.19–0.67); P = 0.023\]. In case of combined use of gloves and protecting creams the RIE was 0.33 (0.12–0.90; \(P = 0.006\) compared to the group not using any protection measure in comparison with the first subgroup).

The RIE increased with a higher number of repetitive applications of protective creams at the time of investigation. This pattern was only seen in workers who did not use gloves on top (Fig. 2; \(n = 55\), standardized beta coefficient = 0.348, \(P < 0.01\)). Based on these data, the employees were divided into three groups: no, 1–3 times, and 4–7 times application of

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**Figure 1** Comparison of RIE levels between different groups of CS\(_2\)-exposed workers. (A) Differentiation by CS\(_2\) ambient air levels. The 182 workers involved in the study were divided into three, about equal-sized groups, depending on their ambient CS\(_2\) levels \( (n = 60, 61, 61; \text{mean } = 1.6, 2.8, 5.0 \text{ ppm}; \text{low, medium, high}) \). Workers with low and medium levels differed significantly from the group with high CS\(_2\) levels \( (P = 0.003, P = 0.01) \). (B) Differentiation by age and CS\(_2\) ambient air levels. The workers were divided by age into three groups \( (n = 60, 61, 61; \text{younger, medium, older}) \) and the RIE related to the ambient CS\(_2\) levels in the three age strata. Mann–Whitney U tests revealed significant differences between the low and high ambient CS\(_2\) groups in the younger \( (P < 0.001) \) and middle aged \( (P = 0.02) \) workers and the medium and high CS\(_2\) groups in the younger \( (P = 0.008) \).
protective creams. The results are depicted in Fig. 3. Individuals not using creams but wearing gloves had a higher RIE (0.33 versus 0.26, \(P = 0.031\)) than workers without gloves. The RIE level of workers wearing gloves was independent from the number of applications of protective creams. In contrast, the RIE of workers solely using protection creams gradually increased, being significantly higher at application frequencies of \(\geq 4\) times per shift (0.26 versus 0.45, \(P = 0.009\)).

The influence of skin irritation on the RIE is shown in Fig. 4A. No difference in RIE at medium and high CS\(_2\) levels in ambient air was seen in workers who do not report an irritation of the skin on a regular basis. The RIE of employees with frequently irritated skin was significantly elevated at medium CS\(_2\) levels compared to high ambient CS\(_2\) (0.38 versus 0.27, \(P = 0.004\)).

One hundred and thirty-eight employees stated that they had dermal contact to wet spinning spools in contrast to 44 workers without contact. Comparison of those two groups across all participants did not show any difference concerning their RIE. However, stratified into three equal-sized groups according to personal CS\(_2\)-air level, age or length of employment each showed RIE differences within the groups. A significant decrease in RIE with increasing personal CS\(_2\)-air level was only seen in connection with contact to wet spinning spools [Fig. 4B, low/medium/high CS\(_2\)-air level: 0.39 (0.16–0.90)/0.34 (0.17–0.67)/0.30 (0.17–0.62)]. In contrast, an influence of age [younger/medium/older: 0.41 (0.19–0.81)/0.33 (0.19–0.46)/0.24 (0.12–0.54)] and length of employment [short/medium/long term: 0.41 (0.19–0.81)/0.26 (0.19–0.54)/0.26 (0.12–0.39)] on the RIE was only seen in workers without contact to wet spinning spools.

Finally, a multiple regression analysis was carried out in order to quantify the impact of the different explanatory factors (CS\(_2\)-air level, age, skin contact with wet spinning spools, gloves, frequency of using skin protection creams, irritation of the skin, length of employment) on the workers’ RIE (Table 1). The CS\(_2\)-air level exhibited the main, inversely proportional
influence on the RIE (β-coefficient: −0.351, P < 0.0001). Likewise, the influence of the participants’ age on the RIE was inversely proportional (β-coefficient: −0.249, P < 0.007). About the same strength of influence was seen when using skin protection creams (β-coefficient: 0.248, P < 0.0005). The remaining four factors showed no or only a weak, non-significant influence on the RIE (Table 1). A sensitivity analysis employing the same set of explanatory variables but TTCA (mg/g creatinine) as outcome identified the same factors as significantly associated (adjusted R² = 0.73), the actual estimates evidently being different. Moreover, we included interaction terms in two further sensitivity analyses, first between using gloves and frequency of hand cream usage or second between CS₂ air levels and age, which were, however, not significant.

DISCUSSION
Like former studies of CS₂ exposed workers (Campbell et al., 1985; Drexler et al., 1994; Chang et al., 2002), the present study demonstrated that the internal exposure of the employees correlated strongly with the individual external exposure to CS₂. However, several factors such as physical work load or dermal resorption affect the uptake of CS₂ by the employee (DFG, 2005). Drexler et al. (1995) showed that an increased minute volume induced by a high physical work load can lead to an elevated RIE. The fact that young workers are more frequently occupied in physically exhausting jobs with a corresponding elevated minute volume may explain the higher RIE of younger individuals in the present study as demonstrated in the multiple regression analysis. Moreover, direct dermal contact to wet spinning spools resulted in an increase of the RIE. This effect was much more pronounced in the group of employees exposed to low CS₂ air concentration. It may be explained by the increased relevance of dermal exposure at low inhalative CS₂ intake. Likewise, the observed increase in RIE in connection with lower personal CS₂ air levels in the total study sample might be attributed to a relative higher impact of direct dermal versus inhalative CS₂ uptake. This was mainly seen in younger and middle aged workers. One explanation could be a more careful work behaviour of long-term and more experienced employees regarding dermal contact to CS₂. On the other hand, recent studies describe age-related changes in dermal resorptive properties. An ex vivo study on dermal penetration of the opioid analgesic fentanyl (using skin samples of donors of different age) demonstrated that the agent...
permeated the skin of younger individuals to a greater extent (Holmgaard et al., 2013). Nevertheless, the significance of the age effect disappeared within the group with dermal contact to wet spinning spools. Thus, the effect of direct contact to CS₂ seems to be more relevant than other determinants and can conceal their effects.

The dermal resorption of CS₂ seems to be important for the internal exposure to CS₂. Like many other chemical substances CS₂ can be readily absorbed even through the healthy skin (DFG, 2005). A skin barrier defect (i.e. skin diseases or frequent skin irritations) can increase the dermal resorption of CS₂ (Drexler et al., 1995; Chou et al., 2004). Therefore, the use of gloves and also of skin protection creams at the workplace is supposed to protect against CS₂ exposure and to help preventing occupational skin diseases. However, in the univariate regression analysis, the use of gloves at work did not lead to a significant decrease of RIE. A similar observation was made in a former study which demonstrated that protective gloves did not lead to a relevant reduction of dermal resorption of CS₂ (Korinth et al., 2000). A more differentiated evaluation of the results revealed that the RIE was actually elevated in employees solely using gloves, that is without the additional use of protection creams.

The indication for an enhancing effect by the use of gloves might have many different reasons. First an average usage of 2–3 h per shift meets the criteria of wet work which may lead to a disturbed skin barrier as a result of occlusive effects (Schliemann, 2007). However, the evidence of a possible skin hazard due to occlusion by gloves is still controversial. Weistenhöfer et al. (2015) did not find any proof that wearing occlusive gloves has visible and persisting effects on healthy skin. They speculate that not simple occlusion, but an interaction with other irritants might be causal for an impairment of the dermal barrier. This is supported by Antonov et al. (2013) who observed in particular under occlusion a substantial increase in transepidermal water loss induced by a skin irritant. Moreover, chemicals can penetrate through the glove material (Nielsen and Sørensen, 2012). Additionally, CS₂ may enter the inner glove via the cuff. In combination with the occlusive effect of the gloves, this might lead to a significant increase of dermal uptake of individuals using only gloves (Fluhr et al., 2005; Nielsen and Sørensen, 2012). Depending on the varying compositions of raw materials and production methods, gloves of different manufacturers made from the same or similar material can have different mechanical and chemical protective effects and material stability (Deutsche Gesetzliche Unfallversicherung, 2009). In order to estimate the resistance of the gloves used by our study population, the gloves would need to be tested experimentally.

The individuals, who only used skin protection creams, showed a significantly elevated RIE too. Furthermore, repetitive, sole application of skin protection creams significantly enhanced the RIE in a dose-dependent manner. These data support a cumulative effect on the RIE caused by frequent applications of

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Table 1. Results of the multiple linear regression analysis.a

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regression coefficient B</th>
<th>Standardised β coefficient</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient CS₂-levels (ppm) (low/medium/high)</td>
<td>−0.059</td>
<td>−0.351</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Age (years)</td>
<td>−0.004</td>
<td>−0.249</td>
<td>0.006</td>
</tr>
<tr>
<td>Frequency of using skin protection creams</td>
<td>0.016</td>
<td>0.248</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Use of gloves (yes/no)</td>
<td>0.029</td>
<td>0.098</td>
<td>0.173</td>
</tr>
<tr>
<td>Irritation of the skin (yes/no)</td>
<td>0.022</td>
<td>0.076</td>
<td>0.284</td>
</tr>
<tr>
<td>Contact with wet spinning spools (yes/no)</td>
<td>0.012</td>
<td>0.039</td>
<td>0.601</td>
</tr>
<tr>
<td>Length of employment (month)</td>
<td>−0.000025</td>
<td>−0.017</td>
<td>0.848</td>
</tr>
</tbody>
</table>

aDependent variable: RIE, R² (adjusted) = 0.17.

bSignificant P values are given in bold.
skin protection cream. In the multiple linear regression analysis the frequency of using skin protection creams per shift remained a significant risk factor, which confirms this hypothesis. Nevertheless, several studies found beneficial effects of skin protection creams preventing occupational skin lesions and diseases (Elser et al., 2007; Zhai and Maibach, 2007; Kütt et al., 2010). On the other hand, the physico-chemical properties of CS₂ and its possible interactions with ingredients of protection creams may create the preconditions for an elevated uptake of the chemical through the skin (Kresken and Klotz, 2003; Schliemann, 2007). Such interactions between skin protection creams and penetrating chemicals are described for many other hazardous substances (Boman, 1989; Boman and Mellström, 1989; Korinth et al., 2003a,b, 2007b; Zhai and Maibach, 2007, Korinth et al., 2008). In previous studies, similar results for CS₂ were demonstrated in vitro and in vivo (Korinth et al., 2000, 2007a). Using intradermal microdialysis in a human in vitro skin model, Korinth et al. (2007a) found a five times higher penetration of CS₂ in skin treated with a skin protection cream compared to untreated skin. This observation is supported by another study of Zhai and Maibach (2007). They showed that an oil-free suspension like one of the three protection creams applied by the employees in the present study increased the penetration of methylene blue and oil red O solutions into the skin with increased application time. Such penetration enhancers in skin protection creams are supposed to be responsible for the facilitated penetration of added agents through the skin (Korinth et al., 2008).

This effect has already been used for several years to improve the efficiency of transdermally applied pharmaceutics (Wellner et al., 2006). Korinth et al. (2008) identified the emulsifier’s glyceryl stearate and stearic acid in tested skin creams to be responsible for causing an increased penetration of aniline and o-toluidine through human skin. These substances are also found as ingredients in the skin protection creams used in the present study. Besides our findings on the enhancing effect of protective creams on the RIE, Schliemann et al. (2013) could not demonstrate a protective effect of creams in terms of preventing solvent-induced contact dermatitis.

The RIE of employees with recurrent episodes of skin irritations was statistically higher in comparison to employees without or only rare cases of irritated skin as observed before (Drexler et al., 1995). This may be explained by a higher susceptibility of irritated skin with respect to absorption of substances (Korinth et al., 2003b; Hino et al., 2008).

For example, lesioned skin enhanced the percutaneous absorption of glycol ether in offset printing workers (Korinth et al., 2003b). It was also shown that a mechanical predamage of the skin further amplifies the penetration of propylene glycol (Gattu and Maibach, 2010). Thus, a disturbed skin barrier can result in an increased resorption of CS₂ through the skin.

**CONCLUSIONS**

The results of the present study confirmed that the portion of the dermal route for the total uptake of the hazardous substance becomes more relevant at low airborne levels. This effect facilitated the disclosure of several determinants of the dermal absorption of CS₂ in the present field study. The results reveal that in practice the use of skin protection creams and gloves can result in an increase of dermal uptake of a chemical substance. This effect may be caused by a false concept or false application of the protective measures. In a recent German guideline, Diepgen et al. (2015) discussed in detail protective measures to prevent the development of hand eczemas. It is well established that skin protection creams do not function like a protective coating film but that the regular application of skin creams contributes to a well-conditioned and healthy skin. On the other hand, skin protective creams contain additives which can enhance the dermal uptake of other substances. This leads to the hypothesis that skin cream application after work may combine positive skin care effects and prevention of adverse dermal uptake effects. Challenging tasks for an effective use of protective gloves are first of all the selection of an adequate glove material which prevents the penetration of the substance through the glove. Secondly, size and design as well as the correct use of the gloves must prevent pollution of the upper arm from trickling into the mouth of the glove. In this case, the occlusive condition facilitates the dermal uptake of the substance. Overall the results of the present study provide indications for problems and solutions to an effective protection from dermal resorption of chemical substances at the workplace.
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CONFLICT OF INTEREST
The authors declare no conflict of interest relating to the material presented in this Article. Its contents, including any opinions and/or conclusions expressed, are solely those of the authors.

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