

Hairdressers' skin exposure to hair dyes during different hair dyeing tasks

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Summary

Background. The high risk of occupational skin disease among hairdressers, caused by skin exposure to irritants and sensitizers, such as hair dye substances, is of great concern.

Objectives. The aim of the present study was to assess how the various tasks involved in hair dyeing contribute to hairdressers' exposure to hair dye, in order to enable the formulation of well-founded recommendations on working routines that will reduce exposure and prevent occupational disease.

Methods. Skin exposure to hair dye was measured for 20 hairdressers applying high-lights and all-over hair colour with the hand rinsing technique. Resorcinol was used as a proxy for hair dye exposure.

Results. Applying hair dye and cutting the newly dyed hair were the tasks that contributed most to exposure in treatments for highlights. After cutting all-over-coloured hair, all hairdressers had measurable amounts of hair dyes on both hands.

Conclusions. Hairdressers are exposed to hair dye ingredients during all steps of the hair dyeing procedure. Cutting newly dyed hair contributes significantly to exposure. As initial steps for the prevention of occupational disease resulting from hair dye exposure, we suggest cutting hair before dyeing it, and wearing gloves during all other work tasks.

Key words: hair dyes; hairdressers; hand rinse sampling; occupational skin exposure.

The high risk of occupational skin disease among hairdressers is well known and remains a great concern. Major risk factors include skin exposure to skin irritants and sensitizers, particularly hair dye substances, preservatives, and fragrance substances (1–4).

Oxidative hair dyes are still among the most common causes of occupational contact allergy among hairdressers in Europe (1, 4, 5). In a study on the incidence of hand eczema among hairdressers, we found that many hairdressers had developed hand eczema at

an early age (6). In a recent study, Danish researchers called for additional strategies to prevent hand eczema among hairdressers (3). The development of efficient strategies to reduce harmful occupational exposure to chemicals requires deeper knowledge and understanding of the exposure scenario (7). The Scientific Committee on Consumer Safety (SCCS) and its predecessors have assessed >110 hair dye substances, and have found that half of them are skin sensitizers mostly potent ones (8, 9).

The SCCS and predecessors have, owing to concerns about bladder cancer, assessed the risk concerning carcinogenicity and some other health effects related to oxidative hair dye products and reaction products for consumers (however, neither concerning sensitization, nor occupational use by hairdressers) on the basis of human, animal and *in vitro* studies, including skin

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absorption studies (10). No clearcut conclusion was drawn by the SCCS with regard to carcinogenicity to consumers. Several other aromatic amines, including *o*-toluidine, are classified as carcinogens (group 1, 2A or 2B), and their use in cosmetics is banned (11, 12). However, recent studies have detected *o*-toluidine in hair dye products, and haemoglobin adducts of *o*-toluidine in blood from hairdressers (13–15). Many aromatic amines are absorbed through the skin, and dermal absorption of *o*-toluidine through human skin has been investigated *in vitro*; 50% of the applied dose was absorbed within 24 h (16). In an evaluation of substances, including hair dyes and aromatic amines, occupations, and associated carcinogenic risks, occupational exposure as a hairdresser has been classified by the International Agency for Research on Cancer as probably carcinogenic (group 2A) (17). A recent population-based case–control study of Finnish women has shown an increased risk of breast cancer among hair dye users (18).

Resorcinol is used in the majority of oxidative hair dye products, as shown in studies of products on the market in Germany, Spain, Sweden, and the United States (19–22). As compared with *p*-phenylenediamine (PPD), toluene-2,5-diamine (2,5-TDA or PTD), and other common hair dye substances, resorcinol is a relatively stable chemical and simple to analyse. A hand rinse method has previously been evaluated for the measurement of resorcinol and some other hair dye substances, and has also been successfully used in field studies (23–26).

The aim of the present study was to assess how the various tasks involved in dyeing hair contribute to hair dye exposure among hairdressers, and, ultimately, to enable the formulation of well-founded recommendations on working routines to reduce exposure and prevent occupational disease.

Materials and Methods

Subjects

In total, 20 hairdressers were recruited at personal visits at 11 randomly selected salons in the centre of Stockholm for participation in the study, performed from November 2012 to May 2013. Their mean age was 38 years (range 22–62 years); 19 were women. All were self-employed, all were renting a space in a larger salon, and all had their own hair products, gloves, and individual working routines. We did not manage to recruit hairdressers who were employed at salons. None of the hairdressers normally wore gloves when applying hair dye for highlights (also called strands) or when cutting newly dyed hair (ID numbers 1–20). The lists of ingredients on all hair

dye products to be used were examined before a hairdresser was included and started the study. It was required that at least one product contained resorcinol. The study adhered to the tenets of the Declaration of Helsinki, and was approved by the regional ethics review board in Stockholm, Sweden (Dnr 2011/600-31/1). All participants gave written informed consent before taking part in the study.

Sampling

Hand rinse samples were collected from both hands of hairdressers, to assess skin exposure from different steps of hair dye treatments. When the hairdressers were dyeing highlights ($n = 15$), samples were taken to assess exposure from mixing, applying dye, various other tasks, shampooing, and cutting the hair (Fig. 1). When they were dyeing an entire head of hair (also called all-over colouring) ($n = 10$), samples were collected only to assess exposure from cutting the freshly dyed hair. The last sample was taken immediately after cutting was completed, before styling and any hairstyling products were added. Five hairdressers (ID numbers 3, 6, 7, 8, and 11) participated, on different occasions, in sampling both when dyeing highlights and dyeing the entire head of hair. In total, 25 hair dye treatments were assessed by collecting and analysing 220 hand rinse samples.

Skin exposure was assessed by use of a previously evaluated hand rinse method for hair dye components, with a sampling efficiency approximately 70–90% (23). The sampling efficiency is defined as the proportion of the amount of the compound(s) on the skin that is rinsed off by the sampling procedure, that is, the proportion of the compound(s) found in the sample. The hands were rinsed in 1-l household polyethylene bags containing 50 ml of rinsing solution (0.2 M ascorbic acid in borate buffer with 10% ethanol). The bags were sealed with a rubber band above the wrist, and the hairdressers were instructed to shake their hands vigorously for 2 min with the fingers apart and slightly bent. Samples were taken from the right and left hands simultaneously, and the rinse liquid was collected in separate bottles by cutting off a corner of the bag. Aliquots of the solutions were immediately transferred to 20-ml glass vials, and stored at room temperature during transport to the laboratory refrigerator on the same day.

Chemicals

The following chemicals were used: resorcinol Analab Normapur[®] analytical reagent (CAS no. 108–46–3) >99% and L(+)-ascorbic acid Analab Normapur[®]

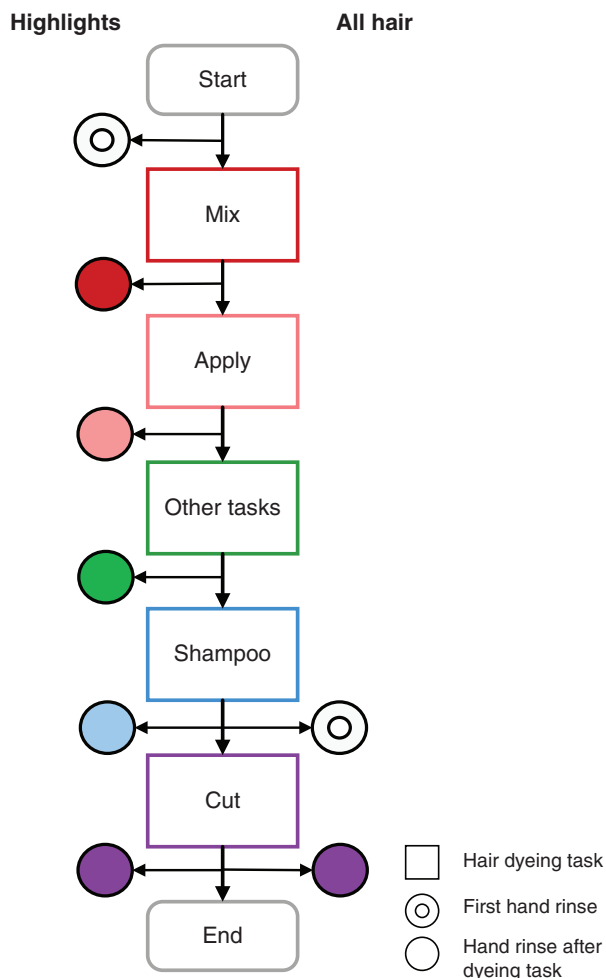


Fig. 1. Flow-chart showing hair dyeing tasks and corresponding hand rinse sampling for assessment of skin exposure to hair dye in hairdressers. The samples (after 'start' for highlights and 'shampoo' for dyeing all of the hair) reflect exposure from the immediately preceding activities.

analytical reagent (CAS no. 50–81–7) >99.0% from VWR International AB (Stockholm, Sweden). Sodium tetraborate decahydrate p. a. (CAS no. 1303–96–4) >99%; methanol, LiChrosolv®, high-performance liquid chromatography (HPLC) grade (CAS no. 67-56-1) >99.8% and hydrochloric acid 25% p.a. EMSURE® from Merck KGaA (Darmstadt, Germany). Ethanol 99.5% was obtained from Kemetyl AB (Haninge, Sweden). Deionised water (16.7 MΩ cm⁻¹ quality) was used for preparing water solutions.

Buffer solution (pH 8.0) was prepared by mixing 0.1 M hydrochloric acid and 0.05 M sodium tetraborate; this previously has been shown to result in a suitable solvent for hair dye compounds (23). Standard solutions of resorcinol were prepared in buffer containing 10%

ethanol, and ascorbic acid was added as an antioxidant, to a final concentration of 0.2 M.

Chemical analysis

The hand rinse samples were analysed within 7 days. The samples were filtered with a syringe filter prior to analysis (VWR® syringe filters, PTFE, 0.45-μm pore size and 25-mm filter size; VWR International). The HPLC analysis method has been described in detail elsewhere (26), and resorcinol in hand rinse samples has been shown to remain stable for 14 days at room temperature (23).

Analysis was performed with an HPLC instrument consisting of a pump, solvent degasser, autosampler, column oven, and diode array detector (Merck Hitachi LaChrome D-7000 HPLC; Merck). The column was a 100 × 4.6-mm Merck ChromoLith Performance RP-18. The sample volume was 10 μl. The column temperature was 30°C. External standards were used for calculation of the concentration in the sample and to verify the retention time (examples are shown in Figure S1). Standard solutions of 0.1, 1, 5 and 10 ppm resorcinol were analysed every day before sample analysis. The wavelength used for detection was 201 nm. The identification and quantification of resorcinol were based on the retention time and the response factor at the chosen wavelength. The amount of resorcinol in this study stands for the amount of resorcinol including other substances or reaction products emanating from hair dye that may have the same retention time as resorcinol in this HPLC analysis. The detection limit was 0.23 nmol/ml, which corresponds to 11 nmol per hand.

Statistical methods

Student's *t*-test (two-sided, paired observations) was used for comparison of the exposure loading on the dominant hand versus the serving hand at each work task, and for comparison of exposure on both hands between highlight-dyeing tasks. A Wilcoxon signed-rank test was used to compare hand rinse samples from the serving hand or the dominant hand between the groups dyeing highlights or all-over-coloured hair after cutting. *p*-Values of <0.05 were considered to be statistically significant.

Results

All hairdressers were exposed to hair dye during hair dye treatments for highlights and for all-over colouring, as shown by the concentration of resorcinol in consecutive hand rinse samples. It is possible that the amount of resorcinol found in this study also includes other hair-dye

related substances not separated from resorcinol by this analytical procedure. The results are shown in Figs 2 and 3, and in Table 1, displaying individuals, accumulated exposure on hands by hands and work task. Comment: only Fig 2 shows accumulated exposure. We noticed during sampling that 1 of the hairdressers (ID 17) was less careful than the others in trying to avoid direct contact with hair dye. This hairdresser had much higher amounts of resorcinol on the hands after applying dye for highlights (1543 nmol/hand on the serving hand and 567 nmol/hand on the dominant hand), and the results from this participant were not included in further data analysis.

The total amounts of resorcinol in consecutive hand rinse samples taken during one hair dye treatment for highlights ($n=14$) and after cutting all-over-coloured hair ($n=10$) are shown in Fig. 2 and Table 1. There was wide variation in overall skin exposure to resorcinol between hairdressers performing treatment for highlights; however, the intraindividual variation between the serving hand and the dominant hand was less prominent, except in 2 cases (ID 4 and ID 19) (Fig. 2a). None of those dyeing highlights used gloves during mixing, applying or cutting; 2 used gloves during shampooing (ID 8 and ID 11). There was similarly large variation in exposure between those performing all-over dyeing, and between the serving hand and the dominant hand (Figs 2b and 3b); none of the participants used gloves during cutting.

The amount of resorcinol in the samples taken before the start of treatment for highlights and before cutting all-over-coloured hair (see Fig. 1) varied considerably between participants (Figs 2 and 3, Table 1). The main purpose of collecting these baseline samples was to clear the hands of hair dye, to enable assessment of the exposure from the following task (applying hair dye and cutting, respectively).

Applying hair dye and cutting the newly dyed hair were the tasks contributing most to exposure in treatments for highlights (Figs 2 and 3, Table 1). After applying dye, 13 of 14 hairdressers had measurable amounts of resorcinol on one or both hands, and after cutting the hair, 12 of 14 had measurable amounts of resorcinol on one or both hands. Comparison of exposure of both hands during different work tasks showed that applying dye resulted in significantly higher exposure than mixing ($p=0.001$) and shampooing ($p=0.008$). After cutting all-over-coloured hair, all hairdressers had measurable amounts of resorcinol on both hands. The exposure from cutting all-over-coloured hair was higher than that from cutting highlights, and the serving hand was significantly more exposed than the dominant hand ($p=0.005$) (Figs 2 and 3, Table 1). Other differences in exposure

between hands and work tasks were not statistically significant, owing to the relatively small sample size and large interindividual differences.

Discussion

Hairdressers' skin exposure to oxidative hair dyes was assessed with a previously evaluated hand rinse method. The hair dye compound resorcinol was used as an indicator of hair dye exposure. Applying dyes to the hair and cutting newly dyed hair resulted in the highest skin exposure. Background exposure was also high among many hairdressers.

Exposure: assessment, sampling, and scenario

The sampling technique that we used, hand bag rinsing, has previously been evaluated and shown to have high sampling efficiency, and it has been used in a field study of hair dye exposure among hairdressers (23, 24). The amounts of resorcinol that we found on the hands were of the same magnitude as in the previous study, in which resorcinol was identified with a complete ultraviolet spectrum of the compound, achieved by diode array detection. In this study, skin exposure from various hair dyeing tasks was studied in more detail than before, by collecting consecutive hand rinse samples from each step of the hair dyeing procedure. This enabled us to describe a stepwise exposure scenario and to identify the tasks that contributed most to hair dye exposure, which is crucial for efficient exposure reduction and disease prevention (7).

Each hairdresser used at least one hair dye product declared to contain resorcinol. We did not measure the concentration of resorcinol in the hair dye mixtures or the amount of hair dye applied. These factors are likely to have contributed to some of the interindividual differences in assessed exposure, but not to the intraindividual differences between work tasks and hands. We assessed the length of the hair (short, medium or long hair style) and recorded the duration of cutting and other hair dyeing tasks. Only the duration of cutting seemed to affect exposure (data not shown).

The prominent difference between the two hands in exposure from cutting newly all-over-coloured hair is of interest. In this study, the serving hand was more exposed. When occupational exposure assessments are designed, it may be important to consider asymmetrical exposure of the hands.

Background exposure to hair dyes (measured by quantifying resorcinol in this study) was significant in the majority of hairdressers. It could have resulted from many sources, including preceding hair dye treatments, washing of contaminated utensils, and contaminated surfaces

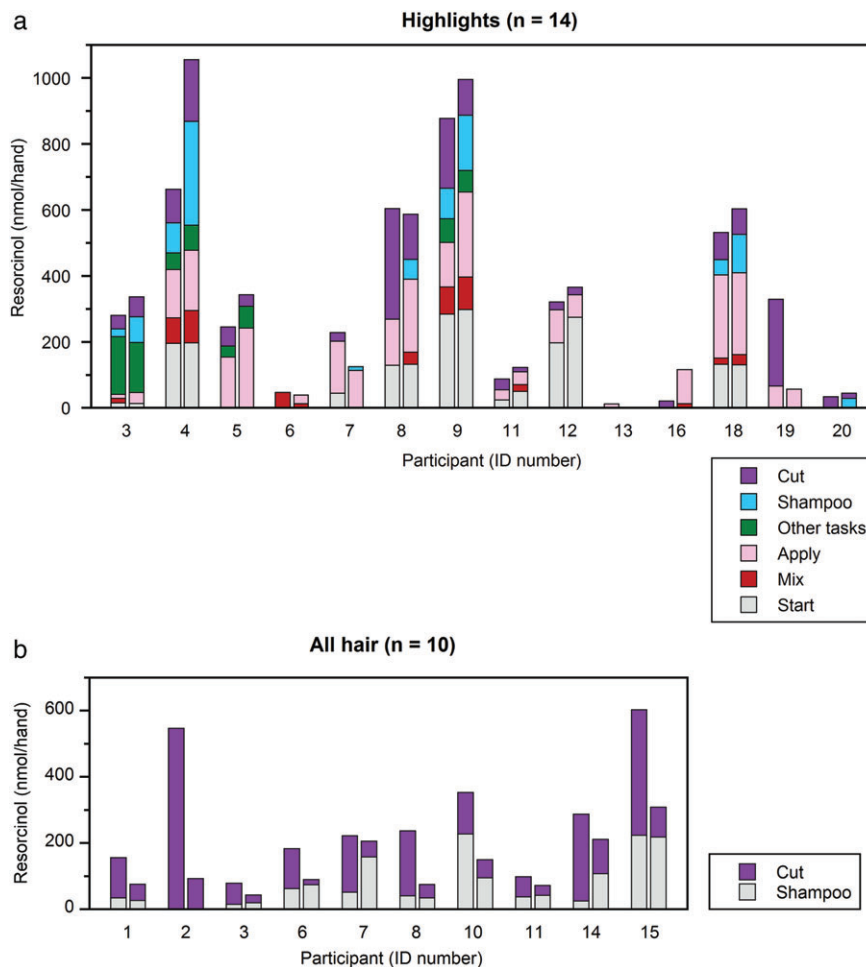


Fig. 2. Accumulated amounts of resorcinol, and possibly other hair dye-related substances with the same retention time as resorcinol, in hand rinse samples from hairdressers. Samples were collected from the serving and dominant hands during consecutive work tasks dyeing (a) highlights and (b) all-over-coloured hair. Analysis was performed with high-performance liquid chromatography. In pairs, to the left = serving hands; to the right = dominant hands.

in the salon. During this field study, surface samples were also collected and analysed (to be published).

Resorcinol is restricted by the Cosmetics Regulation (11); it is permitted only in oxidative hair dye products and products for colouring eyelashes (maximum concentration of 2.5%, or 1.25% after mixing), and in hair lotions and shampoos (maximum concentration of 0.5%). It is also used as a food additive and in topical medicaments (27). The participants in this study had no contact with such products during the study. Having examined numerous hairdressers with hand eczema and their hair products, and products in hairdressing salons, we have not come across a shampoo or hair lotion declared to contain resorcinol. We thus consider it highly unlikely that resorcinol in products other than hair dyes contributed to our results.

Resorcinol as a proxy for other hair dyes

Resorcinol was chosen as a proxy indicator of hair dye exposure on the basis of our previous experience. The

amount of resorcinol in this study represents the amount of resorcinol including other hair dye substances that may have the same retention time as resorcinol in this HPLC analysis. This was a pragmatic approach, as it not would be feasible to measure exposure to all hair dye substances and their reaction products. Resorcinol is relatively stable and simple to analyse (23). The majority of the hairdressers in a previous study had measurable amounts of hair dye substances on their hands. Resorcinol was the most frequently detected substance when five hair dye substances, including resorcinol, PPD, and 2,5-TDA, were assessed (24). It has also been shown that resorcinol is used in 80–90% of oxidative hair dye products on the market in Germany, Spain, Sweden, and the United States (19–22).

Glove use among hairdressers

This study shows that all tasks involved in a hair dye treatment can contribute to overall skin exposure to hair dyes. In a previous study, we found that many hairdressers

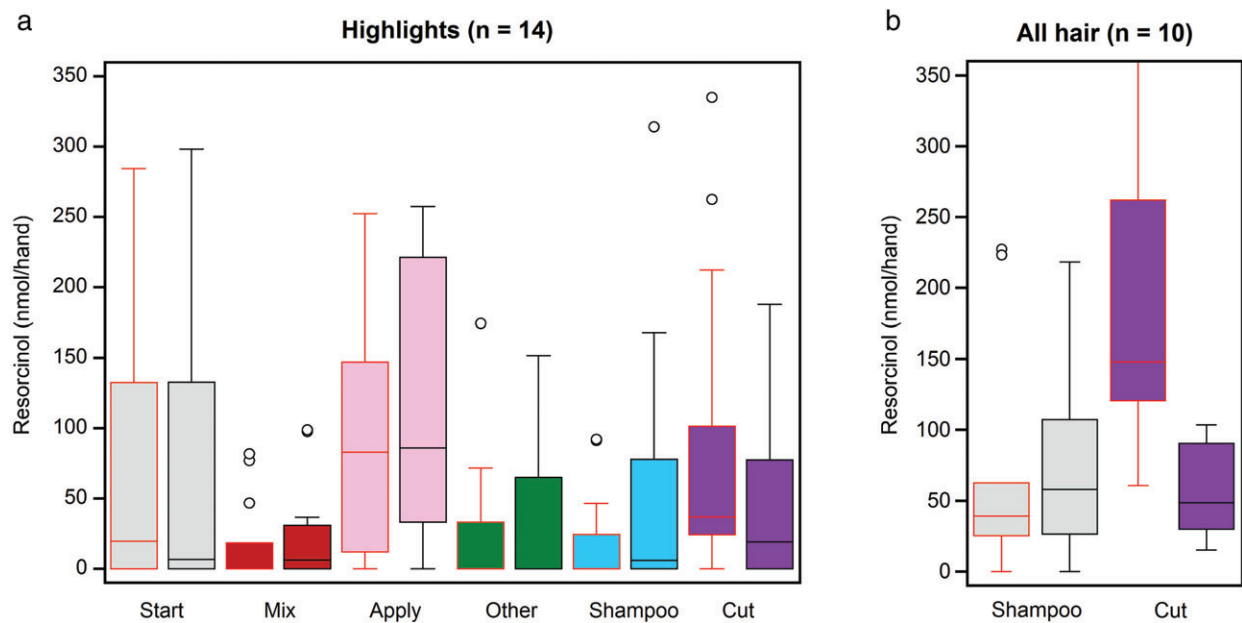


Fig. 3. Distribution of resorcinol, and possibly other hair dye-related substances with the same retention time as resorcinol, in hand rinse samples from hairdressers during dyeing (a) highlights and (b) all-over-coloured hair, depicted as boxplots. The box denotes the 25% percentile, the median, and the 75% percentile. Whiskers extend to data points not considered to be outliers. Outliers, more than 1.5 box widths from the edge of the box, are shown as circles. The maximum value in (b) for serving hands was 546 nmol/hand. Red outline = serving hands; black outline = dominant hands.

Table 1. Skin exposure to hair dye in hairdressers when dyeing highlights or colouring hair all over. One participant (ID 17) excluded in whom excessive exposure when applying dye had been noted (see text)

Hair dyeing task followed by sampling	Amount of resorcinol ^a (nmol/hand) ^b , mean; median (minimum–maximum)		
	Serving hand	Dominant hand	Both hands
Dyeing highlights (n = 14)			
Start ^c	73; 20 (0–285)	78; 7 (0–298)	151; 36 (0–583)
Mixing	17; 0 (0–82)	22; 6 (0–99)	39; 13 (0–181)
Applying	86; 83 (0–252)	114; 86 (0–258)	200; 145 (0–501)
Other tasks ^d	24; 0 (0–174)	26; 0 (0–152)	49; 0 (0–326)
Shampooing	18; 0 (0–92)	55; 6 (0–314)	74; 6 (0–405)
Cutting	88; 37 (0–335)	47; 19 (0–188)	135; 71 (0–472)
All tasks	306; 263 (12–878)	342; 230 (0–1056)	648; 487 (12–1873)
Dyeing all-over (n = 10)			
Shampooing ^c	72; 39 (0–228)	78; 58 (0–218)	149; 106 (0–442)
Cutting	205; 148 (61–546)	55; 48 (15–104)	259; 199 (87–639)

Assessed by consecutive hand rinse samples during hair dye treatments (see Fig. 1), and analysis by high-performance liquid chromatography of resorcinol^a in samples.

^aResorcinol and possibly other hair dye-related substances with the same retention time as resorcinol.

^bThe limit of detection (LOD) was 0.23 nmol/ml, which corresponds to 1.1 nmol/hand. Values below the LOD were treated as 0.

^cThe primary purpose of collecting this sample was to clear the hands of hair dye to enable assessment of the exposure from the following task.

^dIncluding cleaning utensils, washing towels, and answering the telephone, while the dye was left on the hair.

used gloves when dyeing hair all-over, that fewer used gloves when mixing hair dye, dyeing highlights, and shampooing, and that very few used gloves when cutting newly dyed hair (24). A recent publication addressing the risk of exposure to carcinogenic substances during

hairdressing included a questionnaire on glove use; 22% of the hairdressers never used gloves, and 36% used gloves occasionally when dyeing highlights (14). Other studies on glove use have shown that only half of the hairdressers use gloves when dyeing highlights/lowlights, and that

<1% use gloves when cutting hair. The need for education on proper glove use was also emphasized (28, 29).

None of the hairdressers in the present study used gloves when cutting newly dyed hair, and most of them stated that it would be impossible to use gloves when cutting hair, but not during other hair dyeing tasks. Cutting newly dyed hair was one of the largest contributors to skin exposure, affecting almost all hairdressers. We conclude that dyeing and cutting hair must be performed in reverse order to avoid skin exposure and reduce sensitization to hair dyes; that is, that hair should be cut before it is dyed. Hairdressers' comments on the proposal were that the entire treatment would take longer, which would increase the cost for the client.

Work conditions

In Sweden, the majority of hairdressers are self-employed, and rent a space in a salon. In large Swedish cities, some salons employ a staff of hairdressers, a practice that is more common in other European countries. Being a self-employed rather than an employed hairdresser may be a disadvantage from the perspective of work environment, health, and safety. Self-employed hairdressers may not have the same support from responsible employers, safety representatives, or trade unions.

Importantly, scientific intervention studies have shown that training programmes can reduce the incidence of hand eczema in hairdressing apprentices, and reduce systemic exposure to 2,5-TDA in hairdressers (30, 31). SafeHair is an EU-supported project for information, education and training for the prevention of occupational skin diseases in hairdressing work (32). We suggest that the SafeHair project could include our recommendation to perform cutting before dyeing. Knowledge about health risks associated with hair dyes, and about how to improve

skin protection and prevent deleterious effects, is steadily growing. There is an urgent need to implement this knowledge in working life, for protection of hairdressers' occupational health.

Conclusions

Hairdressers are exposed to hair dye ingredients during all steps of the hair dyeing procedure. Cutting newly dyed hair contributes significantly to the exposure. As long as skin sensitizing and possibly carcinogenic hair dyes are in use, efforts should be made to introduce safe working routines and proper use of protective equipment. We suggest, as initial steps for the prevention of occupational disease resulting from hair dye exposure, that hair should be cut before dyeing, and that gloves should be worn during all other work tasks.

Acknowledgements

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Chromatograms for samples analysed by high-performance liquid chromatography on the same day. (a) Resorcinol standard in hand rinse solution (0.2 M ascorbic acid in borate buffer with 10% ethanol). (b) Hand rinse sample from the serving hand after cutting of all-over-coloured hair (participant no. 2). The peak in (b) with the retention time of resorcinol (3.35 min under the analytical conditions) may also represent other hair dye-related substances.

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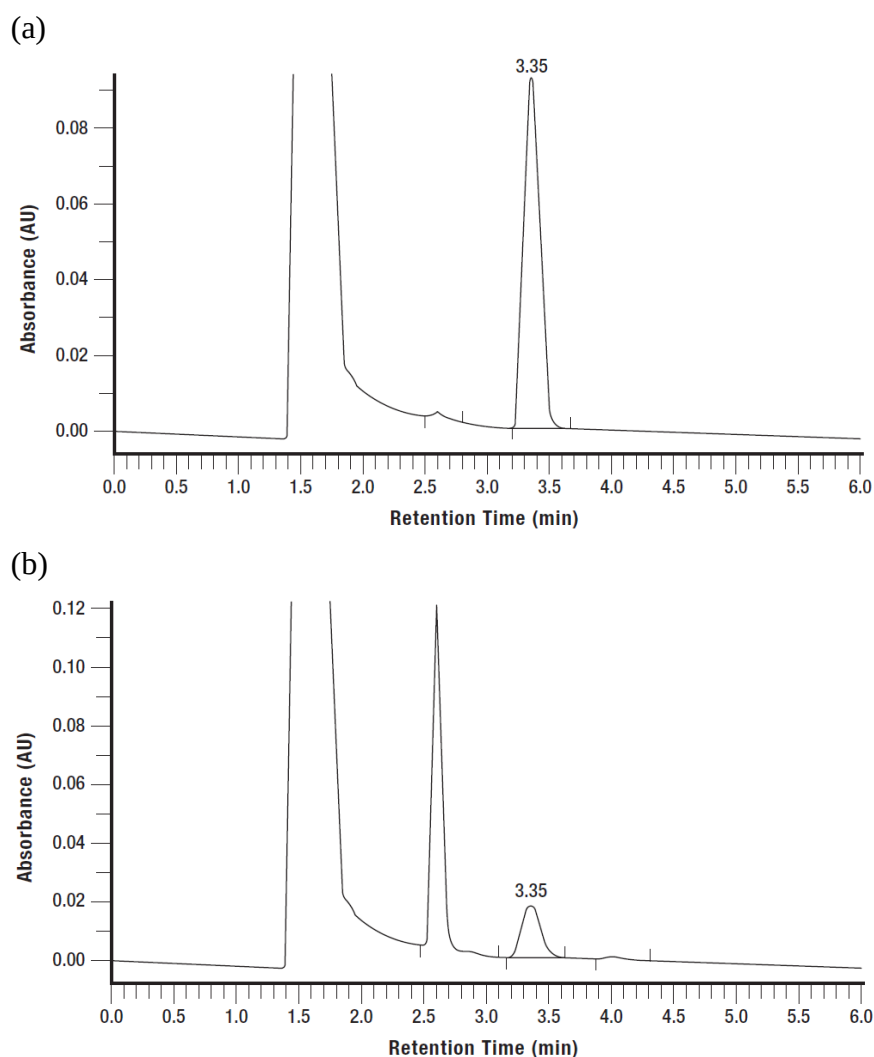


Fig. S1. Chromatograms for samples analysed by high-performance liquid chromatography on the same day. (a) Resorcinol standard in hand rinse solution (0.2 M ascorbic acid in borate buffer with 10% ethanol). (b) Hand rinse sample from the serving hand after cutting of all-over-coloured hair (participant no. 2). The peak in (b) with the retention time of resorcinol (3.35 min under the analytical conditions) may also represent other hair dye-related substances.