Exposure to organic solvents during cosmetic finishing of cars

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The objectives of this study were to assess the exposure to organic solvents during degreasing, washing and polishing of cars, and to obtain information about acute health symptoms in car-finishing workers. Fifteen car shops participated in this study, and at these locations 36 workers had car finishing as their main working task. All 36 car-finishing workers and 17 randomly selected office workers from six of these car shops completed questionnaires on acute health symptoms. Personal monitoring of exposure to organic solvents was carried out in three representative shops. The highest exposure levels were found during degreasing of new cars, the median level of aliphatic hydrocarbons (C9–C13) being 22 p.p.m. (range 7–215 p.p.m.). This exposure level represents 50% (range 20–540%) of the Norwegian 8 h limit value for additive factor for these compounds. Only 28% of the workers used gas respirators regularly during this process. Very low exposure levels were detected during washing of second-hand cars and during polishing processes. The present study shows that car-finishing workers are exposed to high levels of organic solvents only for short periods of time. It seems that they are not adequately protected during these periods. However, the presence of acute symptoms was low, i.e. comparable to the prevalences in the reference group.

Key words: Car washing; degreasing; exposure assessment; organic solvents.

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Introduction

It is well established that exposure to low or moderate concentrations of organic solvents may cause acute and transient symptoms such as headache, dizziness and euphoria [1,2]. The existence of chronic effects in the nervous system is more debated [3,4], but a chronic organic solvent intoxication syndrome caused by long-term occupational exposure [5] has been accepted by the World Health Organization (WHO) since 1985 [6].

In car shops, high exposures to organic solvents have been recorded, particularly during spray painting operations [1,2]. Car washing is another process which might cause high exposure to organic solvents [7]. In Norway, most car shops employ at least one worker who is responsible for the cosmetic finishing of new and second-hand cars before delivery to the customer. The finishing work comprises degreasing, washing and polishing processes, in all of which organic solvents are used. New cars are normally covered by a protective layer of wax on first arrival at the car shop. This layer has to be removed by high-pressure steaming with a degreasing agent. Second-hand cars are washed by applying a cleaning agent at low pressure and low temperature, followed by high-pressure spraying with hot or cold water. After the washing process, the cars are polished either by hand or with a polishing machine.

Of these operations, degreasing of new cars is assumed to produce the highest exposures to organic solvents. In a previous study of car washing in Finland, the levels of hydrocarbons were above the national limit values during the degreasing process [7]. Previously, we have observed that personal protective devices, such as gas respirators and gloves, are not used regularly by car-finishing workers and uptake of organic solvents is therefore likely to occur.

The objectives of this study were to monitor the

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exposure to organic solvents during the different work processes of car-finishing workers and obtain information about acute health symptoms in these workers.

Methods

The car shops participating in this study were selected from the 32 shops affiliated with the occupational health service for car shops in Bergen. In order to be included in this study, the shop must have had at least one full-time car-finishing worker employed. Fifteen shops fulfilled this criterion and were selected for the study. The other 17 shops did not employ car-finishing workers. In total, 36 workers had car finishing as their main operational task. The number of finishers varied between one and four in each of the selected shops. All car-finishing workers completed a questionnaire on acute health symptoms and on the use of personal protective equipment. Owing to limited resources, three car shops were selected for the exposure studies. The selection of shops for exposure monitoring was based on observations made during the initial surveillance of the facilities, the work processes and the identification of chemicals in use. In these respects, the three selected shops were considered to be representative of the other 12.

Observed work operations and chemicals

During the first visit to the car shops, we carried out a basic characterization of the work processes of the car-finishing workers and identified the chemical agents used in the different processes. Material safety data sheets for all of these chemicals were gathered. None of the car-finishing workers had specialized on a single one of these processes. Thus, one finishing worker followed one car from degreasing or washing until the polishing process was completed. None of the workers could finish more than four cars during one working day.

The processes most likely to cause exposure to organic solvents were grouped into three main operations, as follows.

Degreasing of new cars

The protective layer of wax was removed by high-pressure steaming with a mixture of organic solvents and water at a temperature of 70–80°C. This process lasted up to ~40 min and was carried out in a hall with mechanical exhaust ventilation. The entrance gate was always open in the hall. The degreasing agents were low aromatic (<0.1% aromatic hydrocarbons) petroleum distillates, classified on the material safety data sheets as white spirits (hydrocarbon chain lengths of C9–C13, boiling point 205–248°C) or *n*-paraffins (hydrocarbon chain lengths of C10–C13, boiling point 195–225°C).

Washing of second-hand cars

The application time for the cleaning agent was 2–3 min and, 5–10 min thereafter, the car was sprayed at high pressure with cold water. This process was carried out in the same hall as the degreasing of new cars. The cleaning agents were composed of a mixture of tensides (20–50%), petroleum distillates (10–30%) of the same quality as in the previous paragraph and water. Particularly dirty spots were removed manually with agents containing xylene (10–20%) mixed with petroleum distillates (hydrocarbon chain lengths of C9–C13, <22% aromatic hydrocarbons).

Manual or machine polishing of cars

The polishing agent was applied to the car and allowed to rest for ~10 min before the finisher started polishing either manually with a cloth or with a polishing machine. The polishing machine was used only on second-hand cars. The polishing agents contained a mixture of 20–50% petroleum distillates (<2% aromatic hydrocarbons), waxes and water. Window-cleaning agents containing 2-propanol were also used during the polishing process. The polishing processes lasted up to ~1 h for new cars and up to 2 h for second-hand cars. Polishing was carried out in rooms with balanced, mechanical ventilation, having separate air inlets and outlets.

Questionnaire

All 36 car-finishing workers from the 15 car shops completed a questionnaire [9] that included questions about age, the number of years as a car-finishing worker and the use of personal protective equipment (gloves and gas respirators). The use of personal protective equipment was described by the use of a three-point scale, where 1 = never, 2 = occasionally and 3 = always.

The workers also answered questions about the occurrence of acute symptoms during the past month, i.e. headaches, vertigo, nausea, euphoria, sore eyes, soreness or itching in the nose and throat, discomfort in breathing and skin rashes. The occurrence of symptoms was described on a four-point scale, where 1 = never, 2 = 1–2 times per month, 3 = 3–5 times per month and 4 = >5 times per month. The questionnaire was completed during our first visit to the car-finishing departments.

Administrative personnel (n = 17) from six of these 15 car shops were randomly selected as a reference group. These employees worked in offices and were not exposed to chemicals in their work. The reference group answered a questionnaire similar to that for the car-finishing workers, except that they were not asked about the use of personal protective equipment.

Exposure monitoring

Personal monitoring of exposure to organic solvents was carried out in three shops during the following work processes: (i) degreasing of new cars (15 samples); (ii) washing of second-hand cars (six samples); (iii) manual polishing of new cars (10 samples); and (iv) machine polishing of second-hand cars (six samples). Days for the monitoring were chosen at random.

The sampling periods are mentioned in Tables 1 and 2, and varied according to the time spent on the different work processes. The sampling tubes were placed in the breathing zone of the worker, i.e. outside the personal respirators if such protective devices were used.

The organic solvents were adsorbed on activated charcoal tubes (SKC Anasorb CSC Coconut Charcoal). Pumps of type Casella CS1 and SKC 222-3 were used at a flow rate of 100 ml/min. All samples were analysed according to standard procedures at the laboratory of the Directorate of Labour Inspection in Bergen, Norway. This laboratory had passed the intercalibration test run by the National Institute of Occupational Health, Norway. In the laboratory, the collected air impurities were desorbed from the charcoal tubes by carbon disulphide (2 ml overnight) and analysed by gas chromatography with a flame-ionization detector (Perkin Elmer, Auto System 10% FFAP on 80/100 Chromosorb WAW, packed column, isothermal temperature 70°C, flow rate 24 ml/min). External reference standards were used. The detection limit for the gas chromatograph was 0.01 p.p.m.

Evaluation of results from exposure monitoring

We have compared the results from the exposure monitoring with the current Norwegian limit values for 8 h exposure [8]. The limit values are 40 p.p.m. for decans and other higher aliphatic hydrocarbons, 100 p.p.m. for nonane and 2-propanol, and 25 p.p.m. for xylene and toluene. We have also calculated the additive factor for the organic solvents:

$$\text{additive factor} = C_1/LV_1 + C_2/LV_2 + \ldots C_n/LV_n$$

where C indicates the observed concentration in the air and LV the corresponding limit value for the compound. If the additive factor exceeds unity, then the limit value of the mixture should be considered to be exceeded [8]. (Note that in the text, C9 and C10–C13 refer to the number of carbon atoms in the aliphatic hydrocarbon chain.)

Results

Degreasing of new cars

Table 1 shows that the sum of C9–C13 aliphatic hydrocarbons in the 15 samples ranged from 7 to 215 p.p.m. (43–1390 mg/m^3). The exposure level was considerably higher in shop C than in shops A and B. The additive factor of the exposure level in shop C was 290% of the Norwegian limit value. In this shop, the median exposure level to the aliphatic hydrocarbons C10–C13 was 117 p.p.m. The additive factors were 30 and 50% of the limit value in shops A and B, respectively. Shops A and B used an identical degreasing agent, classified as white spirits, while shop C used an agent classified as *n*-paraffins.

Washing of second-hand cars

The exposure level was very low during normal washing of second-hand cars. The additive factor was 2% of the limit value, resulting mainly from the detection of aliphatic hydrocarbons in the C10–C13 range (Table 2). When dirty spots had to be removed by special products (spot removers), the additive factor was 30% of the limit value. In these cases xylene, with a median exposure level of 7 p.p.m., contributed significantly to the total exposure level (Table 2).

Table 1. Median and range of sampling time and exposure levels of organic solvents during degreasing of new cars at three shops (A–C)

					Additive factor	
Shop	*n*	*Sampling time per sample (min)*	*C9 (p.p.m.)*	*C10–C13 (p.p.m.)*	*Median (range)*	*Geometric mean (GSD)*
A	5	28 (19–38)	0.3 (0–0.9)	11 (7–19)	0.3 (0.2–0.5)	0.3 (1.5)
B	5	19 (14–28)	2.3 (0.3–4.1)	20 (7–36)	0.5 (0.2–1.0)	0.5 (1.9)
C	5	17 (15–20)	0	117 (37–215)	2.9 (0.9–5.4)	2.3 (2.1)
A + B + C	15	20 (14–28)	0.3 (0–4.1)	19 (7–215)	0.5 (0.2–5.4)	0.6 (2.9)
Limit values			100	40	1.0	1.0

The Norwegian limit values for 1996 are indicated. Mixed exposures are given as additive factors. Geometric mean and GSD are given for additive factors. C9 and C10–13 refer to the number of carbon atoms in the aliphatic hydrocarbon chain.

Polishing processes

Table 2 show that very low exposure levels were recorded during hand and machine polishing. The additive factors were 4% of the limit value, resulting mainly from exposures to aliphatic hydrocarbons in the C9–C13 range and to 2-propanol.

Questionnaire

The mean age of the 36 car-finishing workers was 35 years. On average, they had worked for 6 years as car-finishing workers. Ten of the 36 workers (28%) stated that they always used half-mask gas respirators and 15 workers (42%) stated that they wore chemical-resistant gloves during degreasing of new cars. Only six of the workers (17%) claimed that they always used such gloves during hand polishing of the cars.

The frequencies of acute symptoms were highest for throat irritation, eye irritation and headache (Table 3).

The reference group consisted of only 17 people, as there were few administrative employees who were totally unexposed to chemical agents. However, all those asked to answer the questionnaire did so. The frequencies of each acute symptom did not differ significantly between the car-finishing workers and the reference group (Mann–Whitney non-parametric test).

Discussion

The highest levels of exposure to organic solvents for the car-finishing workers were found during degreasing of new cars. For this process, the exposure levels in the three shops were 30, 50 and 290% of the Norwegian 8 h limit value [8], respectively. The variation in the exposure levels might be due to the use of different cleaning agents, and/or to different proportions of water and organic solvent in the final solution. Although the washing halls were similarly constructed and equipped with one exhaust fan, differences in the air exchange rate in the washing halls might contribute to the variations in the exposure levels. Variations in the working practices of the finishers, the nozzle of the sprayer, the spraying pressure and the spraying temperature might also explain some of the differences.

Washing of second-hand cars was associated with very low levels of exposure to organic solvents, unless

Table 2. Median and range of sampling time per sample and exposure levels of organic solvents during washing and polishing of cars

								Additive factor	
Process	*n*	*Sampling time (min)*	*C9 (p.p.m.)*	*C10–C13 (p.p.m.)*	*Xylene (p.p.m.)*	*Toluene (p.p.m.)*	*2-propanol (p.p.m.)*	*Median (range)*	*Geometric mean (GSD)*
Car washing	6	11 (9–21)	0	0.5 (0.2–1.1)		0.1 (0–0.3)	0	0.02 (0.01–0.03)	0.02 (1.61)
Car washing + use of spot remover	6	20 (15–43)	1.7 (0.2–2.6)	3.0 (1.9–5.9)	7.0 (2.5–8.4)	0.3 (0.1–0.4)	0.3 (0–1.0)	0.30 (0.10–0.5)	0.31 (2.05)
Hand polishing	10	31 (16–65)	0.7 (0–2.6)	1.4 (0.1–4.0)	0	0	0.3 (0–3.8)	0.04 (0.03–0.10)	0.05 (1.61)
Machine polishing	6	72 (28–114)	0.1 (0–0.7)	1.5 (0.3–2.1)	0.3 (0–0.4)	0	0.7 (0–1.8)	0.04 (0.02–0.11)	0.05 (1.87)
Limit values			100	40	25	25	100	1.0	

The Norwegian limit values for 1996 are indicated. Mixed exposures are given as additive factors. Geometric mean and GSD are given for additive factors. C9 and C10–13 refer to the number of carbon atoms in the aliphatic hydrocarbon chain.

Table 3. Occurrence of acute symptoms during the previous month among a group of car-finishing workers and a reference group

	Car-finishing workers (n = 36)				*Reference group (n = 17)*			
Symptoms	*Never*	*1 or 2 times per month*	*3–5 times per month*	*>5 times per month*	*Never*	*1 or 2 times per month*	*3–5 times per month*	*>5 times per month*
Headache	48	32	9	11	65	29	6	0
Vertigo	79	12	3	6	71	23	0	6
Nausea	90	10	0	0	94	0	0	6
Euphoria	93	7	0	0	94	6	0	0
Eye irritation	55	31	3	11	65	23	0	12
Throat irritation	49	27	6	18	53	29	0	18
Breathing difficulties	82	15	3	0	94	0	0	6
Skin irritation	76	15	6	3	82	12	6	0

Results are given as percentages of the completed questionnaires. No significant differences ($P < 0.05$) were found between car finishers and references (Mann–Whitney non-parametric test).

particularly dirty areas of the car had to be cleaned manually with agents containing aromatic compounds such as xylene, in addition to aliphatic hydrocarbons. In these cases, the median of the additive factor was 30% of the limit value. During manual and machine polishing of the cars, the median of the additive factor was only 4% of the limit value, thus contributing to a very limited extent to the total exposure to organic solvents.

Care should be taken in the interpretation of the results, since our discussion is based on a low number of short-term measurements. However, the sampling was carried out during three typical work processes that appeared to be carried out in a standardized way in all the car shops included in this study.

We have not taken whole-day samples of selected workers. Thus, results from the short-term measurements have been compared with the Norwegian 8 h limit values. Taking into account the time spent and the exposure levels during the different work processes, one may estimate the time-weighted average (TWA) for the 8 h working day for a given set of processes. Such calculations would result in low TWA values compared with the limit value, since each worker carried out only 1–4 degreasing operations in any 1 day. The results show that the workers are exposed to relatively high levels of organic solvents only during the short periods of degreasing. Despite the high exposure in these periods, only 28% of the workers used respirators regularly during this process. Dermal uptake of hydrocarbons will also contribute to the total uptake of solvents. It is probable that manual polishing will contribute significantly to dermal uptake, since most workers (83%) did not regularly use chemical-resistant gloves during this process.

To our knowledge, no previous studies of car-finishing workers have been published in Norway. In Finland, Niemelä *et al.* [7] found exposure levels to white spirits in the range 5–465 mg/m^3 during degreasing, i.e. lower levels than found in the present study (range 43–1390 mg/m^3). In the Finnish study, the methods for sampling and analysis of solvents were similar to those used here.

The prevalence of frequent acute symptoms among the car-finishing workers was low and did not differ from that found in a reference group from the same car-repair shops. There are no normal values available for the questionnaire we have used.

The results from the exposure assessment indicate that, for short periods, the car-finishing workers are exposed to higher levels of organic solvents than shown for car painters by Moen and Hollund [9]. In their study, the arithmetic mean of the additive factor for organic solvents was 0.3 (range 0.07–0.54). Furthermore, the prevalence of acute symptoms was also low. Previous studies of car painters with higher exposure to organic solvents have revealed a higher frequency of acute symptoms compared with reference groups [1,2].

This study shows that car-finishing workers can be exposed to relatively high levels of organic solvents for short periods, during specific work tasks. Bearing in mind that this exposure is less frequent, the TWA exposure during the working day is expected to be well below the current Norwegian limit values. We found no evidence of any pronounced acute effects of this exposure, but it seems wise to avoid unnecessary high exposure, even if brief and infrequent, in order to reduce the risk of developing chronic health effects. Since the use of respiratory protection devices while carrying out exposed work tasks was uncommon, such use should be encouraged.

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