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Original Article

Exposure Characteristics of Construction Painters to Organic Solvents

Hyunhee Park, Hae Dong Park, Jae-Kil Jang*

Occupational Safety and Health Research Institute, Korea Occupational Safety and Health Agency, Ulsan, Republic of Korea

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ABSTRACT

Background: Construction painters have not been studied well in terms of their hazards exposure. The objective of this study was to evaluate the exposure levels of total volatile organic compounds (TVOCs) for painters in the construction industry.

Methods: Activity-specific personal air samplings were carried out in three waterproofing activities [polyurethane (PU), asphalt, and cement mortar] and three painting activities (epoxy, oil based, and water based) by using organic-vapor-monitor passive-sampling devices. Gas chromatograph with flame ionization detector could be used for identifying and quantifying individual organic chemicals. The levels of TVOCs, by summing up 15 targeted substances, were expressed in exposure-index (EI) values.

Results: As arithmetic means in the order of concentration levels, the EIs of TVOCs in waterproofing works were 10.77, 2.42, 1.78, 1.68, 0.47, 0.07, and none detected (ND) for indoor PU-primer task, outdoor PU-primer task, outdoor PU-resin task, indoor PU-resin task, asphalt-primer task, asphalt-adhesive task, and cement-mortar task, respectively. The highest EI for painting works was 5.61 for indoor epoxy-primer task, followed by indoor epoxy-resin task (2.03), outdoor oil-based-spray-paint task (1.65), outdoor water-based-paint task (0.66), and indoor oil-based-paint task (0.15). Assuming that the operations were carried out continuously for 8 hours without breaks and by using the arithmetic means of EIs for each of the 12 tasks in this study, 58.3% (7 out of 12) exceeded the exposure limit of 100% ($EI > 1.0$), while 8.3% (1 out of 12) was in 50–100% of exposure limit ($0.5 > EI > 1.0$), and 4 tasks out of 12 were located in less than 50% of the limit range ($EI < 0.5$).

Conclusion: From this study, we recognized that construction painters are exposed to various solvents, including carcinogens and reproductive toxins, and the levels of TVOC concentration in many of the painting tasks exceeded the exposure limits. Construction workers need to be protected from chemical agents during their painting works by using personal protective devices and/or work practice measures. Additional studies should focus on the exposure assessment of other hazards for construction workers, in order to identify high-risk tasks and to improve hazardous work environments.

1. Introduction

Solvent exposure is related to adverse disorders of the skin, lung, kidney, and nervous system [1]. Painters who are exposed to organic solvents have high rates of cancers than other workers; increased prevalence of neurotoxic effects; and elevated rates of slips, trips, and falls [2]. Construction painters are also known to suffer from respiratory symptoms and diseases [3,4] and neurotoxic symptoms [5]. Although health effects are well reported, on-site studies for construction workers, especially construction painters, are rare in terms of personal exposure levels to hazards. The reason why only a few studies have focused on this group is that most of the construction painters are highly mobile from one site to the other, and they tend to be temporary workers, and also their work environment continuously changes at every construction site on a daily basis.

In this study, we evaluated the exposure concentrations of total volatile organic compounds (TVOCs) among construction painters to build up the chemical-job-exposure matrix. The data might be valuable for protecting construction painters from related occupational diseases by identifying high-risk tasks.

* Corresponding author. Occupational Safety and Health Research Institute, Korea Occupational Safety and Health Agency, 400, Jongga-ro, Jung-gu, Ulsan 44429, Republic of Korea.
E-mail address: cihjj@kosha.net (J.-K. Jang).

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2. Materials and methods

2.1. Target works and tasks

In this study, waterproofing and painting works were monitored at eight construction workplaces, five apartment buildings, an office building, a logistics center, and a swimming pool. Twelve tasks, including seven waterproofing and five painting tasks, were evaluated in 18 sampling units. Several sampling units were included in one task. The representative job tasks for waterproofing work were polyurethane (PU)-primer task (indoor/outdoor), PU-resin task (indoor/outdoor), asphalt-primer task, asphalt-adhesive task, and cement-mortar task (Table 1). Epoxy-resin task, epoxy-primer task, oil-based-paint task (brush/spray), and water-based-paint task were the major job tasks for painting work in this study (Table 2).

2.1.1. PU-primer/resin tasks for waterproofing work

Six sampling units, four outdoor (PU 1–PU 4) and two indoor (PU 5 and PU 6) units, were selected for the PU-primer/resin tasks. Primer was applied as the first layer, followed by PU-resin coating additionally as the second outer layer. The PU primer contains 50–60% solvents, such as toluene, xylene, ethyl benzene (EB), methyl ethyl ketone (MEK), and ethyl acetate. PU resins were normally composed of the key material (about 9 kg) and the curing agent (about 24 kg), and they might be formulated just before their application. The PU key material contains 30–35% organic solvents; and the PU-resin curing agent contains 50–60% calcium carbonate, 15–25% polypropylene glycol, and 10% petroleum hydrocarbons.

2.1.2. Asphalt-primer/adhesive tasks for waterproofing work

Two outdoor sampling units (AS 1 and AS 2) were selected for the asphalt-primer and asphalt-adhesive tasks. Asphalt primer was applied on the construction surface as the first layer, and then it was additionally covered with asphalt adhesive, followed by attachment of the asphalt sheet. The asphalt sheet consisted of asphalt (60–65%), synthetic rubber (15–20%), inorganic filler (10–15%), and solvents, such as hydrocarbon mixture (5–10%). The asphalt primer and asphalt adhesive (asphalt-sheet adhesive) contained several organic solvents, but material safety data sheets (MSDSs) were not available to identify the components. Organic vapors were generated from the asphalt primer and sheet adhesive rather than the asphalt sheet itself, as the sheet was already commercially hardened before the waterproofing work.

2.1.3. Cement-mortar task for waterproofing work

One restroom of the apartment commercial building complex was selected to quantitatively measure the concentration of TVOCs during the cement-mortar waterproofing work (cement-mortar task). Liquid-water-based chemicals, which mainly consisted of a copious amount of water and a small amount of oleic acid without volatile organic compounds, were mostly used in the task.

2.1.4. Epoxy-primer/resin task for painting work

Six sampling units were selected for the epoxy-primer (ER 1, ER 3, and ER 5) and -resin tasks (ER 2, ER 4, and ER 6) in the underground parking lot of the apartment (Table 2). Epoxy coating was performed by applying a primer for good adhesion on building surfaces as the first layer, followed by the second outer epoxy-resin coating by using materials, such as resin mortar, lining material, and/or coating agent on the first primer layer. The epoxy primer usually consisted of 60–70% solvents, such as toluene, xylene, methyl isobutyl ketone (MIBK), and EB. The organic-solvent content in each epoxy resin varied according to the manufacturer, but they usually contained 20–40% solvents.

Table 1
Target-monitoring workplaces for waterproofing work

Material	Environment	Task	Sampling unit	Building type (sampling location)	Application area (m^2)	Daily used amount (kg/d)	Applied amount (kg/m^2)	Applying method
Polyurethane	Outdoor	Polyurethane primer	PU 1	Apartment (first floor)	400	1,980	3.3	Roller
		Polyurethane resin	PU 2	Apartment (first floor)	600	1,320	3.3	Roller
			PU 3	Apartment (rooftop)	590	900	1.5	Roller
			PU 4	Logistic center (rooftop)	1,500	2,835	1.89	Roller
	Indoor	Polyurethane primer	PU 5*	Swimming pool (pool floor)	400	200	0.5	Roller
		Polyurethane resin	PU 6*	Swimming pool (pool floor)	400	900	2.25	Roller
Asphalt	Outdoor	Asphalt primer	AS 1	Apartment (first floor)	800	400	0.5	Roller
		Asphalt adhesive	AS 2	Apartment (first floor)	1,200	600	0.5	Roller
Cement mortar	Indoor	Cement mortar	CM 1	Apartment (first floor)	NA	NA	NA	Paddle
			CM 2	Apartment (restroom)				

* PU 5 and PU 6 were identical places.
NA, not available; PU, polyurethane.

Table 2
Target-monitoring workplaces for painting work

Material	Environment	Task	Sampling unit	Building type (sampling location)	Application area (m^2)	Daily used amount (kg/d)	Applied amount (kg/m^2)	Applying method
Epoxy	Indoor	Epoxy primer	ER 1*	Apartment (underground parking lot)	5,300	1,600	0.3	Roller
			ER 3*	Apartment (underground parking lot)	2,000	540	0.27	Spray
			ER 5*	Apartment (underground parking lot)	400	100	0.25	Roller
		Epoxy resin	ER 2*	Apartment (underground parking lot)	5,300	1,600	0.3	Roller
			ER 4*	Apartment (underground parking lot)	2,000	180	0.27	Roller
			ER 6*	Apartment (underground parking lot)	100	25	0.25	Roller
Oil-based paint	Indoor	Oil-based paint	OP 1	Office building (door frame)	NA	7	NA	Brush
	Outdoor	Oil-based paint	OP 2	Logistic center (steel structure)	NA	180	0.27	Spray
Water-based paint	Outdoor	Water-based paint	WP 1	Apartment (underground parking lot)	10,000	2,700	0.27	Spray

* ER 1 and ER 2, ER 3 and ER 4, and ER 5 and ER 6 were identical places, each other except different application areas for ER 5 and ER 6.