Quality of Chemical Safety Information in Printing Industry

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ABSTRACT

Objectives: Employees in printing industries can be exposed to multiple solvents in their work environment. The objectives of this study were to investigate the critical components of chemical solvents by analyzing the components of the solvents and collecting the Safety data sheets (SDSs), and to evaluate the hazard communication implementation status in printing industries.

Method: About 152 printing-related industries were recruited by area-stratified random sampling and included 23 plate-making, 102 printing and 27 printing-assistance companies in Taiwan. We analyzed company questionnaires ($n = 152$), SDSs ($n = 180$), and solvents ($n = 20$) collected from this sample of printing-related companies.

Results: Analytical results indicated that benzene and ethylbenzene, which were carcinogen and possibly carcinogen, were detectable in the cleaning solvents, and the detection rate were 54.5% (concentrations: <0.011 – 0.035 wt%) and 63.6% (concentrations: <0.011 – 6.22 wt%), respectively; however, neither compound was disclosed in the SDS for the solvents. Several other undisclosed components, including methanol, isopropanol and *n*-butanol, were also identified in the printing inks, fountain solutions and dilution solvents. We noted that, of the companies we surveyed, only 57.2% had a hazard communication program, 61.8% had SDSs on file and 59.9% provided employee safety and health training. We note that hazard communication programs were missing or ineffective in almost half of the 152 printing industries surveyed.

Conclusions: Current safety information of solvents components in printing industries was inadequate, and many hazardous compounds were undisclosed in the SDSs of the solvents or the labels of the containers. The implementation of hazard communications in printing industries was still not enough for protecting the employees' safety and health.

KEYWORDS: chemical solvents; hazard communication; printing industries; undisclosed components

INTRODUCTION

The global printing industry had a total output approximating US 720 billion dollars in 2011, and

the top three were from Europe (31%), Asia (30%), and North America (28%) (Xu, 2013). Printing-related industries can be generally divided into three

categories: plate-making, printing, and printing assistance. The most common printing processes are lithography, letterpress, gravure, and screen (Labour Department of the Government of the Hong Kong Special Administrative Region, 2004).

Workers in printing industries may be exposed to potentially hazardous levels of solvents, inks, adhesives, organic and inorganic pigments, polycyclic aromatic hydrocarbons, acrylates, lead, paper dust, and noise (Beaulieu, 1978; IARC, 1996; Michaels *et al.*, 1991; Vineis and Magnani, 1985). A Danish overview of the printing industry reported that workers were exposed to 300 different substances, 26 of which were known or suspected carcinogens (Lyngé *et al.*, 1995). Employees have close contact with chemicals used in cleaning or to the ink solvent evaporating during the printing process. The IARC classified occupational exposures in printing processes as possibly carcinogenic to humans based mainly on reported excesses of bladder and lung cancer (IARC, 1996).

Many health problems have been reported in printing industry workers. These health problems include cancers, neurological and neuropsychiatric disorders, mucous membrane irritation, and dermatitis. In addition to bladder and lung cancer, the printing works have been associated with melanoma, and cancers of the kidney, skin, brain, breast, ovary, cervix, esophagus, and stomach (Aronson and Howe, 1994; Bulbulyan *et al.*, 1999; Cocco *et al.*, 1998; Malke and Gemne, 1987; Pukkala, 1995). Several years ago, cholangiocarcinoma, a recently identified occupational cancer, was diagnosed in 11 printing industry workers in Japan. This disease has also been linked to 1,2-dichloropropane (1,2-DCP) and/or dichloromethane (DCM) usage for cleaning the transcription rubber roller (Kumagai *et al.*, 2013). Furthermore, it is well known that high-dose exposures to organic solvents can produce severe impairment of the central or peripheral nervous system. Long-term or chronic exposure conditions have been associated with several neurological and neuropsychiatric disorders, such as anosmia, hearing loss, color vision dysfunctions, peripheral polyneuropathy, depression, irreversible chronic toxic encephalopathy (CTE), and sleeping problems (Anger, 1990; Bolla *et al.*, 1995; Colvin *et al.*, 1993; Gilioli, 1993; Godderis *et al.*, 2006; Godderis *et al.*, 2011; Kishi *et al.*, 2000; Moser *et al.*, 2003; Schäper *et al.*, 2008; Viaene *et al.*, 2009; Yu *et al.*, 2004). In 1991,

an outbreak of polyneuropathy occurred in a printing factory in Hong Kong and affected 17 printing workers (Chang *et al.*, 1993). Moreover, working in the printing industry is believed to be a risk factor for dermatitis. Several case reports and studies of the dermatological effects of chemicals in the printing industry have been reported (Cronin, 1980; Garabrant, 1985; Livesley *et al.*, 2002; Meyer *et al.*, 2000; Nethercott and Nosal, 1986).

Solvents used in the printing industries are usually mixtures of chemicals rather than a single substance. Many of these substances are proprietary prepared formulations, and their chemical components are not always labeled conspicuously on their original containers. The objectives of this study were to investigate the potentially toxic components of chemical solvents in printing industries by analyzing the components of the solvents and collecting the safety data sheets (SDSs), and to evaluate the hazard communication programs in place in Taiwan's printing industries.

METHODS

Study subjects and strategies

For this study, we recruited companies by area-stratified random sampling from lists of printing-related industries from the Department of Statistics, Ministry of Economic Affairs of Taiwan. The total printing-related industries were about 3000 companies, and 15.4% were plate-making companies, 62.6% were printing companies and 22.0% were printing-assistance companies, respectively. We used 152 company questionnaires, 180 SDSs collection, and 20 solvent analyses for the work reported here. Recruited companies were spread throughout Taiwan and included companies from north (41.4%), central (30.3%), and south (28.3%) Taiwan. The geographic distribution of our sample was similar to the overall geographic distribution of printing-related industries in Taiwan. The 152 printing-related industries included 23 plate-making companies, 102 printing companies, and 27 printing-assistance companies; the proportion in categories was also similar to the distribution of the printing-related industries in Taiwan. Table 1 shows the descriptions of the study subjects.

All investigated companies were required to complete the questionnaire and to provide the SDSs of the solvents used in printing-related processes.

Table 1. Descriptions of the study subjects

	Plate-making industry (<i>n</i> = 23)	Printing industry (<i>n</i> = 102)	Printing-assistance industry (<i>n</i> = 27)
Employees ^a	11.0 ± 7.7 (1–26)	19.3 ± 39.5 (1–330)	9.5 ± 8.8 (1–32)
Printing type ^b			
Lithography	—	76 (74.5%)	—
Letterpress	—	13 (12.8%)	—
Gravure	—	5 (4.9%)	—
Screen	—	8 (7.8%)	—

^aMean ± SD (range).^bPrinting type was only classified in printing industry.

Meanwhile, the chemical solvents were also collected for volatile organic components analysis from the companies if they could provide. Questionnaire items included the printing category of the company, the printing type, numbers of employees, annual average chemical usages for each kind of solvent, and the safety and health management situation (including hazard communication program, SDSs providing, ventilation systems, employee health examinations, personal protective equipment usage mask, glove and protective clothes, and safety and health education/training).

Components analysis of solvents

The 20 samples collected from the printing-related industries included eleven cleaning solvents, five inks, three fountain solutions, and one dilution solvent. The methods used for component analyses were referred to NIEA M735 (detection method of volatile organic components in raw materials and productions) and A733 (detection method of alcohols for stack emission) from Taiwan Environmental Protection Administration. Briefly, a 100-g bulk sample of each solvent was stored in a brown glass bottle. Before analysis, the bulk sample was mixed with vortex at least 5.0 min. Then, 1.0 g of the sample was taken and made up to 10.0 mL by methanol for ultrasonic extraction. After that, appropriately diluted the extract to ppb concentration level, and then analyzed the dilution by gas chromatography mass spectrometry (GC-MS) for components identification and quantification. For methanol, isopropanol, and *n*-butanol analysis, 0.1 g of sample was taken and made up to 10.0 mL by propylene glycol and then mixed. The extract was then

analyzed by gas chromatography flame ionization detector (GC-FID).

A 60-m DB-624 column (film thickness 1.8 μm, internal diameter 0.32 mm, Agilent J&W) was used for GC-MS. The initial temperature of the GC oven was 40°C for 10 min and then increased from 40°C to 200°C at 8°C min⁻¹, and maintained at 200°C for 5 min. The GC-MS interface was at 230°C, and the mass spectrometer scanned from 35 to 260 amu every 0.2 s. A 60-m RTX-1 column (film thickness 1.5 μm, internal diameter 0.53 mm, Restek) was used for GC-FID. The initial temperature of the GC oven was 40°C for 0.7 min and then increased from 40°C to 50°C at 1°C min⁻¹, 50°C to 250°C at 40°C min⁻¹, and maintained at 250°C for 4.5 min. The detector temperature was set to 270°C. Chromatographic mass spectral matching (NBS57K.L mass spectral library) and retention time were used to confirm component identity. Compounds were declared unknown if their matching probability was less than 80 (100 = perfect match). The organic compounds were quantified using more than five different concentrations identified as standard solutions, which were made by commercial high-purity liquid standard. The calibration standard curve was approved with a correlation coefficient (*R*) over 0.995. The detection limits were 0.0040 wt% for dichloromethane, 0.0039 wt% for 1,1-dichloroethane, 0.0038 wt% for chloroform, 0.0039 wt% for 1,1,1-trichloroethane, 0.0041 wt% for carbon tetrachloride, 0.0038 wt% for 1,2-dichloroethane, 0.0038 wt% for benzene, 0.0038 wt% for trichloroethene, 0.0034 wt% for toluene, 0.0044 wt% for tetrachloroethene, 0.0031 wt% for ethylbenzene, 0.0072 wt% for

m-/*p*-xylene, 0.0032 wt% for *o*-xylene, 0.0030 wt% for styrene, 0.032 wt% for methanol, 0.024 wt% for isopropanol, 0.025 wt% for *n*-butanol, and 0.057 wt% for 2-butanone.

RESULTS

Study subjects and solvents usage

Table 1 shows the descriptions of the subjects. The numbers of the employees in the investigated companies were 11.0 ± 7.7 persons in plate-making industries, 19.3 ± 39.5 persons in printing industries, and 9.5 ± 8.8 persons in printing-assistance industries. Among the printing industries, most printing type of them was lithography (74.5%), and follows were letterpress (12.8%), screen (7.8%), and gravure (4.9%). These results were consistent with a 2008 study that also observed lithography to be the major printing type in Taiwan (Taiwan IOSH, 2008).

Table 2 shows the average annual chemical solvent usages in each printing-related company. The pre-press chemicals used in the plate-making industries were 768.4 ± 968.2 kg for each company, and the cleaning solvents used were 38.7 ± 36.3 kg for each company. The most common solvent used in the printing companies was ink ($13\,652.3 \pm 10\,4241.2$ kg per company). The other solvents used were 1053.6 ± 1957.7 kg for fountain solutions, and 774.4 ± 1726.2 kg for cleaning solvents. The use of cleaning solvents was 20-fold higher in the printing industries than in the plate-making industries. Although the usage of dilution solvents ($18\,790.3 \pm 63\,510.6$ kg for each company) was more than ink in the printing industries, data were

collected from only 13 large (at least 52 employees) companies. The only solvents used in the printing-assistance industries were adhesives and glues ($11\,300.2 \pm 30026.4$ kg per company).

Components analysis results of the solvents from SDSs collection and chemical determination

Solvent SDSs were collected from 112 printing-related companies and included SDSs for 22 pre-press chemicals, 72 printing inks, 9 fountain solutions, 56 cleaning solvents, 13 adhesives and glues, and 8 dilution solvents. Table 3 lists the components of each solvent from SDSs. The compounds with the highest percentage (13.6%) of use in pre-press chemicals were *n*-hexane, *n*-heptane, toluene, isopropanol and acetic acid. Other compounds used in pre-press chemicals were ethylene glycol, xylene, sodium hydroxide, diethylene glycol and etc. Soybean oil, polybutylene terephthalate resin, organic pigment, mineral oil and auxiliaries were observed in 84.7% of printing inks. Other compounds used in printing inks were toluene (6.9%), xylene (5.6%), isopropanol (5.6%), *n*-heptane (4.2%), cyclohexanone (4.2%), 2-butanone (2.8%), ethyl acetate (2.8%), 1-octane (1.4%), phthalate esters (1.4%), and butyl acetate (1.4%). The compound with the highest percentage (66.7%) of use in fountain solutions was glycerol. Other compounds used in fountain solutions were ethylene glycol ethers (11.1%), toluene (11.1%), and gum arabic (11.1%). In cleaning solvents, the most commonly used compounds were kerosene (41.1%). Other compounds used in cleaning solvents were toluene (23.2%), *n*-heptane (16.1%), isopropanol (16.1%), 92 gasoline (12.5%), *n*-hexane (10.7%), 1-octane (3.6%), xylene

Table 2. Average annual use of chemical solvents in each printing-related company

	Plate-making industry (<i>n</i> = 23)	Printing industry (<i>n</i> = 102)	Printing-assistance industry (<i>n</i> = 27)
Pre-press chemicals	768.4 ± 968.2	2638.2 ± 4103.2	—
Printing inks	1560.0 ± 2036.5	$13\,652.3 \pm 10\,4241.2$	—
Fountain solutions	—	1053.6 ± 1957.7	—
Cleaning solvents	38.7 ± 36.3	774.4 ± 1726.2	—
Adhesives and glues	—	3227.0 ± 4635.7	$11\,300.2 \pm 30\,026.4$
Dilution solvents	—	$18\,790.3 \pm 63\,510.6^a$	—

Mean $\pm$ SD. Units in kg.

^a*n* = 13.

Table 3. Components of solvents in safety data sheets (SDSs) in the printing industries

Pre-press chemicals (n = 22)			
<i>n</i> -Hexane (13.6%)	<i>n</i> -Heptane (13.6%)	Toluene (13.6%)	Acetic acid (13.6%)
Ethylene glycol (9.0%)	Xylene (9.0%)	Sodium hydroxide (9.0%)	Acetone (4.5%)
Methanol (4.5%)	Ethanol (4.5%)	Sorbitol (4.5%)	Butyl acetate (4.5%)
Nitric acid (4.5%)	Boric acid (4.5%)	Citric acid (4.5%)	Potassium carbonate (4.5%)
Printing inks (n = 72)			
Soybean oil (84.7%)	Polybutylene terephthalate resin (84.7%)	Organic pigment (84.7%)	Auxiliaries (84.7%)
Toluene (6.9%)	Xylene (5.6%)	Isopropanol (5.6%)	Cyclohexanone (4.2%)
2-Butanone (2.8%)	Ethyl acetate (2.8%)	1-Octane (1.4%)	Butyl acetate (1.4%)
Fountain solutions (n = 9)			
Glycerol (66.7%)	Ethylene glycol ethers (11.1%)	Toluene (11.1%)	Gum Arabic (11.1%)
Cleaning solvents (n = 56)			
Kerosene (41.1%)	Toluene (23.2%)	<i>n</i> -Heptane (16.1%)	92 Gasoline (12.5%)
<i>n</i> -Hexane (10.7%)	1-Octane (3.6%)	Xylene (3.6%)	Methanol (1.8%)
Ethanol (1.8%)	Propanol (1.8%)	Ethylene glycol (1.8%)	Butyl cellosolve (1.8%)
Sodium carbonate (1.8%)	Isoamyl acetate (1.8%)	Dichloromethane (1.8%)	
Adhesives and glues (n = 13)			
Polyvinyl acetate (100.0%)			
Dilution solvents (n = 8)			
Toluene (37.5%)	2-Butanone (37.5%)	<i>n</i> -Heptane (25.0%)	Cyclohexanone (25.0%)
1-Octane (12.5%)	Xylene (12.5%)		Methyl isobutyl ketone (12.5%)

One hundred and eighty SDSs were collected from 112 printing-related companies; the percentage was (the no. of the SDSs with the chemical/ the no. of all the SDSs in each kind of solvent).

(3.6%), cleaning naphtha (3.6%), methanol (1.8%), ethanol (1.8%), propanol (1.8%), ethylene glycol (1.8%), washing water (1.8%), butyl cellosolve (1.8%), sodium carbonate (1.8%), isoamyl acetate (1.8%), and dichloromethane (1.8%). In adhesives and glues, polyvinyl acetate was the only one compound listed in the SDSs. The compounds with the highest percentages of use in dilution solvents were toluene (37.5%) and 2-butanone (37.5%). Other compounds used in dilution solvents were *n*-heptane (25.0%), cyclohexanone (25.0%), methyl isobutyl ketone (12.5%), 1-octane (12.5%), and xylene (12.5%).

Table 4 shows the analysis results for volatile organic components of solvents used in studied

printing industries. The detected compounds included benzene, toluene, ethylbenzene, xylene, 2-butanone, methanol, isopropanol, and *n*-butanol. All of these compounds could be detected in the cleaning solvents, and the detection rates were 54.5% for benzene, 72.7% for toluene, 63.6% for ethylbenzene, 81.8% for xylene, 45.5% for 2-butanone, 100.0% for methanol, 100.0% for isopropanol, and 100.0% for *n*-butanol, respectively. The maximum concentrations of toluene and xylene were 44.1 wt% and 57.7 wt%, respectively. Particularly, benzene and ethylbenzene have been classified as carcinogenic to humans (IARC group 1) and possibly carcinogenic to humans (IARC group 2B), respectively, by the International Agency of Research

Table 4. Analytical results for volatile organic components in the solvents used in printing industries

Chemical	Solvent type	Concentration (wt%)	Detection rate (%)	IARC category
Benzene	Cleaning solvents	<0.011–0.035	54.5 (6/11)	Group 1
Toluene	Cleaning solvents	0.015–44.1	72.7 (8/11)	Group 3
Ethylbenzene	Cleaning solvents	<0.011–6.22	63.6 (7/11)	Group 2B
Xylene	Cleaning solvents	<0.015–57.7	81.8 (9/11)	Group 3
2-Butanone	Printing inks	<0.057	20.0 (1/5)	—
	Fountain solutions	<0.057	33.3 (1/3)	
	Cleaning solvents	<0.057–38.5	45.5 (5/11)	
Methanol	Printing inks	<0.032	100 (5/5)	—
	Fountain solutions	<0.032–0.117	100 (3/3)	
	Cleaning solvents	<0.032–0.051	100 (11/11)	
	Dilution solvents	<0.032	100 (1/1)	
Isopropanol	Printing inks	<0.024–0.052	100 (5/5)	Group 3
	Fountain solutions	<0.024	100 (3/3)	
	Cleaning solvents	<0.024–0.036	100 (11/11)	
	Dilution solvents	<0.024	100 (1/1)	
<i>n</i> -Butanol	Printing inks	<0.025	100 (5/5)	—
	Fountain solutions	<0.025	100 (3/3)	
	Cleaning solvents	<0.025–0.94	100 (11/11)	
	Dilution solvents	<0.025	100 (1/1)	

IARC category: group 1, carcinogenic to humans; group 2b, possibly carcinogenic to humans; group 3, not classifiable as to its carcinogenicity to humans.

on Cancer (IARC, 2015); however, these compounds were undisclosed in the SDSs of the solvents. 2-Butanone, methanol, isopropanol, and *n*-butanol could be detected in the printing inks, and the detection rates were 20.0, 100.0, 100.0, and 100.0%, respectively. Among these compounds, methanol and *n*-butanol were undisclosed in the SDSs of the inks. Additionally, 2-Butanone, methanol, isopropanol, and *n*-butanol were detected in the fountain solutions, and the detection rates were 33.3, 100.0, 100.0, and 100.0%, respectively. Methanol, isopropanol, and *n*-butanol were detected in the dilution solvent. However, methanol, isopropanol, and *n*-butanol were undisclosed in the SDSs of the fountain solutions and dilution solvents. Table 5 summarizes the undisclosed compounds in the SDSs for each kind of solvent.

Hazard communications and safety and health management in the printing industries

Table 6 presents the implementation status of hazard communications and safety and health management in the printing industries. Most plate-making and printing-assistance industries did not have hazard communication programs, and the proportions were 60.9 and 55.6%, respectively. The percentage of the printing industry with hazard communication programs was 64.7%. About the SDSs of the solvents, most plate-making and printing-assistance industries did not provide SDSs, and the proportions were 52.2 and 59.3%, respectively. The percentage of printing industry companies that provided SDSs was 70.6%. Most of the plate-making, printing, and printing-assistance industries had ventilation systems, and the proportions were 91.3, 85.3, and 81.5%, respectively. About the employees' general health examination, most (60.9%) plate-making companies did not provide health examinations. Most printing and printing-assistance

industries (68.7 and 59.3%, respectively) provided general health examinations for employees. None of the plate-making and printing-assistance companies provided specific health examinations, and the proportion of providing the employees' specific health examination for printing industry was 30.4%. The industry with the highest proportion of companies that provided personal protective equipment (PPE) was the printing industry (84.3%) followed by the printing-assistance industry (51.9%) and plate-making industry (47.8%). The industry with the highest proportion of companies that provided safety and health education/training was the printing industry (66.7%) followed by the plate-making industry (47.8%) and printing-assistance industry (44.4%).

DISCUSSION

An increase in cholangiocarcinoma was noted at a printing company in Japan in 2013. The increase was attributed to worker exposure to 1,2 DCP and DCM in an unventilated basement (Kumagai *et al.*, 2013). In this study, we did not find any 1,2-DCP used in the solvents in the study companies. However, DCM was used as a cleaning solvent in a printing company. This requires immediate attention because DCM is carcinogenic and can impair the nervous system in humans (Kumagai *et al.*, 2013; Winneke, 1974). Cases of polyneuropathy have also been reported in printing industries not only in Hong Kong (Chang *et al.*, 1993), but also in Taiwan (Taiwan CDC, 1985). This study found that *n*-hexane and *n*-heptane were still widely used in pre-press chemicals, printing inks, cleaning solvents, and dilution solvents in printing industries, and this should be concerned because the chemicals had been linked to the nervous system impairment for the printing workers. Additionally, phthalate esters were observed in printing inks and phthalate ester exposure is associated with possible endocrine disruption in humans (Albert and Jégou, 2014). Previous study had found that high concentration of ambient phthalate esters exposure and their urinary metabolites could be detected for the printing industry workers (Taiwan IOSH, 2011). Several chemicals are known to be used in various solvents in printing industries, including toluene, isopropanol, 2-butanone, ethyl acetate, and methanol (Nagasawa *et al.*, 2011). This study found that these chemicals were widely used in the pre-press chemicals, printing inks, fountain solutions, cleaning

Table 5. Undisclosed compounds in the SDSs for each kind of solvent

	Undisclosed compounds
Cleaning solvents	Benzene; ethylbenzene
Printing inks	Methanol; <i>n</i> -butanol
Fountain solutions	Methanol; isopropanol; <i>n</i> -butanol
Dilution solvents	Methanol; isopropanol; <i>n</i> -butanol

Table 6. The implementation status of hazard communications and safety and health management in the printing industries

Items	Plate-making industry (<i>n</i> = 23)	Printing industry (<i>n</i> = 102)	Printing-assistance industry (<i>n</i> = 27)
Hazard communication program	9 (39.1)	66 (64.7)	12 (44.4)
Safety data sheets	11 (47.8)	72 (70.6)	11 (40.7)
Ventilation systems	21 (91.3)	87 (85.3)	22 (81.5)
Employees' general health examination	9 (39.1)	70 (68.7)	16 (59.3)
Employees' specific health examination	0	31 (30.4)	0
Personal protective equipments	11 (47.8)	86 (84.3)	14 (51.9)
Safety and health education/training	11 (47.8)	68 (66.7)	12 (44.4)

Units in companies (%).

solvents, and dilution solvents, which was consistent with previous reports. As the major concern regarding solvents in the printing industry is cancer, the history of occupational exposures is particularly relevant due to the long latency between exposure and cancer occurrence. This study indicates the present components information of the solvents used in the printing industries. In contrast with the previous studies, several carcinogens and possible carcinogens, such as polycyclic aromatic hydrocarbons, aromatic amines, and DCM, are seldom found from the information of used solvents in this study. However, the data of chemicals usage and workers exposure in workplaces should be continuously monitored, particularly for the hazardous substances, in order to protect the workers' safety and health, and to assist the occupational diseases judgment.

To ensure the safe use of chemicals in the workplace, information about the identities and hazards of the chemicals must be available and understandable to workers. Hazard Communication Standard (HCS) announced by Occupational Safety and Health Administration (OSHA) was designed to ensure that information about these hazards and associated protective measures was adequately disseminated (OSHA, 2012). In this study, we found the implementation of hazard communications in the printing industries was insufficient. Many printing-related industries did not provide safety and health education or training, PPE, and SDSs to employees. The lack of training, hazard communication, and PPE may contribute to the risk

for occupational exposure and associated disease, as reported for printing workers. Particularly, the chemical analysis results of the solvents in this study revealed that not all of the hazardous compounds were disclosed in the SDSs of the solvents. Several of the undisclosed compounds in SDSs were carcinogenic or possibly carcinogenic and present potential health risks to printing workers who may be unknowingly exposed. Many solvents used in printing industries are mixtures of chemicals and proprietary prepared formulations. The manufacturers might not disclose all the chemical constituents of the solvents in the SDS and the label of container due to the trade secrets. With this reason, several trouble compounds, such as toxicants, might be undisclosed by the manufacturers. To improve the safety and health information, the contents of SDS are recommended to be reviewed by OSHA before they are published by the suppliers. Meanwhile, the flow data of the toxicants is also recommended to be systematically integrated between Ministry of Economic Affairs, Environmental Protection Agency and OSHA, to ensure the validity of SDS.

CONCLUSIONS

We note here, several inadequacies in hazard communication programs in printing industries that need to be addressed such that solvent exposure and potential health risks are mitigated in the printing industry. Employees who work in printing industries can be exposed to multiple solvents in their work environment, and many health problems have been reported

for these employees. This study assessed the chemical constituents in solvents used in printing industries by chemically analyzing the solvents, collecting SDSs, and summarizing the chemical pattern of the solvents in these industries. The study results indicated that the current safety information of solvents components in printing industries was inadequate, and many hazardous compounds were undisclosed in the SDSs of the solvents or the labels of the containers; some of them were carcinogenic or possibly carcinogenic to humans. The content of the SDSs should be strictly managed by governments, particularly for hazardous components. We note that the implementation of hazard communication in the industries surveyed here was insufficient. Additionally, a high proportion of plate-making and printing industries did not provide SDSs of the solvents and PPEs to employees. Furthermore, many printing-related industries did not provide safety and health education/training for the employees. Further efforts in printing industries should emphasize the implementation of hazard communication, and provide appropriate education/training and PPEs for protecting the employees' safety and health.

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DECLARATION

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