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***Brief Report***

# Control banding assessment of exposure of offset printing workers to organic solvents

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**Abstract: Objectives:** We aimed to assess the exposure of offset printing workers to hazardous substances in the rinsing processes of small-sized companies using a control banding method. **Methods:** We obtained half-year amounts of hazardous substances purchased through a questionnaire survey and the hazardous information from the safety data sheets (SDSs) and related literature. **Results:** The amount of petroleum kerosine and carbon hydride markedly increased in 2013 compared with that in 2010. In contrast, the amount of dichloromethane (DCM) decreased in 2013, and 1,2-dichloropropane (DCP) was not used in either 2010 or 2013. Mineral oil and xylene were allocated to Hazard Group D and judged to require Control Approach 3. In addition to DCM with Global Harmonization System's carcinogenic category 1, mildly treated mineral oil and solvent naphtha, allocated into Hazard Group E, are carcinogenic to humans and were judged to require Control Approach 4. There are two limitations of the control banding assessment: first, only limited and scarce hazard information could be obtained from SDSs, and second, safe-sided judgment for control technology for industrial hygiene. **Conclusion:** Small-sized enterprises are encouraged to implement control banding assessment for hazardous substances and to access expert advice available from Regional Industrial Health Centers. Easy access to appropriate expert advice is important to compensate for the limited and scarce hazard information and safe-sided judgment for control technology for Control Approaches 3 and 4.

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**Key words:** Organic solvents, Control banding, Exposure to solvents, Offset printing, small- and medium-sized enterprises

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## Introduction

It was reported in 2012 that occupational cholangiocarcinoma occurred among workers exposed to 1,2-dichloropropane (DCP) and dichloromethane (DCM) in a small-sized offset printing company in Osaka, Japan[1] and that the printing workers were exposed to extremely high concentrations of DCP (100-670 ppm) and DCM (80-540 ppm)[2]. This exposure has raised serious concerns about the occupational health management for hazardous substances. The National Diet of Japan amended the Industrial Safety and Health (ISH) Law in 2014. 1,2-DCP and DCM were designated as the specified chemical substances under the Ordinance on Prevention of Hazards due to Specified Chemical Substances of ISH Law. The revision of the ordinance strengthened workplace management.

Recently, the International Agency for Research on Cancer (IARC, 2014) evaluated the carcinogenicity of DCP as Group 1 (carcinogenic to humans) and revised that of DCM from Group 2B to 2A[3]. The Japan Society for Occupational Health (JSOH, 2015) recommended classification of 1,2-DCP and DCM as Group 1 and Group 2A (probably carcinogenic to humans), respectively[4]. The employers of small-sized enterprises employing less than 50 workers have no legal obligation to appoint either a health supervisor or an occupational physician in Japan, and they cannot afford sufficient financial, technical, and human resources to improve the work environment. It is difficult for such employers to comprehensively implement risk assessment of hazardous substances used in the workplace. The control banding method is a simplified risk assessment system designed for small- and medium-sized enterprises (SMEs) by the Health and Safety Executive, UK (HSE, 2015)[5] and the International Labour Organization (ILO, 2015)[6].

The present study was intended to examine the exposure of offset printing workers to hazardous substances used in small-sized companies using the control banding method with a questionnaire survey. We focused on three processes, i.e., rinsing an ink-roll, a transcription rubber-roll, and a printing plate, because workers were at higher risk of excessive exposure to hazardous substances in these processes than in others. The survey was conducted with an emphasis on DCP and DCM use in 2010 and 2013 because the outbreak of cholangiocarcinoma in a small printing company in Osaka was made public through the media in 2012 and also because DCP was not regulated by the ISH Law as of 2013.

## Materials and Methods

Out of the 29 printing companies in Matsumoto city, Nagano Prefecture of Japan, which were affiliated with a regional branch of the Printing Industry Association, 26 (89.7%) participated in this study. Twenty-one companies had offset printing machines, and 18 were categorized as small-sized enterprises having less than 50 employees. We obtained written informed consent and information including total number of employees and workers engaged in printing jobs, the printing machines and chemical substances used as well as their manufacturers, the half-year amounts of the substances used, and safety data sheets (SDSs). This information was obtained through a questionnaire survey. This study was approved by the Ethics Review Committee of the Shinshu University School of Medicine.

The control banding method of the HSE COSHH Essentials (HSE, 2015)[5] and the ILO Chemical Control Toolkit (ILO, 2015)[6] was used in this study. The amount of each hazardous substance used daily was categorized into one of three groups, namely "small (milliliter levels)," "medium (liter)," and "large (cubic meter)," on the basis of the half-year amounts of each substance in 2010 and 2013. These two years were chosen because of the publicity of cholangiocarcinoma among offset printing workers through the media in 2012. The volatility of each substance was categorized into one of three categories, namely "high," "medium," and "low," corresponding to boiling points below 50℃, 50℃-150℃, and higher than 150℃, respectively. On the basis of the health hazard caused by the substances, they were allocated into one of the five Hazard Groups from A to E as well as Hazard Group S on the basis of SDSs supplied by individual printing companies and those issued by the Inter-Ministerial Committee on Global Harmonisation System (GHS) of the Japanese Government (NITE, 2015)[7] or the IARC publications on carcinogenicity[3,8] according to the hazard statements of the Chemicals Classification, Labeling and Packaging using GHS (HSE, 2015)[5].

## Results

Table 1 shows the half-year amounts of 14 materials used for the three rinsing processes in the 21 offset printing companies in 2010 and 2013. The number of employees/printing company was 19.8 ± 32.2 (mean ± SD; range 1-117), and the number of workers assigned to the printing jobs was 4.4 ± 7.2 (mean ± SD; range 1-31). The amount of kerosine and carbon hydride increased by 400% in 2013 compared with that in 2010. The amount of mineral oil and solvent naphtha also increased in 2013. In contrast, the amount of DCM decreased by 38% in 2013. DCP was not used in any printing company in either 2010 or 2013. Sizable amount of ethylene glycol monobutyl ether (EGME) was also used in both 2010 and 2013; however, EGME was used in only two companies having more than 50 employees. Carbon hydride was excluded from the present risk assessment because this substance was not used in any of the 18 small-sized companies.

Table 2 shows the categorized control approaches on the basis of the volatilities, amounts used daily, and categorized hazards of eight substances used in 18 small-sized printing companies with less than 50 employees by the control banding method. The amounts used daily are expressed as the means of the values obtained from 18 small-sized printing companies; however, these amounts did not exceed 1 L in any of the 18 companies. We focused on small-sized enterprises having less than 50 employees because they have no legal obligation to appoint either a health supervisor or an occupational physician and could not afford sufficient financial, technical, or human resources to improve the work environment. Every substance used in the 18 small-sized printing companies was allocated into one of the four categories referred to as Hazard Groups B through E, excluding the substances allocated as Hazard Group A. All these substances were also allocated into Hazard Group S because they were grouped as GHS category 1 or 2 because they cause skin corrosion/irritation and serious eye damage/eye irritation; in addition, the amounts of these materials used daily did not exceed one liter in any of the 18 companies. DCM was categorized into Hazard Group E, which represents the highest risk, because IARC's recent revision of DCM from Group 2B to 2A upgraded GHS's carcinogenic category from 2 to 1B according to the GHS Classification Guidance for the Japanese Government (Edited by the Inter-Ministerial Committee on GHS in the Japanese

**Table 1.** Materials used for three rinsing processes* in 21 offset printing companies** .

| Materials | 2010 (Jan-Jun) Half-year amount purchased (Liter) | % | 2013 (Jan-Jun) Half-year amount purchased (Liter) | % | Growth rate % |
|---|---|---|---|---|---|
| Mineral spirit | 788 | 37.6 | 707 | 26.6 | –10.3 |
| Mineral oil | 316 | 15.1 | 383 | 14.4 | 21.2 |
| Trimethyl benzene | 231 | 11.0 | 232 | 8.7 | 0.4 |
| Emulsifiers | 184 | 8.8 | 0 | 0.0 | –100.0 |
| Carbon hydride*** | 169 | 8.1 | 851 | 32.0 | 403.6 |
| Ethyleneglycol monobutylether | 58 | 2.8 | 50 | 1.9 | –13.8 |
| Cyclohexane | 66 | 3.2 | 40 | 1.5 | –39.4 |
| Solvent naphtha | 56 | 2.7 | 78 | 2.9 | 39.3 |
| Dichloromethane | 37 | 1.8 | 23 | 0.9 | –37.8 |
| Surfactants | 27 | 1.3 | 47 | 1.8 | 74.1 |
| Xylene | 27 | 1.3 | 39 | 1.5 | 44.4 |
| Petroleum Kerosine | 7 | 0.3 | 36 | 1.4 | 414.3 |
| 1,2-dichloropropane | 0 | 0.0 | 0 | 0.0 | |
| others | 54 | 2.6 | 98 | 3.7 | 81.5 |
| | 2,020 | 100 | 2,584 | 100 | 27.9 |

*: The three rinsing processes include rinsing an ink-roll, a transcription rubber-roll and a printing plate.
**: Number of employees/printing company and number of workers assigned for the printing jobs were given in TEXT.
***: A general term used as carbon hydride in the SDSs to refer to solvents including various kinds of commercially available hydrocarbons refined from prtroleum, except for the above-mentioned materials.
Growth rate (%)={(half-year amount purchased in 2013) – (half-year amount purchased in 2010)} / (half-year amount purchased in 2010)×100

Government, Revised Edition, 2013). Mineral oil and xylene were allocated into the second severest group, Hazard Group D, on the basis of GHS's noncarcinogenic classifications and judged to require Control Approach 3 involving containment. One of the kerosines, specified as CAS No. 8008-20-6, was categorized into Hazard Group D because this product was classified as GHS's carcinogenic category 2. Mineral oil and solvent naphtha can also be categorized into Hazard Group E and judged to require Control Approach 4, which involves seeking expert advice, because untreated or mildly treated mineral oil can also be classified as a human carcinogen (IARC, 2013; ACGIH, 2010)[8,9] and because solvent naphtha, specified as CAS No. 8030-30-6, was classified as probably carcinogenic to humans in EU (IARC, 2013)[8]. Trimethyl benzene and mineral spirits were allocated into Hazard Group C and judged to require Control Approach 2 involving engineering control. Cyclohexane and solvent naphtha were allocated into Hazard Group B and judged to require Control Approach 1 involving general ventilation. Two printing companies with more than 50 employees reported the use of EGME in the three rinsing processes. The control banding assessment for EGME can be summarized as follows: the amount of EGME used daily was at the "milliliter" level, its volatility was "low," and EGME was allocated into Hazard Group D because it falls into GHS's category 2 for reproductive toxicity. EGME was judged to require Control Approach 3 involving containment.

## Discussion

The present study showed that the half-year amounts of carbon hydride, mineral oil, mineral spirits, naphtha, and kerosine used in the three rinsing processes increased markedly in 2013 in comparison with 2010. In contrast, the amount of DCM decreased by 38% in 2013 compared to 2010. DCP was not used in any printing company either in 2010 or 2013. The markedly decreased use of DCM in 2013 may have been influenced by the publicity regarding cholangiocarcinoma among printing workers exposed not only to DCP but also DCM. Kubo et al.[10] reported that 22 chemical substances, including chlorinated organic solvents, mineral oil, kerosine, solvent naphtha, and others, were used in the offset proof-printing department at a printing company in Osaka. The substances used in the offset printing companies in Matsumoto city of Nagano agreed well with those reported by Kubo et al.[10].

In the present study, however, all eight substances were found to be hazardous to workers' health according to the different hazard groupings on the basis of SDSs. DCM is

**Table 2.** Hazardous organic solvents used in 18 small-sized printing companies and categorized Control Approaches based on Hazard Group, amount used daily, and volatility, assessed by the control banding method.

| Hazardous substances | Engineering control equipment installed [1] | Hazard Group | Amount used daily [2] | Volatility | Control Approach |
|---|---|---|---|---|---|
| Dichloromethane | GV | E & S | milliliters (46.7/47.3) | High | 4 (seeking expert advice) |
| Mineral oil | GV | D or E & S | milliliters (170/163) | Low | 3 (containment) or 4 (seeking expert advice) |
| Xylene | GV | D & S | milliliters (20/20) | Medium | 3 (containment) |
| Trimethyl benzene | GV | C & S | milliliters (73.3/57.3) | Low | 2 (engineering control) |
| Mineral spirits | GV | C & S | milliliters (220/159) | Low | 2 (engineering control) |
| Cyclohexane | GV | B & S | milliliters (0/4.0) | Medium | 1 (general ventilation) |
| Solvent naphtha | GV | B or E & S | milliliters (147/207) | Low | 1 (general ventilation) or 4 (seeking expert advice) |
| Petroleum Kerosine | GV | B or D & S | milliliters (0/216) | Low | 1 (general ventilation) or 3 (containment) |

[1]: Only general ventilation (GV) was installed as an engineering control in the work environment in 2010 and 2013 in all the printing companies.
[2]: Categorized amount of each organic solvent used daily was designated as the "milliliter" level, and the parenthesized value indicates the mean daily amount of each solvent averaged over the printing companies in 2010 and 2013.
Eight hazardous substances were chosen out of 14 materials (Table 1) except for ethyleneglycol monobutylether (EGBE), since those substances were categorized to one of the Hazard Groups from B to E and in Hazard Group S. EGBE was used at two printing companies with more than 50 employees, and its assessement result was given only in the text.

a probable human carcinogen allocated into Hazard Group E. It was also noteworthy that sizable amounts of EGME, a reproductive toxicant classified in GHS's category 2, were used in the two companies having more than 50 employees, although EGME was not used in any 18 small-sized companies.

Even for small amounts of EGME, refined mineral oil, and xylene used daily at a "milliliter" level, Control Approach 3 was recommended for the three rinsing processes. On the other hand, the use of mineral spirits and trimethyl benzene can be designated as falling under Control Approach 2. All eight substances were also categorized into Hazard Group S, for which workers are asked to wear personal protective equipment such as gloves and goggles.

The control banding assessment has some limitations in terms of its ability to judge the safety of highly hazardous substances. The first limitation was the limited and scarce hazard information available from the SDSs. Control Approach 4, which entails seeking expert advice, is required for substances designated in GHS's category 1 of carcinogenicity. Mildly treated mineral oil and solvent naphtha can be classified as Group E carcinogens and petroleum kerosine as a Group D carcinogen in GHS (IARC, 2013)[8]. Mackerer et al.[11] showed that some petroleum-based oils may contain polycyclic aromatic compounds with carcinogenic potential, depending on the refinery distillation process and the hydrogenation of the petroleum. Our control banding assessment recommended Control Approach 4 for DCM, untreated or mildly treated mineral oil, and naphtha specified as CAS No.8030-30-6 used in the three rinsing processes. Replacement of the chemicals with a less hazardous ones should be attempted (HSE, 2015)[5]. Experts may have difficulty in judging whether the quality of the hazard information regarding the human carcinogenicity of petroleum distillates is sufficiently informative on the basis of the SDSs supplied by the chemical manufacturers. Indeed, none of the SDSs of the mineral oils supplied by chemical manufacturers in Japan indicate a GHS carcinogenicity category of 1, while crude or mildly treated mineral oil is classified in the GHS's carcinogenic category 1 in SDS issued by the Inter-Ministerial Conference on SDS of the Japanese government. Experts should examine the latest correct information about the carcinogenic potential of solvents as seen in the recent IARC revisions of the carcinogenic classification of Groups 2B and 2A for DCM and Group 1 for DCP (IARC, 2014)[3].

The second limitation was the possibility of excessively safe-sided judgment for occupational exposure. A process in which EGME, refined mineral oil, and xylene were handled to rinse the plate was required to install a containment system when using Control Approach 3. It may be technically difficult to enclose the entire process without disturbing the manual tasks involved in the three rinsing processes with solvents because the relative efficacy of containment in comparison with general ventilation was expected to result in a 100-fold reduction of exposure to these substances (HSE, 2015)[5]. However, an alternative control technology, such as a local exhaust ventilation system equipped with an enclosed hood, may be effective. The relative efficacy of the local exhaust ventilation system having a 100-fold reduction of exposure can be maintained by controlling the capture velocity at greater than 0.4 m/sec[12]. Thus, the three rinsing processes can be performed manually with the ventilation system instead of using containment.

Jones and Nicas[13] reported that the margins of safety were much larger for the substances categorized in Hazard Group D than for those categorized in Hazard Group B or C. Tischer et al.[14] also showed that in 55% of offset printing workplaces under general ventilation, the measured concentrations were lower than those predicted by the control banding in comparison with 45% where the measured concentrations were within the predicted concentrations. Control banding assessment may be inherently designed to compensate for insufficient exposure information by a safe-sided judgment in order to secure the safety of high risk workplaces by requesting expert intervention, as argued by Hashimoto et al.[15]. The above-mentioned limitations can be solved by obtaining appropriate expert advice for Control Approaches 3 and 4.

The recently revised Japanese ISH Law stipulate that employers have a legal obligation to implement risk assessments for 640 ISH Law-notified substances, although small-sized enterprises having less than 50 employees cannot afford sufficient financial, technical, and human resources to improve the work environment. The employers will have to investigate any 640 notified substances used in workplaces on the basis of the SDSs delivered from chemical products companies. The employers are also asked to strengthen management of work environment by appointing the operations chief of the work for handling these substances. SMEs, such as small-sized printing companies, are encouraged to implement the control banding assessment and then to access free expert advice from the Regional Industrial Health Centers subsidized by both Ministry of Labour, Health and Welfare and the Japan Medical Association. The Regional Centers are asked to coordinate the experts to take the countermeasures for improving the work environment upon the request from the employers. Therefore, experts are urgently needed to provide SMEs with the latest correct hazard information regarding human health effects and state-of-the-art industrial hygiene control technology to reduce exposure to highly hazardous substances used in workplaces.

In conclusion, the half-year amounts of petroleum kerosine and carbon hydride increased markedly in 2013. In contrast, the amount of DCM decreased in 2013 and DCP was not used in any company in either 2010 or 2013. Easy access to appropriate expert advice is of primary importance for the implementation of control banding assessment in SMEs to effectively reduce occupational exposure to highly hazardous substances.

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