FORMALDEHYDE IN SCREEN PRINTING INDOOR

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ABSTRACT

The presence of formaldehyde in air samples has been detected in five screen printing facilities in Novi Sad, Serbia. Air samples were sampled continuously during 4 hours, and concentration levels of formaldehyde was determined by UV-VIS spectrometry at 580 nm. The range of formaldehyde concentrations was from 0.413 to 0.836 ppm. Comparison of the detected concentration levels with the permissible exposure limit of 0.75 ppm (the OSHA standard) indicated that the formaldehyde concentration in facility 5 was 1.11 times higher than prescribed value.

INTRODUCTION

Formaldehyde is one of the most prevalent pollutants in indoor air. Industrial releases of formaldehyde can occur at any stage during the production, use, storage, transport, or disposal of products with residual formaldehyde. Formaldehyde have been emitted from chemical manufacturing plants, pulp and paper mills, forestry product plants, tire and rubber plants, petroleum refining and coal processing plants, textile mills, automotive manufacturing plants, and the metal products industry [1]. Screen printing is possibly the most versatile of all printing processes. It can be used to print on a wide variety of substrates, including paper, paperboard, plastics, textile, glass, metals fabrics, and many other materials [2]. Liquid materials (printing ink, cleaning solution, varnish, adhesive, etc.) used in screen printing process generate numerous toxic, hazardous substances of organic origin, especially contaminants from the group of volatile organic compounds (VOCs), such as formaldehyde, benzene, toluene, xylene, and methanol, are well known to enable the so-called building-related sickness [3]. Depending on the type of used compound, the printing and drying processes, substrates and end-use application requirements, the amounts of formaldehyde are changed [4, 5].

Formaldehyde (CH_2O) is a simple compound consisting of hydrogen, oxygen and carbon. It is also known as methyl aldehyde, methylene oxide, oxymethylene and oxomethane. It is a colorless gas with a pungent, irritating odor. It is a naturally occurring substance in the environment, but since the discovery and industrial processing of formaldehyde it has become one of the most common indoor air pollutants. It is highly reactive, readily undergoes polymerization, highly flammable and in air can form explosive mixtures. It decomposes at temperatures above 150 °C. Formaldehyde is readily soluble in water, alcohols and other polar solvents. It is harmful to human health, causing adverse respiratory effects and even cancer. Because of the toxicity, formaldehyde is classified as hazardous substances able to affect the workers' health [1, 3-5].

For this reason, extensive research has been conducted for the first time in Serbia on developing a continuous monitoring of the formaldehyde concentration levels in screen

printing indoor. The objective was to determine the main emission sources of this hazardous pollutant in screen printing environment.

MATERIALS and METHODS

The air sampling was performed in five screen printing facilities (1-5) during manual printing process. Continuous sampling lasted for 4 hours. Air samples were collected using air sampler PRO-EKOS AT. 401X. The ambient air was infiltrated through the Drechsel bottles with diffuser frit containing absorption solution for formaldehyde (95 cm^3 concentrated sulfuric acid and 0.5 cm^3 1% hromotropic acid). Air flow was 0.5 dm^3/min. Upon the sampling completion it was necessary to immediately determine the formaldehyde concentration, as the intensity of purple color of absorption solution is stable only a few hours. The absorption intensity was determined by UV-VIS spectrometry at 580 nm. The concentrations of formaldehyde were determined from the calibration curve using the standard formaldehyde solution of 1 mg/cm^3 [6].
All used chemicals were of analytical reagent grade (Merck, Germany).
The microclimate parameters were measured using instrument Mannix DLAF-8000 during the experiment. The values of temperature, relative humidity and light intensity of all printing facilities are presented in Table 1.

Table 1 Values of microclimate parameters in screen printing facilities

Screen printing facilities	Microclimate parameters		
	t [°C]	RH* [%]	LI** [lx]
1	19.3 - 21.3	41.3 - 45.6	99 - 870
2	19.1 - 21.8	38.9 - 52.1	85 - 340
3	23.6 - 24.2	38.3 - 50.3	265 - 447
4	25.8 - 28.2	48.0 - 53.9	493 - 1163
5	27.8 - 35.0	48.5 - 61.7	783 - 1076

RH* - Relative humidity
LI** - Light intensity

RESULTS and DISCUSSION

Experimental results were confirmed the presence of formaldehyde in screen printing environment. The formaldehyde concentrations varied from 0.413 to 0.836 ppm (Table 2 and Fig. 1). Only facility 5 has the formaldehyde concentration above 0.75 ppm as the PEL (permissible exposure limit) value prescribed by OSHA (Occupational Safety and Health Administration) standard. The formaldehyde concentration levels were almost 1.11 to 1.82 times lower than PEL (facilities 1-4), whereas in facility 5 the formaldehyde concentration was 1.11 times higher than PEL value. According to the STEL (short-term exposure limit) value, the formaldehyde concentrations in all investigated facilities were below 2 ppm [7]. Based on the detected and quantified formaldehyde concentrations we confirm that printing raw materials (inks, cleaning solution, adhesive and paper) are the main emission sources of formaldehyde in screen printing indoor.
Basically, formaldehyde and formaldehyde-releasing compounds are widely used as cross linking agents and binders in printing inks, biocides in water-based inks and fungicidal

products. The concentrations of free formaldehyde in these products are generally less than 2%. During the printing these formaldehyde-based materials help bind dyes and pigments to fabrics, prevent colors from running, improve a fabric's resistance to wrinkles, ease clothing care and maintenance and prevent mildew. Additionally, unsaturated VOCs from conventional cleaning solutions in the reaction with ambient ozone contribute the releasing of formaldehyde in indoor environment.

Table 2 Concentrations of formaldehyde in screen printing facilities

Screen printing facility	Concentration (ppm)	MAC (ppm)	
		PEL	STEL
1	0.413	0.75	2
2	0.678		
3	0.564		
4	0.451		
5	0.836		

Beside the chemical composition of raw materials the variations in the formaldehyde concentrations in screen printing facilities were related also to the ambient conditions, volume production, and distance from the printing desk, as well as the presence of ventilation installed in workplace. Numerous studies have reported that the indoor emission of formaldehyde increases with increasing of temperature and relative humidity [8]. In accordance with the literature it was confirmed the dependence of formaldehyde concentration on temperature and relative humidity. Therefore, increased concentration of formaldehyde in facility 5 was caused by a significant increasing of temperature and relative humidity (Table 1).

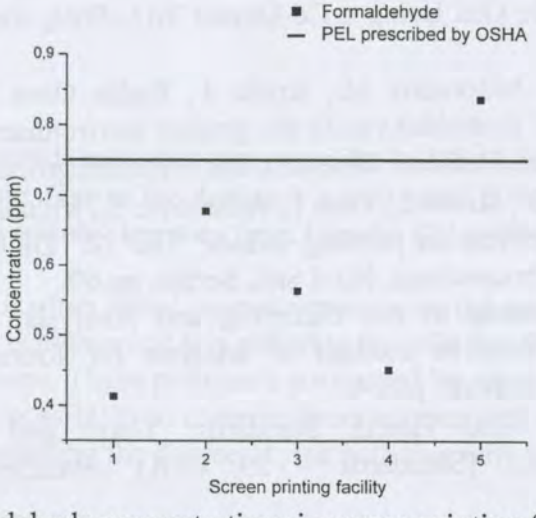

Fig. 1 Formaldehyde concentrations in screen printing facilities (1-5)

Obtained results indicate that formaldehyde concentrations in press department of screen printing facility, especially in printing facility 5, have a potential risk factor to workers' health. Many researches also confirm that formaldehyde can be toxic for human health and considered to be carcinogenic, mutagenic, or teratogenic [9, 10]. Thus, nowadays environmental regulations and EU Directives are increasingly pushing printing industry to reduce emission of formaldehyde, or find alternatives non-formaldehyde materials. The use of

alternative materials is environmentally responsible choice that will reduce the generation of hazardous formaldehyde in screen printing environment.

CONCLUSION

This study provides experimental data concerning the indoor air pollution in screen printing facilities in Novi Sad for the first time. The main indoor sources of formaldehyde were conventional printing inks and cleaning solutions. The results pointed out that the manual screen printing processes generate formaldehyde in working environment due to the higher volume production (25-50 printed products during 1 hour) and application of conventional raw printing materials. During the production campaign, the formaldehyde concentration in screen printing facility 5 exceeds the PEL prescribed by the OSHA standard. Such high concentrations suggest that formaldehyde is the risk indoor air pollutant for workers. Thus, in order to better quantify the worker exposure level of hazardous formaldehyde it is recommended to carry out further investigation and long-term monitoring.

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LIST OF REFERENCES

[1] World Health Organization, (2002). Concise International Chemical Assessment Document 40, Formaldehyde, Geneva, p. 1-81.
[2] Printers' National Environmental Assistance Center, Print process descriptions: Printing industry overview: Screen printing, http://www.pneac.org/printprocesses
[3] Wen Z., Tianmo L., Zhongchang W., Susumu T., Mitsuhiro S., Yuichi I. (2009). Selective Detection of Formaldehyde Gas Using a Cd-Doped TiO_2-SnO_2 Sensor, *Sensors* 9, p. 9029-9038.
[4] Kiurski J., Vojinovic Miloradov M., Krstic J., Radin Oros I., Adamovic D. (2009). Detection and influence of formaldehyde in the graphic environment, The 2nd Symposium of Chemistry and Environment, Book of Abstracts, Bar, Montenegro, pp. 124.
[5] Kiurski J., Adamovic D., Krstic J., Oros I., Adamovic S., Mihailovic A., Grujic S. (2010). The influence of formaldehyde on printing indoor, The 12th DKMT Conference on Food, Environment and Health, Proceedings, Novi Sad, Serbia, pp.69.
[6] Kats M. (1972). Methods of Air Sampling and Analysis, American Public Health Association, part 408: Tentative method of analysis for formaldehyde content of the atmosphere (colorimetric method), p.194.
[7] Occupational Safety and Health Standards, Toxic and Hazardous Substances, Formaldehyde, Regulations (Standards - 29 CFR), Standard Number: 1910.1048, www.OSHA.gov.
[8] Suh H. H., Bahadori T., Vallarino J., Spengler D. J., (2000) Criteria Air Pollutants and Toxic Air Pollutants, *Environmental Health Perspectives* 108(4), p. 625-633.
[9] World Health Organization, International Agency for Research on Cancer, (2006). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 88, Formaldehyde, 2-Butoxyethanol and 1-tert-Butoxypropan-2-ol, Lyon, France.
[10] Pinkerton L. E., Hein M. J., Stayner L. T. (2004). Mortality among a cohort of garment workers exposed to formaldehyde: An update, *Occupational Environmental Medicine* 61, p. 193-200.