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Indoor air quality investigation from screen printing industry

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ABSTRACT

The paper investigates the quality of air in working premises of screen printing in Novi Sad, Serbia. The concentrations of Volatile Organic Compounds, formaldehyde, acetone and ozone were measured in a five screen printing facilities. Measurements were carried out during 4 h, every 40 min, using the air sampler PRO-EKOS AT 401X and mobile gas chromatograph. The sampling position was determined according to the technical characteristics of screen printing desk. Air was sampled from one sampling point as the most suitable in terms of production volume. Determined concentrations of certain gases indicate not only their presence, but also the fact that their level exceeds the prescribed value of the OSHA and NIOSH standards. The concentrations of acetone, isopropanol and methyl ethyl ketone increased from 0.120 to 0.214 ppm within 80 min of printing process in most investigated facilities. The ozone concentrations varied from 0.650 to 3.997 ppm and they differ between facilities almost 1.5 to 6 times depending on intensity of the ventilation, diffusion processes, or interaction with other Volatile Organic Compounds of indoor air. The obtained results confirmed the existence of mutual dependence between pollutants. The regression models determined the quantitative dependence of the studied phenomenon.

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1. Introduction

It is a well known the fact that in the printing process hazardous substances occur in the air, threatening human health. Thus the protection of the working environment is one of important tasks of all employees from management down to the last worker in printing industry. More and more attention is given to the environment protection, so this operation is widely recognized as one of the most serious potential environment risks to human health [1,2]. Indoor air is also important because people spend a substantial proportion of their time in buildings. In residences, day-care centres, retirement homes and other special

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environments, indoor air pollution affects population groups that are particularly vulnerable owing to their health status or age [2].

The printing indoor air can be completely polluted with hazard gases, depending on kind of occurred activities, emissions sources and type of used equipment. Polluted printing indoor air can be connected with employees' health problems [3]. Considering that, the removal of pollutants (VOCs—Volatile Organic Compounds, ozone, acetone, formaldehyde, methyl ethyl ketone, xylene, benzene, toluene, isopropyl alcohol, etc.) became a major requirement among industries [4]. In printing environment there are various emission sources of chemical contaminants, such as VOCs, ozone, and particulate matter. Ozone is a particularly reactive gas and may affect the indoor air quality indirectly through the reaction of high molecular VOCs into formaldehydes, organic acid, and free radicals. Since printing offices have printers and photocopiers, pollutants emitted from printing machines have recently become a serious issue with respect to the indoor air [5–10]. When the workplace environment is considered as a source of ambient air pollution, the type, quantity and way of the chemicals application, as well as the dimensions of facility, ambiental conditions, and the capacity of the aspirators, determine the intensity of chemical pollution of indoor air [11,12]. About 70% of the pollutants classified as hazardous air pollutants (HAPs) are volatile organic compounds (VOCs) [13]. It is therefore important to be able to evaluate the emission of VOCs and ozone from printing facilities and their impact on the indoor environment.

The materials containing HAPs used in the screen printing are the printing inks, coatings, adhesives and cleaning solvents. Other HAPs emission sources of screen printing production include the operations of washing machines, binding and finishing equipment, and some prepress equipment. These pollution sources are generally not significant, but their emissions need to be included in a total facility emission inventory [14].

The emissions of printing air pollutants may affect the indoor environment in several ways: affect health and well-being, give rise to troublesome odors, contaminate other materials, result in discoloration of adjacent materials, and condense on electronic equipment and result in poor production. Indoor pollution caused by VOCs, formaldehyde and ozone is an important aspect of IAQ (indoor air quality) which raises particular concern since many organic indoor pollutants are either known, or are suspected to be allergenic, carcinogenic, neurotoxic, immunotoxic, irritant or indicative of sick building syndrome [15]. Even low concentrations of VOCs (benzene, toluene, xylene, methyl ethyl ketone, acetone, isopropyl alcohol) have been associated with discomfort, irritation and disease [16] including mucous membrane irritation, headache and fatigue [17–19], others are known as carcinogens [20]. The Scientific Committee on Health and Environmental Risks (SCHER) states that formaldehyde (like carbon monoxide, nitrogen dioxide, benzene, naphthalene, environmental tobacco smoke (ETS), radon, lead, and organophosphate pesticides) is a compound of concern in the indoor environment [21,22]. Each of the individual pollutants associated with office equipment has the potential to cause adverse effects if exposures are sufficiently high or if people exposed are sensitive. Therefore it is important to examine the emission sources, but it is associated with difficulties due to the differences between equipment and appropriate techniques in specific printing press. For example, for the same model of printing machine, the emission levels would be affected by some factors such as age, product history, maintenance cycle, air exchange rate, and product loading. Evaluation of emissions control should not only concentrate on one strategy, but also on source control, ventilation, and air cleaning or a combination of these all [23]. Identifying specific constituents of concern can direct efforts to reformulate the raw material (e.g., ink, UV-curing) or make alterations of process that will reduce the emission potential [5]. During the screen printing, printers use organic solvents to clean the excess ink from the screens after printing for the next run or reuse. The cleaners that are used nowadays may contain toxic materials which pose a risk to workers and community members. Virtually all of these pollutants are classified as VOCs [24]. A respectable number of studies about indoor pollution have been conducted so far in residences, schools, hospitals, public buildings, working places, but not in the screen printing facility [25–27].

This paper investigates the quality of air in working premises of screen printing in Novi Sad, Serbia. The investigation is directed to monitoring of potential pollutants (VOCs, ozone, formaldehyde and acetone) in the screen printing press. Analyzed results enable the evaluation of statistical regression model who determine which of the pollutants has the greatest impact on the indoor air and worker's health. It was the main goal of the paper.

2. Materials and methods

2.1. Site description

Based on preliminary testing of screen printing pollution the highest concentrations of VOCs, acetone, formaldehyde and ozone were found. That was the reason why they were only tested. The concentrations of pollutants were monitored in a five screen printing facilities (SPF 1–5) of Novi Sad, Republic of Serbia. The randomly selected facilities are small with manual production, similar in area (50–70 m^2), number of employees (3–4), production volume (50–70 printing products per hour) and all are unventilated. For example, a scheme of screen printing facility 5 (SPF-5) is presented in Fig. 1. Printing production covers a range of products: labels, folders, planners, posters, lighters and T-shirts. The main equipment of facility was desk with screen holder. The materials mainly used in production process were a porous mesh stretched tightly over a metal frame, paper, cardboard, textile, screen emulsion, screen printing ink, solvent and adhesive.

2.2. Sampling

Air sampling (VOCs, acetone, formaldehyde and ozone) was carried out during one working shift when the printing operations were largest in volume and continuously. In terms of production volume air was sampled from one sampling point as the most suitable. The position of sampling point was determined according to the technical characteristics of screen printing desk.

The VOCs (isopropanol, methyl ethyl ketone, benzene, toluene, xylenes) and acetone were continuously detected in situ for 6 times, once per 40 min, during 4 h by mobile gas chromatograph Voyager (PerkinElmer Photovac Inc). The time of high volume production of one working shift was 4 h.

Batch-sampling methods was performed for formaldehyde and ozone. Formaldehyde and ozone were continuously sampled during 4 h using air sampler PRO-EKOS AT. 401X. Air sampler was placed at a height of 1.3 m from the floor and 2.4 m distance from the screen printing desk. The indoor air was infiltrated through the Drechsel bottles with diffuser frit containing absorption indicator solutions for ozone (1% potassium iodide in 0.1 M sodium hydroxide) and formaldehyde (95 cm^3 concentrated sulfuric acid and 0.5 cm^3 1% hromotropic acid). The air flow was 0.5 dm^3/min and 0.2 to 0.4 dm^3/min for formaldehyde and ozone, respectively.

2.3. Methods

2.3.1. VOCs determination by mobile gas chromatography

Standard of investigated pollutants (acetone, isopropanol, methyl ethyl ketone, benzene, toluene, xylenes) was used for the calibration and quantification of VOCs. Supelcowax 10–polyethylene glycol (PEG)