

## EMISSIONS OF TOTAL VOLATILE ORGANIC COMPOUNDS DURING THE DIGITAL PRINTING PROCESS

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### Abstract

The impact of the type of digital machine on increasing of total volatile organic compounds (TVOCs) in the ambient air of the digital printing office was analysed in this study. For that purpose, the TVOCs concentrations in gas samples were measured by mobile gas chromatograph Voyager-Photovac. The cumulative concentrations values of TVOCs for the single-color digital machine were in the range from 0.56 to 5.90 ppm and almost 4 and 25 times below compared to the same values for the four-color digital machine (14.01 - 24.84 ppm). The obtained results could be useful for the future risk assessment of indoor exposure of TVOCs, and for the creation of printing indoor air quality guidelines of the Republic of Serbia.

**Key words:** Digital printing process, total volatile organic compounds, indoor air quality

### Introduction

Indoor air quality contaminants consist of the following compounds: CO, CO<sub>2</sub>, NO<sub>2</sub>, H<sub>2</sub>S, SO<sub>2</sub>, NH<sub>3</sub>, formaldehyde, volatile organic compounds (VOCs), ozone, radon, and microorganisms, which are considered harmful [1].

VOCs are a class of organic compounds which have the following characteristics: boiling temperatures less than 50-260°C at standard atmospheric pressure and melting points below room temperature [2]. VOCs are the most common chemical harmful pollutants in the indoor air that we breathe and exposure to them can induce health problems such as asthma, nervous system impairment and cancers [3]. These pollutants can be classified into the following groups: aliphatic, aromatic, halogenated, and oxygenated, including, for instance, benzene, trichloroethylene, toluene, alcohols, acrolein, and polycyclic aromatic hydrocarbons [1].

The sources of VOCs in indoor environments can be divided into external (vehicular traffic and industry which emitted gas streams) and indoor [4]. Indoor sources of VOCs include building materials (floor and insulation), decorative materials (paints, furnishings, and carpet), cleaning compounds, cosmetics products, combustion products, tobacco smoke, insecticides, and copying and printing machines [1,4]. Also, gas streams contaminated VOCs produce variety industrial and commercial processes, such as printing, metal decorating, oil supplying, dry cleaning, metal degreasing, manufacturing of organic compounds and polymers, food processing, etc. [5].

The use of digital printing equipments (laser printers and photocopiers) has grown exponentially over the last decade as one of the major technologies for printing a document [6,7], a wide range of market application (decoration of porcelain, glass, ceramic tile products, etc.) [8] and the textile industry products [9]. The digital printing CMYK (i.e., cyan, magenta, yellow and black) inks, which are called toners, are a composite of polymer, colourant, and other additives that are essential for printing process [7].

As the sum of all individual VOCs in the target gas stream, the TVOCs often were used for evaluating the air indoor quality. It is important to note that currently there are no TVOCs emission standards that prescribe indoor TVOCs concentration levels [10].

The objective of this study was to evaluate the impact of the type of digital machine on increasing of TVOCs concentrations in the ambient air of the digital printing office. The quantification of the concentration levels of TVOCs in the ambient air of the digital printing office was conducted over ten working days.

## Experimental

### *Digital printing office*

Digital printing processes (electrophotographic procedure) were performed on single-color Xerox D95A and the four-color Xerox DocuColor 252 printing machines during ten days of monitoring of TVOCs concentrations. The offset paper ( $G = 80 \text{ g/m}^2$ ) and cyan, magenta, yellow and black (CMYK) digital toners (manufactured by Xerox), were used as the graphic material. There are two employees in the digital printing office, but as the printing office is used for student education, from two to five students were present in practice during the monitoring of TVOCs concentrations.

### *Measurement of TVOCs concentrations*

The TVOCs concentrations have been analysed in gas samples by Perkin Elmer Photovac Voyager-mobil GC chromatograph. The Voyager-mobil GC uses the principles of gas chromatography (GC) to separate and identify volatile organic compounds.

Mobile gas chromatograph Voyager-Photovac is a device with in-situ and online, on a short time interval, qualitatively and quantitatively and very precisely (with a detection limit of 1 ppb) determines the composition of the components of the gaseous samples. The standard for each component is stored in the Voyager database as retention time, peak area and concentration. In each analysis of an unknown gaseous sample, the retention time of the peak was compared with the retention times from the "base". The Site Chart software package is used to quickly and accurately processing the obtained results [11].

The operational parameters of ambient air during analysis of TVOCs concentrations by mobile gas chromatograph Voyager-Photovac are temperature (25 - 34°C), pressure (1005 - 1010 mbar) and relative humidity (21.5 - 33.7%). Parameters of ambient air were measured by the RH520A, manufactured by Extech Instruments, USA.

The time required for sampling, analysis and data processing by the gas chromatograph Voyager-Photovac is 40 minutes. For this reason, the monitoring of TVOCs concentrations was carried out every hour. Daily eight-time values of TVOCs concentrations are calculated by a cumulative compilation of one-hour data updated every hour. Also, concentration levels of TVOCs were measured one-hour before the start of the operations of digital machines during sampling.

## Results and discussion

Detected concentrations of TVOCs before operation of digital machines (zero values) during monitoring were in the range from 0.04 to 0.10 ppm for single-color and from 0.07 to 0.12 ppm for four-color digital machine. The detected concentrations of TVOCs during the eight-hour operation for the tested machines were reduced by the zero value to obtain real TVOCs concentrations.

The statistical overview of minimum and maximum concentrations, their cumulative and mean values of TVOCs during ten days of monitoring for single-color and four-color digital machines are shown in Table 1.

Table 1. A statistical overview of TVOCs data for single-color and four-color digital machines for ten days of monitoring

Data	Single-color digital machine	Four-color digital machine
Total number of measurements	80	80
MIN $C_{TVOCs}$ (ppm)	0.10	1.11
MAX $C_{TVOCs}$ (ppm)	1.06	4.66
MIN cumulative value of $C_{TVOCs}$ (ppm)	0.56	14.01
MAX cumulative value of $C_{TVOCs}$ (ppm)	5.90	24.84
MIN mean value of $C_{TVOCs}$ (ppm)	0.07	1.75
MAX mean value of $C_{TVOCs}$ (ppm)	0.74	3.11

The lowest concentration of TVOCs (0.10 ppm) in addition to a single-color printing machine was measured during the eighth hour of the sixth day of monitoring. The highest individual concentration of TVOCs (1.06 ppm) was measured during the fourth hour of the first day of monitoring. In the case of the four-color digital machine results for ten working days shows that the highest concentration of TVOCs of 4.66 ppm was measured during the fifth hour of the fourth day, while the lowest concentration level of TVOCs (1.11 ppm) was measured at eight hours on the tenth day.

Analyzing the influence of the type of digital machine on increasing the concentrations of TVOCs in the ambient air of the digital printing office, it has been found that the significant contribution has four-color (Figure 1a) than the single-color digital machine (Figure 1b). The cumulative and mean values of TVOCs concentrations for the single-color digital machine were in the range: from 0.56 to 5.90 ppm and from 0.07 to 0.74 ppm, respectively (Table 1). For a four-color digital machine cumulative and mean values are almost 4.2 to 25 times higher compared to the same value for the single-color machine.

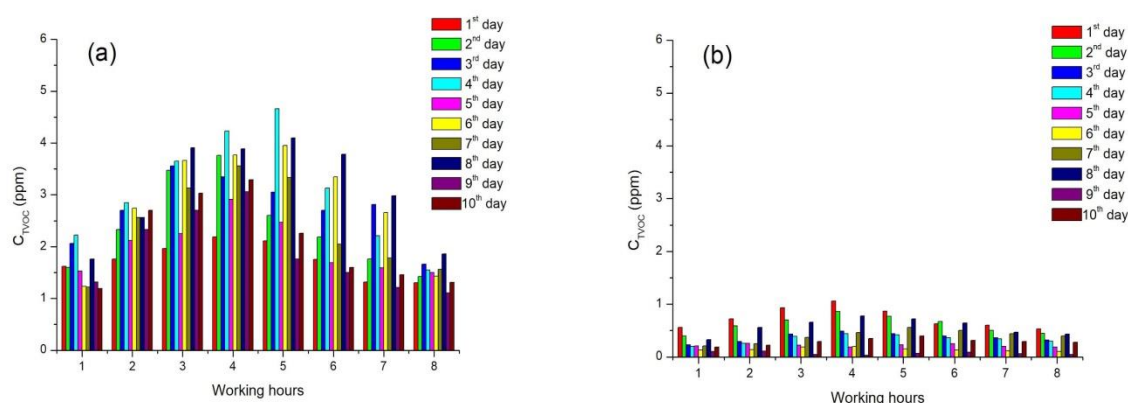


Figure 1. Concentrations of TVOCs for eight-hour operation during ten days of monitoring in addition to a) four-color Xerox DocuColor 252 and b) single-color Xerox D95A printing machines

According to the manufacturer, Xerox toners broadcast minimal quantities of VOCs concentrations because they consist mainly of pigments, polymers (styrene-acrylic, styrene-butadiene or polyester polymers) and small amounts of functional additives [12]. However, the conducted ten-day monitoring showed that the digital printing process broadcasts the cumulative value of TVOCs concentrations for eight-hour working hours at intervals from almost 0.5 to 6 ppm and 14 to 25 ppm for a single-color and four-color digital machine, respectively.

The Occupational Safety and Health Administration (OSHA) prescribes Permissible Exposure Limits (PEL) and the Short-Term Exposure Limit (STEL) for individual VOC, but not for TVOCs [13]. Also, Regulation on the conditions for monitoring and air quality requirements of the Republic of Serbia [14] does not prescribe emission limit values for TVOCs. Therefore, it is necessary to carry out long-term monitoring in digital as well as in other printing techniques and include increasing number of production printing facilities (which vary in size, type of machine they use, variety of printing materials, etc.) in order to obtain relevant data to complement legal regulations of the Republic of Serbia.

### **Conclusion**

The conducted ten-day monitoring showed that the digital printing process contributes to the quality of ambient air through the emission of TVOCs. The results of the TVOCs concentrations control indicate that the highest concentration levels of 1.06 ppm and 4.66 ppm were detected during a one-hour of measurement for a single-color and four-color digital machine, respectively.

Analyzing the increase in the concentration of TVOCs in the ambient air of the digital printing office, it has been found that a more significant contribution has a four-color than a single-color machine. The cumulative and mean values for the four-color digital machine are in the range from 14.01 to 24.84 ppm and from 1.75 to 3.11 ppm, respectively. For the single-color digital machine, the cumulative (0.56 - 5.90 ppm) and mean (0.07 - 0.74 ppm) values are lower almost 4.2 to 25 times compared to the same value for the single-color machine.

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