Non-Methane Hydrocarbons Emission during the Photocopying Process

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Abstract—Prosperity of electronic equipment in photocopying environment not only has improved work efficiency, but also has changed indoor air quality. Considering the number of photocopying employed, indoor air quality might be worse than in general office environments. Determining the contribution from any type of equipment to indoor air pollution is a complex matter. Non-methane hydrocarbons are known to have an important role on air quality due to their high reactivity. The presence of hazardous pollutants in indoor air has been detected in one photocopying shop in Novi Sad, Serbia. Air samples were collected and analyzed for five days, during 8-hr working time in three time intervals, whereas three different sampling points were determined. Using multiple linear regression model and software package STATISTICA 10 the concentrations of occupational hazards and microclimates parameters were mutually correlated. Based on the obtained multiple coefficients of determination (0.3751, 0.2389 and 0.1975), a weak positive correlation between the observed variables was determined. Small values of parameter F indicated that there was no statistically significant difference between the concentration levels of non-methane hydrocarbons and microclimates parameters. The results showed that variable could be presented by the general regression model: $y = b_0 + b_1xi_1 + b_2xi_2$. Obtained regression equations allow to measure the quantitative agreement between the variables and thus obtain more accurate knowledge of their mutual relations.

Keywords—Indoor air quality, multiple regression analysis, non-methane hydrocarbons, photocopying process.

I. INTRODUCTION

PEOPLE spend most of their time in indoor environment either in residences, offices or public building where the indoor air pollutants are commonly much higher than outdoors, due to poor ventilation system. Electronic equipments such as photocopier machines, printers, fax machines and laser printers are more common in an office environment. They can contribute to the emissions of primary pollutants such as ozone, volatile organic compounds (VOCs) and particulate matters in the indoor environment [1]. Nowadays, there is a growing concern about the levels of potentially harmful pollutants that may be emitted during

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photocopying process, from equipment that uses supplies such as toner, ink and paper [2].

Laboratory and field studies have showed that up to 60 different VOCs may be emitted during photocopying operation. Volatile organic compounds include a wide range of chemicals such as aliphatic and aromatic hydrocarbons, non-methane hydrocarbons (NMHCs), alcohols, aldehydes, ketones and halogenated compounds, sharing the same characteristics of high volatility in the ambient environment and result in alteration of the atmosphere chemistry [3]. The reaction of VOCs with various oxidants (hydroxyl radical, nitrate radical, halogens) produce organic and hydroperoxy radicals which react with nitrogen oxides (NO_x) and generate secondary species, such as troposphere ozone, organic nitrates, and peroxides, and regulates the oxidation capacity of the atmosphere [4].

The previous studies have been focused mainly on the emissions of carbon-dioxide, carbon-monoxide, nitrogen-dioxide, ozone and ammonia [5]–[7]. In general, published data on non-methane hydrocarbons emissions from photocopying process are limited and the impact of photocopiers on indoor air quality has rarely been studied in this field.

Non-methane hydrocarbons (NMHCs) are known to have an important role on air quality due to their high reactivity. Short chain alkanes ($C_2 - C_5$) are predominantly emitted because of extensive usage of toner during photocopying process. As a class of volatile organic compounds, they are key ozone precursors and play a very important role in troposphere chemistry. Photochemical reactions of non-methane hydrocarbons with hydroxyl radicals and NO_x result in the formation of ozone and other atmospheric oxidants such as peroxyacetylnitrate (PAN). These products can affect the global distribution of hydroxyl radical, and consequently influence the lifetime of other trace species in the troposphere. Therefore, the abundance and speciation of VOCs emitted from photocopying process significantly affect the atmospheric chemistry [8].

Exposure to low levels of NMHC from photocopiers is potentially associated with a wide range of adverse health effects. Sneezing, coughing and minor eye and skin irritation are some symptoms after the start of exposure to a polluted indoor environment. Respiratory and cardiovascular problems, even potential carcinogenicity have been reported after long-term exposure to certain indoor air contaminants. Therefore, it is necessary to identify and characterize the atmospheric distributions and sources of these pollutants in order to

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develop and validate emission inventories and to reduce the concentration levels. Regarding to this, printing industry has been making efforts to reduce emissions of reactive non-methane hydrocarbons in the atmosphere, in order to improve the indoor environment [9].

The aim of this study was to investigate the air quality in one photocopying shop, through the determination of non-methane hydrocarbons concentration during photocopying process. In addition, multiple regression analysis is applied to investigate influence of microclimates parameter on non-methane hydrocarbons concentration.

II. MATERIALS AND METHODS

A. Site Description

In order to determine the concentration levels of non-methane hydrocarbons, one photocopying shop from Novi Sad, Serbia, was selected. This facility has small area (20 m²), 2 employees and relatively high production volume (500-700 copies per hour).

Three sampling points A, B and C were selected based on the pollutants sources:

A. between desktop computer (1a) and photocopier Aficio DS m651 (2);

B. between laptop computer (1b), photocopier Aficio DS m651 (2), photocopier Aficio MP 6500 (3) and plotter Canon iPF 765 (4);

C. near photocopier Aficio MP 6500 (3) and door. The technological scheme of a photocopying procedure *is* represented in Fig. 1.
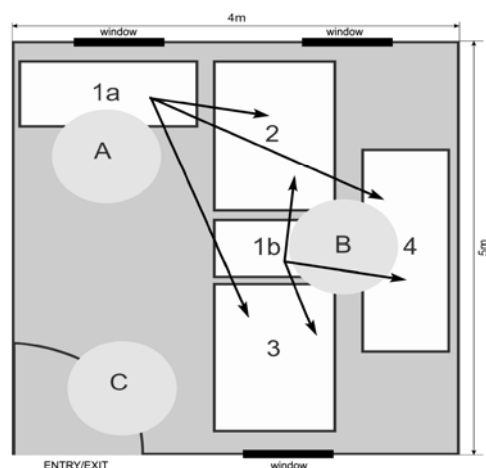

Fig. 1 Technological scheme of the photocopying procedure [6]

B. Sampling Method

Air samples were collected and analyzed by using an instrument Aeroqual Series 200 (Aeroqual Limited, New Zealand). Three different time intervals (beginning of the working time -from 8 to 10 a.m., maximum productivity time - from 13 to 15 p.m. and the end of the working time - from 16 to 18 p.m.) were selected for the daily measurement. Each time interval included five measurements in the range of two minutes.

C. Ambient Conditions

Temperature (t), light intensity (LI) and relative humidity (RH) measurements were carried out simultaneously by using a Mannix DLAF-8000 instrument. The magnitude values of microclimate parameters are presented in Table I.

TABLE I
VALUES OF MICROCLIMATE PARAMETERS IN PHOTOCOPYING ENVIRONMENT

Day	Microclimates parameters		
	T [°C]	RH[a] [%]	LI[b] [lx]
1	23.1 - 24.8	45.2 - 57.6	124 - 161
2	23.3 - 24.2	48.7 - 53.4	169 - 180
3	20.9 - 22.7	48.4 - 57.3	148 - 216
4	22.8 - 24.2	45.1 - 48.4	130 - 163
5	21.6 - 24.4	38.5 - 46.1	173 - 198

[a]RH - relative humidity
[b]LI - light intensity

D. Multiple Regression Analysis

Many phenomena occur not under the influence of one factor, but the simultaneous influence of two or more factors. Measurement of multiple correlations, as in the case of two features (one dependent and one independent variable), requires considering the linear relationship between them.

Multiple linear regression analysis allows the measurement of quantitative matching variables and their variations. Therefore a clearer and more accurate knowledge of their relations can be observed.

The relationship between the dependent variable and the independent variables is represented by [10]:

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + ... + \beta_p x_{pi} + e_i \qquad (1)$$

where: β_0 is the constant term; β_1 to β_p are the coefficients relating the p independent variables to the variables of interest; and e_i is stochastic gradient.

In this study, multiple linear regression analysis was used to evaluate the influence of microclimates parameters as independent variables on non-methane hydrocarbons as dependent variable.

III. RESULTS AND DISCUSSION

The data analysis confirmed the presence of non-methane hydrocarbons in the photocopying environment, due to extensive usage of toner and cleaning solvent during photocopying process. Average daily concentrations of pollutant are represented in Table II.

Multiple linear regression analysis examined the form of interdependency concentrations of non-methane hydrocarbons and microclimates parameters. Data analysis was performed using software STATISTICA version 10 and the results are presented in Table III.

Based on the obtained multiple coefficient of determination (0.3751, 0.2389 and 0.1975) a weak positive correlation between observed phenomena was determined. Obtained values of parameter F (0.9826, 0.3635 and 0.9027) which are smaller than the theoretical value (3.89), indicate that the

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interaction between investigated variables was not statistically significant.

Figs. 2–4 show the surface obtained from regression models.

TABLE II
AVERAGE NON-METHANE HYDROCARBONS CONCENTRATIONS IN THE PHOTOCOPYING ENVIRONMENT

| Measurement day | Time interval | Average non-methane hydrocarbons concentration (ppm) | | |
| | | Sampling point | | |
		A	B	C
1	1	2.90	1.22	1.68
	2	0.40	0.30	0.30
	3	0.32	0.32	0.22
2	1	0.42	0.82	0.28
	2	0.32	0.22	0.24
	3	0.30	0.34	0.30
3	1	0.28	0.26	0.18
	2	0.20	0.10	0.14
	3	0.16	0.36	0.18
4	1	0.22	0.24	0.16
	2	0.10	0.10	0.14
	3	1.48	1.30	0.64
5	1	0.64	0.46	0.26
	2	0.30	0.30	0.44
	3	0.12	0.24	0.60

TABLE III
THE RESULTS OF MULTIPLE REGRESSION ANALYSIS

Mutual Influence	Multiple Coefficient of Determination	F	Regression Model
RH and T on NMHC	0.3751	0.9826	$\hat{y} = -2.0037 - 0.0109x_1 + 0.1289x_2$
RH and LI on NMHC	0.2389	0.3635	$\hat{y} = 1.7141 - 0.0212x_1 - 0.0013x_2$
T and LI on NMHC	0.1975	0.9027	$\hat{y} = -3.2765 + 0.1519x_1 - 0.0012x_2$

Fig. 2 The dependence of T, RH and NMHC concentrations

The resulting surface shows an average stacking variation between investigated variables, which can be present by the general regression model: $y = b_0 + b_1xi_1 + b_2xi_2$, where independent variables x_1 and x_2 present the microclimates parameters (x-axis and y-axis), whereas dependent variable y presents the non-methane hydrocarbons concentration (z-axis).
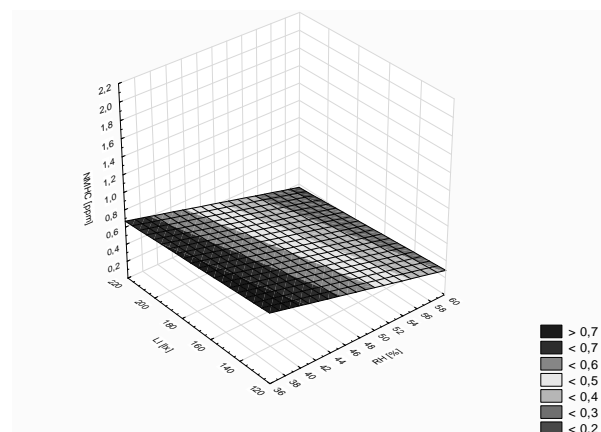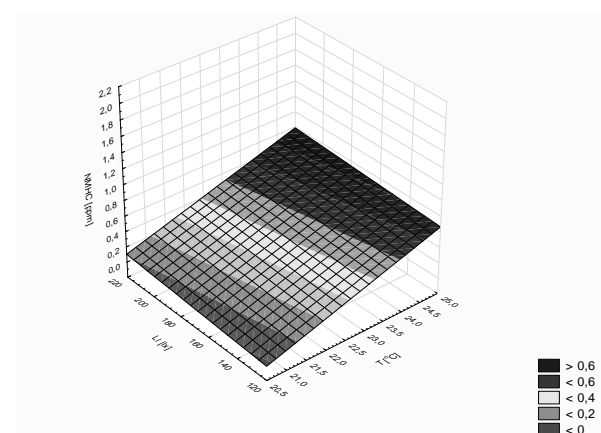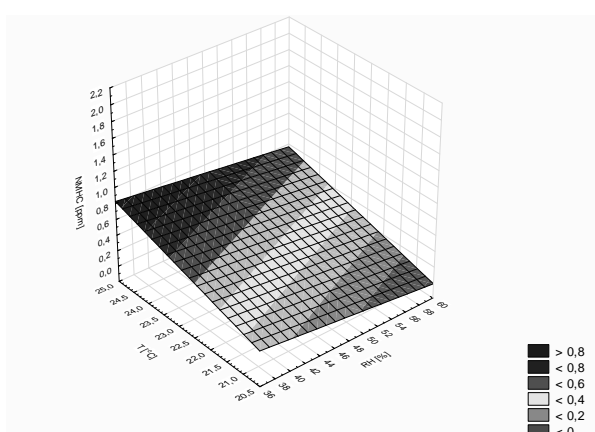

Fig. 3 The dependence of RH, LI and NMHC concentrations

Fig. 4 The dependence of T, LI and NMHC concentrations

Individual regression models are presented by (2)-(4):

$$\hat{y} = -2,0037 - 0,0109x_1 + 0,1289x_2 \qquad (2)$$

$$\hat{y} = 1,7141 - 0,0212x_1 - 0,0013x_2 \qquad (3)$$

$$\hat{y} = -3,2765 + 0,1519x_1 - 0,0012x_2 \qquad (4)$$

IV. CONCLUSIONS

The concentration levels of non-methane hydrocarbons were determined in one photocopying shop in Novi Sad, Serbia. The major factor affecting the presence of organic hazard was the extensive usage of toner during photocopying process which contributed to the volatility of non-methane hydrocarbons in printing environment. A multiple linear regression analysis was performed to predict and determine the mutual correlation between dependent variable (non-methane hydrocarbons concentration) and independent variables (microclimates parameters). The obtained multiple coefficient of determination pointed out a weak positive correlation between the investigated variables. Graphical

representations of the spatial dependence between non-methane hydrocarbons concentration and microclimate parameters were constructed in order to better represent the mutual influence of the pollutants.

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