Ammonia Release during Photocopying Operations

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***Abstract*—**The paper represents the dependence of ammonia concentration on microclimate parameters and photocopying shop circulation. The concentration of ammonia was determined during 8-hours working time over five days including three sampling points of a photocopying shop in Novi Sad, Serbia. The obtained results pointed out that the room temperature possesses the highest impact on ammonia release. The obtained ammonia concentration was in the range of 1.53 to 0.42ppm and decreased with the temperature decreasing from 24.6 to 20.7°C. As the detected concentrations were within the permissible levels of The Occupational Safety and Health Administration, The National Institute for Occupational Safety and The Health and Official Gazette of Republic of Serbia, in the range of 35 to 200ppm, there was no danger to the employee's health in the photocopying shop.

***Keywords*—**Ammonia, emission, indoor environment, photocopying procedure.

I. Introduction

THERE is a growing concern about the level of potentially harmful pollutants that may be emitted from office equipments (personal computers, photocopiers, laser printer, ink-jet printers, and scanners) and for which either toxicological effects or potentially significant exposures must be known. The office equipments have been found to be a source of ozone, particulate matters, non-volatile organic compounds (non-VOCs), volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). All pollutants emitted during photocopying may affect the indoor air quality and potentially have adverse health effects on the employees as well as on all other users [1], [2].

During photocopying, the image is formed by a dry toner that adheres to the photoconductive drum, which is then transferred to paper [3]. About 25% of the toner particles do not adhere to the photoconductive drum, and therefore become available for emission to the indoor air [1].

Dry toner is a mixture of fine powders consisting of carbon black, polymer resin (polyester) with quaternary ammonium salts and additives. Quaternary ammonium salts incorporated into the toner powders are used as charge control agents. The toner powder fuses temperature depressants and paper adhesion promoters. Ammonia salts are preferably dispersed in a polymeric binder matrix comprising a portion of the toner particle. They are compatible with the polyester resins [4].

Depending on the characteristics of the toner and fuser materials, the toners consistently emit benzene, toluene, styrene, ethylbenzene, xylenes, acetophenone, alkanes, aldehydes as VOCs; phenols, cresols, phthalates, phosphorous esters, siloxanes as SVOCs; ammonia, carbon dioxide as non-VOCs, which all contribute to the formation of aerosols as presented in Fig. 1 [1], [5].

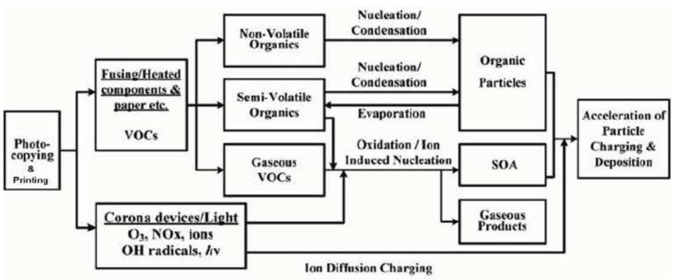

Fig. 1 Conceptual model of the chemical elements in the air indoors based on particle formation and removal during the photocopying and printing procedures [1]

The previous studies have been focused mainly on the emissions of benzene, toluene, styrene, ethylbenzene, xylenes, formaldehyde, TVOC, ozone, carbon dioxide, nitrogen dioxide and particulate matter (PM_{10} and $PM_{2.5}$) from laser and ink-jet printers, dry-process photocopiers, personal computers and other office equipment [6]-[10]. Nowadays, the discussions are focused on the ultra-fine and fine particles release from hardcopy devices, printers and photocopiers and their impact on the health of the workers [2], [11]. Due to the lack of data about ammonia emissions from photocopiers, the objective of the research presented in the paper was to determine the emission rates of the ammonia during the photocopying procedure, as well as to investigate the possible correlations of the ammonia concentrations with the microclimate parameters and the copying circulation (number of copies).

II. Materials and Methods

A. Site Description

In order to determine the concentration levels of ammonia, a photocopying shop from Novi Sad was selected as a measuring location. The technological scheme of the photocopying shop with the marked sampling points (A, B and C), devices (1a - desktop computer, 1b - laptop, 2 - Aficio DS m651, 3 - Aficio MP 6500 and 4 - Canon iPF 765), shop dimensions (4m x 5m x 3.5m) as well as the process of

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photocopying is presented in Fig. 2. There were three sampling points A, B and C, which were selected based on the ammonia sources; position of the copiers and the characteristics of the shop where the photocopying devices were located.

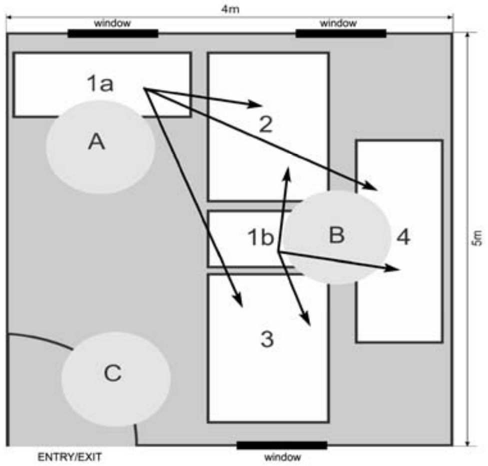

Fig. 2 Technological scheme of the photocopying procedure

B. Toner

The black toner 57P1887 (Ricoh Company, Ltd., Japan) was used during the photocopying procedure. The toner contains polyester resin (80 mass.%), pigment black 12 (5-10 mass.%), solvent black (1-5 mass.%), carnauba wax (1-5 mass.%), silica (0.1-1 mass.%) and quaternary ammonia salts (<1 mass.%).

C. Sampling Method

The ammonia concentrations were measured for 5 days during an 8-hour working time by using an instrument Aeroqual Series 200 (Aeroqual Limited, New Zealand). Three different time intervals were selected for the daily measurement: 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.). Each time interval included five measurements in the range of two minutes.

D. Process Conditions

During the entire experiment the procedure conditions were the following: two photocopier machines worked continuously, the plotter did not work, there was no procedure of cleaning machines, the door was open permanently and the ventilation system was turned on. The copying circulation had a great affect on ammonia emission in the photocopying environment. The number of copies was recorded from both copying machines in the determined period of time. Table I represents the average number of copies during five days of measuring in the photocopying shop.

TABLE I
COPYING CIRCULATION

Measurement day	Number of copies		
	Time interval		
	1st	2nd	3rd
1	3055	1265	1806
2	2586	3015	1770
3	1240	1684	3428
4	580	3747	5717
5	614	2370	3754

E. Ambient Conditions

The microclimate parameters were measured by using a Mannix DLAF-8000n instrument. The values of temperature, relative humidity and light intensity are presented in Table II.

TABLE II
MICROCLIMATE PARAMETERS OF PHOTOCOPYING ENVIRONMENT

Measurement day	Time interval	Microclimate parameters		
		t [°C]	RH[a] [%]	LI[b] [lx]
	1	24.6	42.8	211
1	2	25.7	29.9	265
	3	25.2	33.7	218
	1	21.5	34.1	267
2	2	23.2	37.1	239
	3	24.7	41.5	196
	1	21.0	36.9	252
3	2	22.6	37.8	186
	3	23.8	35.4	233
	1	22.5	31.6	182
4	2	21.3	34.7	249
	3	24.1	36.2	193
	1	20.7	35.6	228
5	2	22.3	38.4	208
	3	23.3	45.2	263

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

III. RESULTS AND DISCUSSION

The data analysis confirmed the presence of the ammonia in the photocopying environment due to the usage of a dry toner. The average ammonia concentrations in the photocopying indoor air are presented in Table III.

The highest ammonia concentrations were detected mainly in the first time interval, forming the following order considering the analyzed points: C<B<A. In contrast, the lowest concentrations were obtained in the third time interval due to the continuous air circulation so that the ammonia, as a rarefied gas, was repressed from the photocopying shop.

The results of the first time interval at the sampling points A, B and C, are presented in Fig. 3 showing the dependence of the ammonia concentration in time of measurements. Evidently, the ammonia concentrations significantly varied during the measurement periods in the sampling points A, B and C.

TABLE III
AVERAGE AMMONIA CONCENTRATIONS IN THE PHOTOCOPYING ENVIRONMENT

Measurement day	Time interval	Average ammonia concentration (ppm)			Permissible value (ppm)			
		Sampling point						
		A	B	C	PEL[c]	REL[d]	MEL[e]	STEL[f]
	1	1.53	0.89	1.35				
1	2	0.74	0.50	0.62				
	3	0.96	0.38	0.62				
	1	1.07	0.99	0.84				
2	2	0.76	0.66	0.75				
	3	0.65	0.69	0.52				
	1	0.99	1.15	0.74				
3	2	0.58	0.54	0.66	50	35	100	200
	3	0.84	0.70	0.56				
	1	0.64	0.58	0.57				
4	2	0.83	0.88	0.54				
	3	0.73	0.55	0.57				
	1	0.88	0.53	0.71				
5	2	0.84	0.76	0.63				
	3	0.79	0.60	0.42				

[c]PEL - Permissible Exposure Limit prescribed by the Occupational Safety and Health Administration [12]
[d]REL - Recommended Exposure Limit prescribed by the National Institute for Occupational Safety and Health [13]
[e]MEL - Maximum Exposure Limit prescribed by Official Gazette of Republic of Serbia [14]
[f]STEL - Short-Term Exposure Limit prescribed by Official Gazette of Republic of Serbia [14]

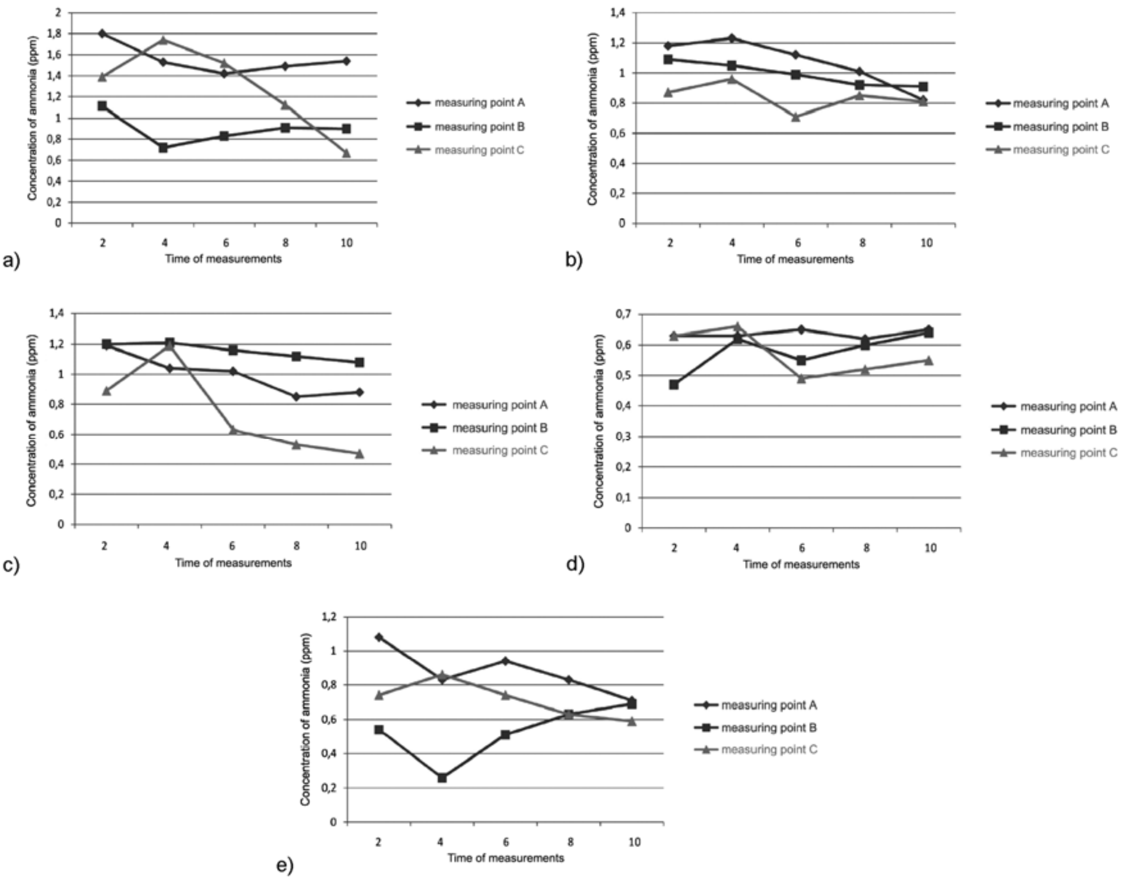

Fig. 3 Ammonia concentrations as the function of the measurement time (first time interval, sampling points A, B and C)

The copying circulation varied between 580 and 5717 copies during the measurements. By comparing the average ammonia concentration in the first time interval at all three sampling points, it was indicated that the ammonia concentrations decreased at the sampling points A and C with the decreasing of the number of copies. On the other hand, the increasing of ammonia concentrations was affected by the increased number of copies made during the period of five days (Fig. 4). The distance of the sampling point B from the two photocopier machines could be the reason of the absence of mutual correlation between the ammonia concentrations and the number of copies.

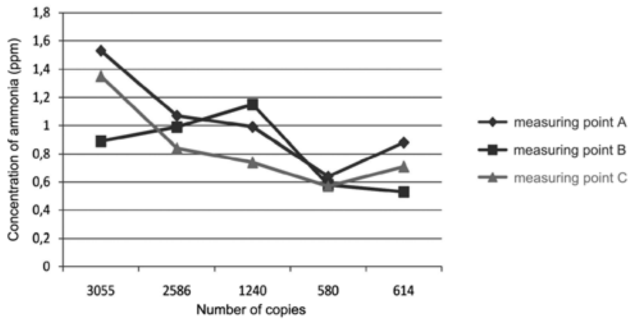

Fig. 4 Influence of copying volume on the ammonia concentrations

The dependence of ammonia concentrations on temperature, relative humidity and light intensity values (first time interval, sampling points A, B and C) are presented in Figs. 5-7. The values of temperature, relative humidity and light intensity varied from 20.7 to 25.7°C; 29.9 to 45.2% and 182 to 267 lx, respectively, Table II.

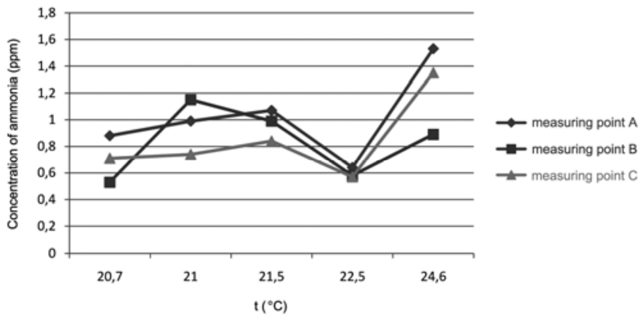

Fig. 5 Ammonia concentrations as the function of temperature values during the photocopying process

The highest ammonia concentrations at sampling points A and C were in compliance with the highest temperature value (24.6°C) and relative humidity (42.8%), Figs. 5 and 6. The highest ammonia concentrations were measured at the light intensity of 211 lx (Fig. 7) and further increasing of the light intensity affected the relatively constant ammonia concentrations (about 1ppm). The lowest concentrations of ammonia were detected at the lowest relative humidity (31.6%) and the light intensity (182 lx), Figs. 6 and 7.

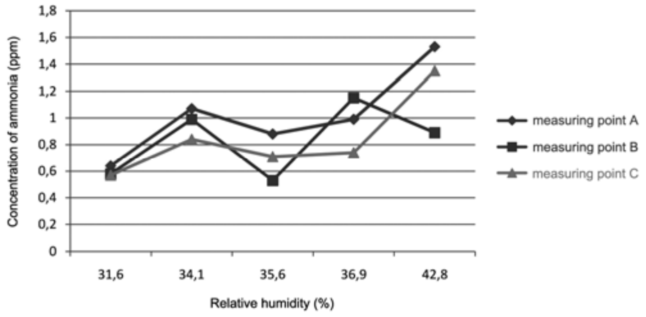

Fig. 6 Ammonia concentrations as the function of the relative humidity values during the photocopying process

At the sampling point B, the lowest ammonia concentration was detected at the lowest temperature value (20.7°C), Fig. 5. Evidently, the relative humidity and light intensity (Figs. 6 and 7) have the same influence on the variation of ammonia concentrations in the photocopying environment.

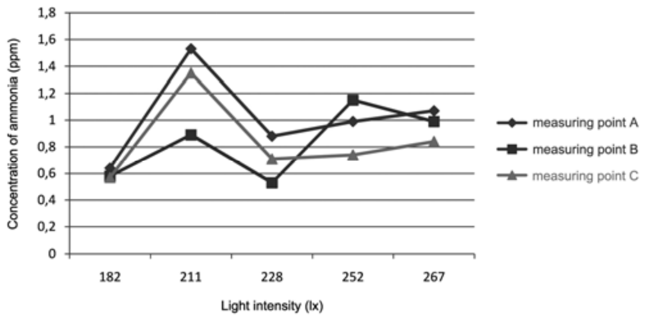

Fig. 7 Ammonia concentrations as the function of the light intensity values during the photocopying process

The comparison of the average ammonia concentrations with the prescribed PEL, REL, MEL and STEL values, Table III, indicates that the highest ammonia concentration of 1.53ppm (the first day of the measurement, first time interval, sampling point A) was about 23 and 131 times less than the values prescribed by the international and national standards [12]-[14]. As the detected ammonia concentrations are much below the permissible values there is no danger for the health of either the employees or for the other users of the facility.

IV. Conclusions

The study investigated the indoor air quality, by means of ammonia release, in one photocopying shop from Novi Sad, Serbia. The results suggested that the dry toners with ammonia salts were the main sources of ammonia release during the photocopying process. The time variation of ammonia concentrations was caused by the temperature changes, relative humidity, light intensity and the copying circulation. The highest ammonia concentrations (up to 1.53ppm) were detected in the first measuring interval in the case of all sampling points. The ammonia concentrations at sampling points A and C were in accordance with temperature and relative humidity, whereas at the sampling point B, the ammonia concentrations varied depending on the values of relative humidity and light intensity (the obtained curves have the same trend).

The results also pointed out that the concentration levels of ammonia in the photocopying shop did not exceed the permissible limits, according to the national and international standards. Therefore, there is no danger to the health of either the employees or the other users of the facility. However, the results of this monitoring are not sufficient to provide a classification of possible health related problems with the pollutants generated by the photocopier. More detailed characterization of the gases and a model for the exposure assessments would be required. The fact that the used devices are not the only sources of inorganic and organic compounds in indoor environment also needs to be considered. The magnitude of emissions, the link from emissions to personal exposure, the toxicological significance of the chemicals emitted, and the costs and impacts of the alternative materials should also be considered in order to evaluate the potential importance of the workers exposures and health risks.

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