Indoor air quality for chemical and ultrafine particle contaminants from printers

Naoki Kagi[a,*], Shuji Fujii[b], Youhei Horiba[b], Norikazu Namiki[c], Yoshio Ohtani[c], Hitoshi Emi[c], Hajime Tamura[d], Yong Shik Kim[e]

[a]*National Institute of Public Health, 3-6, Minami-2, Wako-shi, Saitama 351-0197, Japan*
[b]*Tokyo Institute of Technology, 12-1, Ookayama-1, Meguro-ku, Tokyo 152-8552, Japan*
[c]*Kanazawa University, Kakuma-machi, Kanazawa, Ishikawa 920-1192, Japan*
[d]*Techno Ryowa Ltd., 33-6, Kyodo-5, Setagaya-ku, Tokyo 156-0052, Japan*
[e]*University of Incheon, 177, Dohwa-dong, Nam-gu, Incheon 402-749, Korea*

Received 12 January 2003; received in revised form 27 February 2006; accepted 3 April 2006

Abstract

There are various emission sources of chemical contaminants, such as volatile organic compounds (VOCs) and ozone and particulate matter. This report is a study into the indoor air of a room containing either a laser printer/ink-jet printer, and the air contaminations were monitored for VOCs, ozone and ultrafine particle. The result confirmed an increase in the concentration of ozone and ultrafine particle numbers in the printing processes of the printer. The emission of VOCs and ozone were measured by the use of a test chamber. The chamber concentrations of styrene, xylenes and ozone were increased in printing process of the laser printer, and pentanol was detected from the ink-jet printer. The results suggest that an office or residential printer may be a source of indoor air contamination. It is necessary for emission from printers to monitor not only VOCs and particle but also ultrafine particles and other contaminants in indoor air.

Keywords: Indoor air quality; VOC; Ozone; Ultrafine particle

1. Introduction

There are various emission sources of chemical contaminants, such as volatile organic compounds (VOCs) and ozone, and particulate matter. VOCs cause chemical sensitivity and sick-building syndrome. Ozone is a particularly reactive gas and may affect the indoor air quality indirectly through reaction of high molecular VOCs into formaldehydes, organic acid, ultrafine particles and free radicals. Since offices and most residential properties have printers and photocopiers, contaminants (VOCs, ozone, particles, etc.) emitted from these machines have recently become a serious issue with respect to the indoor environments [1–5]. It is therefore important to be able to evaluate the emission of VOCs and ozone from printers and their impact on the indoor environment. In this study, the indoor air of a room containing either a laser printer/ink-jet printer was monitored for VOCs, ozone and ultrafine particle. The contaminants emitted from each printer were measured by the use of a test chamber.

2. Measurement of indoor environment containing a printer

2.1. Measuring method

Firstly, the indoor air of a room containing either a laser printer/ink-jet printer was monitored for VOCs, ozone and ultrafine particle. Two laser printers and an ink-jet (or bubble-jet printer) in Table 1 were selected as test samples, printer 1 and printer 3 were used for about 1 year, and brand new type printer 2 was prepared for this study. Continuous printing speed of printer 1, 2 and 3 is 12, 17 and 6 pages/min, respectively.

*Corresponding author. Fax: +81 48 458 6253.
E-mail address: nkagi@niph.go.jp (N. Kagi).

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doi:10.1016/j.buildenv.2006.04.008

Table 1
Printer specification/type selected as test samples in this study

Tested printer	Printing form	Date of manufacture
Printer 1	Laser	2001
Printer 2	Laser	2002
Printer 3	Bubblejet	2001

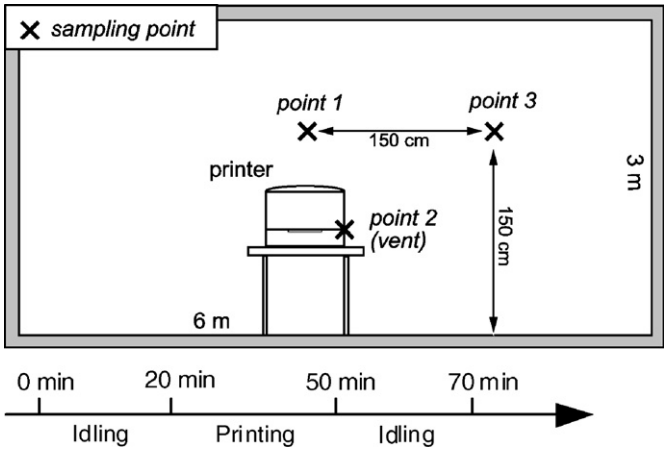

Fig. 1. Outline of measuring plan for indoor air measurement.

Each test printer was placed in the center of the meeting room (volume: 120 m^3, temperature: 25 °C, air exchange rate: 2.1 /h) as shown in Fig. 1. The measuring plan was that after a 20 min idling period, standard black text copies were printed for a period of 30 min after which the printer idled for a further 20 min. The sampling points were above the printer (point 1), the exhaust opening (point 2) and 150 cm away from the printer (point 3).

The air concentrations of ozone, ultrafine particles and VOCs were monitored (Table 2). The concentration of ozone was automatically and continuously monitored by an ozone analyzer (Thermo Electron 49C). Ultrafine particle number concentration for each size were measured using SMPS-CPC (Scanning Mobility Particle Spectrometer-Condensation Particle Counter: TSI model3080 + 3022A), SMPS distributes from 20 to 500 nm diameter particles and CPC counts ultrafine particles distributed. VOCs were collected by glass tubes packed with Tenax GR, and were sampled with the rate of 0.5 L/min for 10 min at a given point in time. The samples were desorbed and cryofocused in a Parkin-Elmer ATD and analyzed with GC/MS (Gas Chromatograph Mass spectrometry: Shimadzu GC-17A + QP5050).

2.2. Results of monitoring

2.2.1. Ozone

Fig. 2 shows the time variation of the indoor ozone concentration for printers 1 and 2. Ozone emission from printer 3 was not detected as the printing method is different from that of the laser printers that operate

Table 2
Measuring methods for ozone, ultrafine particles and VOCs

Measured object	Measuring instrument
O_3	O_3, Analyzer
Ultrafine particles	SMPS, CNC
VOCs	Sample: Tenax Analyze: GC/MS

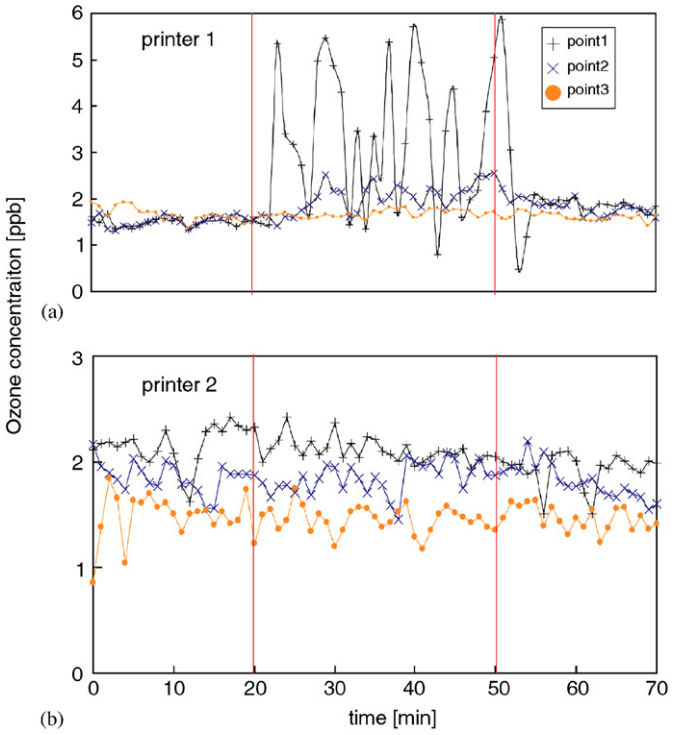

Fig. 2. Time variation of indoor ozone concentration for printer 1 and printer 2.

according to corona discharge technology. Ozone was generated as the by-product of the printing process of laser printers and photocopiers. During operation the ozone concentration rose from 1.5 to 6 ppb at point 1. The reason why the point 1 ozone concentration for printer 1 was up and down would depend on airflow around the printer, diffusion of ozone in the air, the characteristic of ozone monitor used in this study or ozone reaction with other VOCs in the air. The exhaust ozone air was constant as the exhaust air ozone was removed through the chemical filter. At point 3, as the ozone emitted from the printer was diffused and reacted with other compounds, the change in ozone concentration could be not confirmed [6]. Ozone at each measuring point was not detected from the brand new printer, printer 1.

2.2.2. Particle

The effect of ultrafine particles on respiratory symptoms has been discussed in several studies [7]. It is very important that ultrafine particles (particles smaller than

0.5 μm) are monitored in indoor air. Fig. 3 indicates the size distribution of particles at point 1 during printing. The concentrations of smaller particles under 100 nm were at high level, especially in the case of printer 1. The concentration for printer 2 and printer 3 were low level and they had the highest peaks around 50 nm particles. Fig. 4 shows the time variation of the indoor particle concentrations for 50 and 500 nm diameter particles from printer 1 at each measuring point. The smaller particle, 50 nm diameter, concentration increased during printing, especially at point 1. The toner particles are about 10 μm. It needs further consideration, but is indicating that the ultrafine particle detected in this test were not directly generated from toner particles but by the secondary formation of the VOCs and the water mists emitted during the operation of the printers.

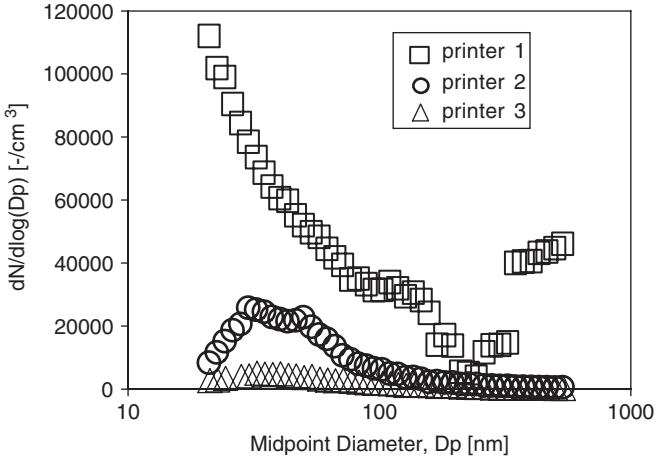

Fig. 3. Size distribution number concentration of particles at point 1 during printing.

2.2.3. *Volatile organic compounds*

The time variation of indoor VOC concentrations is shown in Fig. 5. Printer 1 concentrations on styrene, *m*,*p*-xylene and *o*-xylene slightly increased to 150–200 μg/m^3 in the printing process. In the case of printer 1, styrene was detected, but was not detected in one of printer 3, bubble-jet type. The concentrations of point 1 were larger than on of point 2 just like the ozone measuring, therefore ozone

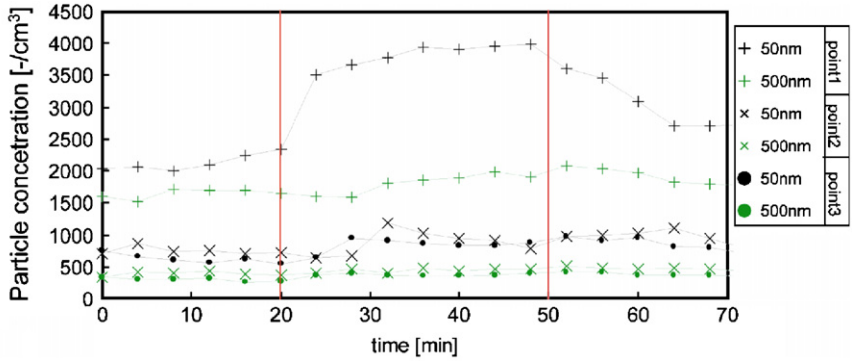

Fig. 4. Time variation of indoor particle concentration of 50 and 500 nm emitted from printer 1 at each point.

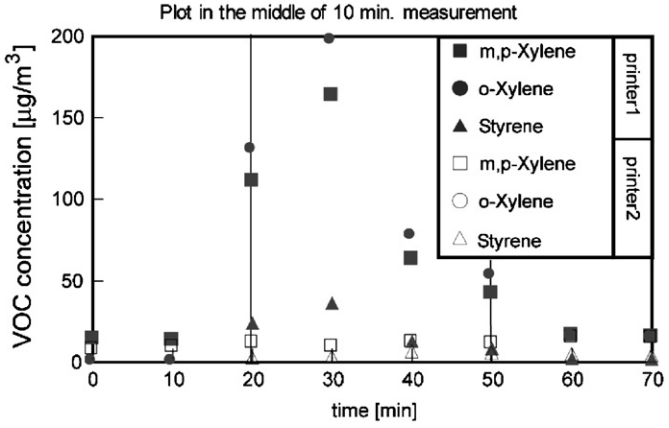

Fig. 5. Time variation of indoor VOC concentrations for printer 1 and printer 2.

and VOCs were transferred at the head of printers, riding an up current of hot air.

3. Chamber test for printers

3.1. Outline of chamber test

A special chamber (Fig. 6, net volume: 562 L) was designed for this study [8,9]. Boards coated with tedlar film were used as the interior surfaces because of its non-adsorbent and chemically inert properties, in order to minimize any sink or reaction effect. The clean air supply of 10 L/min (air exchange rate: 1.1 /h) was drawn from the bottom side of the chamber and the exhaust air from the top of the chamber was used as the sampling point for measuring the VOCs and ozone. The chamber was designed for measuring gaseous matters, particles could not be detected in the chamber, because the chamber was too large, humidity high and airflow for ultrafine particles bad to measure distributing particle number concentration. During monitoring, the standard text was printed and the white paper fed for 10 min after which time the printer idled for 10 min and the printer was idling again for 10 min. The printing period of time was for only 10 min in the chamber instead of 30 min in the room. The reason is that the feeding paper speed of laser printers was so high that other papers were changed during testing. And temperature and humidity in the chamber were too of high level with long printing. The concentrations of VOCs were also measured when the printer was idling and powered off. VOCs were sampled with the rate of 0.5 L/min for 5 min at a given point in time.

3.2. Result of the chamber tests

The time variation of the ozone and VOC concentrations in the chamber are shown in Figs. 7 and 8. The chamber's VOC concentrations, after a 15 min printing, is shown for each condition in Fig. 9. Ozone concentration in the chamber increased when the laser printer was operated, and leveled out at about 30 ppb. The ozone concentration in the chamber for printer 1 was higher value than that for

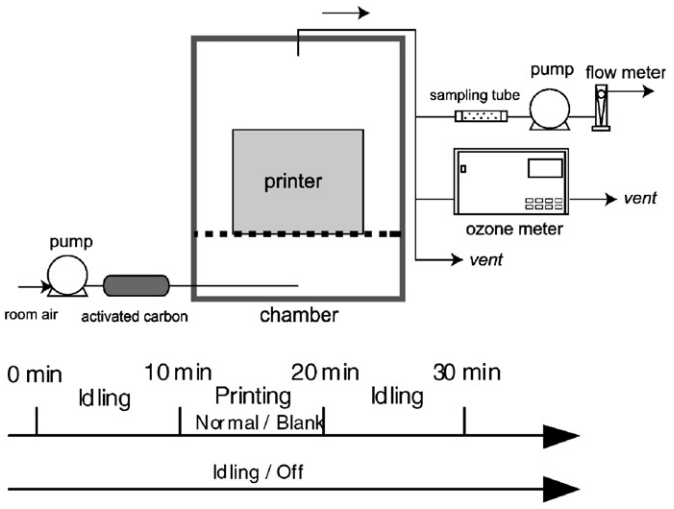

Fig. 6. Experimental apparatus and measuring plan for chamber test.

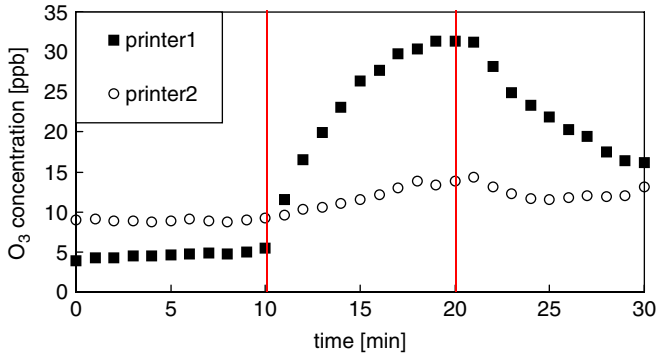

Fig. 7. Time variation of ozone concentration in chamber for printer 1 and printer 2.

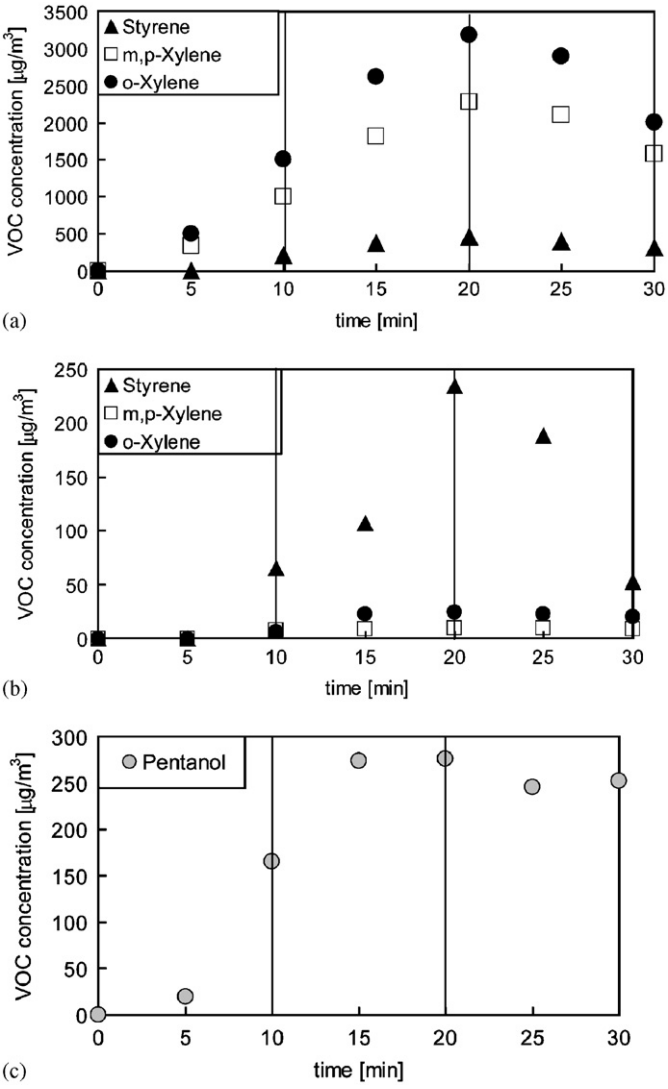

Fig. 8. Time variation of VOC concentrations in the chamber. (a) printer 1, (b) printer 2 and (c) printer 3.

printer 2, just as the measurement of indoor environment test. The concentrations of styrene, *m*,*p*-xylene and *o*-xylene for printer 1 during and after the printing procedure were of very high level, 380, 1800 and 2300 μg/m^3, respectively. While styrene for printer 2 were detected only at printing procedure.

Each VOC concentration during the printing of standard text was higher than that of the white paper feed and idling values. In order to characterize the emission compounds from the toner, the screening test was undertaken [10]. The procedure of this test was that emitted gas from toner (50 mg) in hot sampling vessel heated about 175 °C was sampled onto a solid adsorbent (Tenax GR) as soon as they were emitted (Fig. 10). This sample was analyzed with GC/MS. Fig. 10 shows the chromatogram of emitted gas from toner. As the peak of retention time about 9 min was styrene, the toner contained a great amount of styrene (about 50 μg/g). The source of styrene in this environment is the toner. Other compounds, *m*,*p*-xylene and *o*-xylene, were emitted during operating from the printers materials, because these compounds were generated when printers were not only normally printing but also idling. Printer 3 emitted a small amount of pentanol from ink. The results suggest that an office or a residential printer is a source of indoor air contamination.

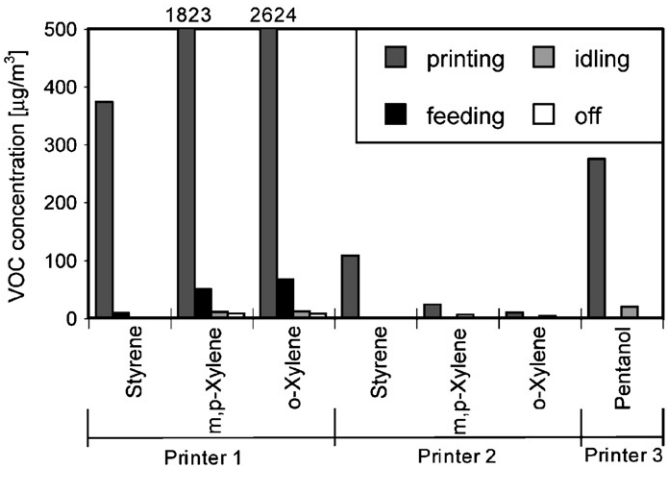

Fig. 9. VOC concentrations in the chamber on each printing condition.

4. Conclusion

In this study, the indoor air of a room containing either a laser printer/ink-jet printer was monitored for VOCs, ozone and ultrafine particles. The results confirmed an increase in the concentration of ozone from 1.5 to 6 ppb and ultrafine particle number in the printing processed of the printers. Especially for the case of around 50 nm particles, particulate concentration increased greatly during printing. The emission of the VOCs and ozone were measured by the use of a test chamber. Styrene and ozone were detected from the laser printer and alcohols were detected from the ink-jet printer. The concentrations on styrene and xylenes slightly increased to 200–3000 μg/m^3 in the printing process for the laser printer. The source of styrene from the laser printer was the toner and that of pentanol from the ink-jet printer was the ink. The result suggests that an office or residential printer may be a source of indoor air contamination. It is important to clarify the emission mechanism of ultrafine particle. While the ozone concentration is not increased in indoor air by generating from laser printers or copiers, the ozone from these equipment may oxidize VOC into other contaminants, such as ultrafine particles, aldehydes, acids and etc. It is necessary for emission from printers to monitor not only VOCs and particle but also aldehydes such as formaldehyde and acetaldehyde and formic acid in indoor air. It needs further consideration of a comparison between the measurements in the room and in the chamber.

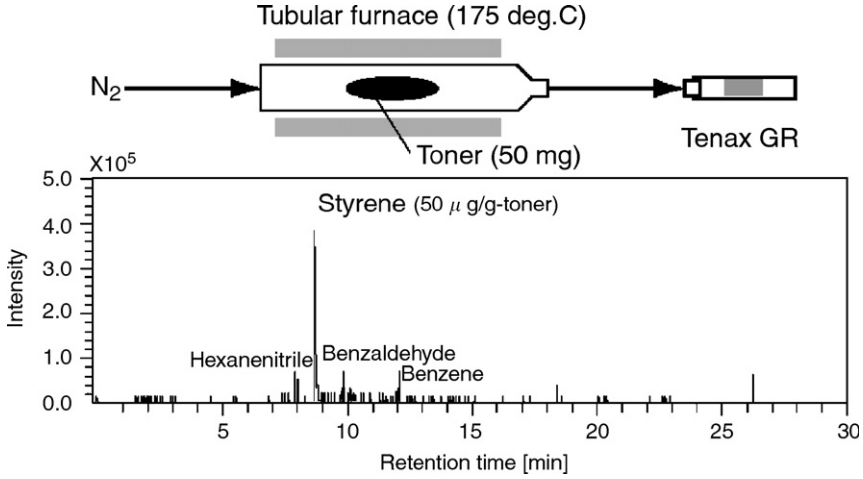

Fig. 10. Experimental apparatus and result of screening test for toner.

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