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Ozone Level Emitted from Photocopiers and Its Exposure

Aungsiri Tipayarom [1 +] and Danutawat Tipayarom [2]

[1] Department of Environmental Science, Faculty of Science, Silpakorn University, Nakhon Pathom, Thailand
[2] NCE for Environmental and Hazardous Waste Management, Thammasat University, Bangkok, Thailand

Abstract. A study of ozone emitted from photocopiers was conducted in a photocopying kiosk located in an academic building, Silpakorn University, Thailand, to measure the levels of ozone and to identify ozone exposure sources of different people. The air samples were continuously collected for 8 hours in a photocopying kiosk, a kiosk-surrounded area and a nearby car park. Paired sample t-test was applied to test the differences of average ozone levels among three sampling sites at 95% ($\alpha = 0.05$) confidence interval. Simultaneously, exposure sources of ozone to photocopying staffs and students around the photocopying kiosk were identified and represented in terms of indoor to outdoor (I/O) ratio. If the ratio was greater than 1, that means the indoor source was prevalent. Ratios of ozone levels in the kiosk/kiosk-surrounded area (for staffs) and the kiosk-surrounded area/nearby car park (for students) were obtained. The results illustrated that the average ozone level in the kiosk was 0.05±0.02ppm, which may caused adverse health effects on staffs for long-term exposure since several values exceeded ACGIH standard for workplace. The results also presented that the levels of ozone at the kiosk-surrounded area and the nearby car park were 0.03±0.01 and 0.02±0.01ppm, respectively. Statistical tests found good correlation between level of ozone in the kiosk and at the kiosk-surrounded area (R^2=0.74) whereas the poor correlation was obtain between the kiosk-surrounded area and the nearby car park (R^2=0.55) reflecting the influence of photocopier emission only on the surrounded area. Paired sample t-test results suggested that average ozone level in the kiosk was significantly different from average ozone level at the kiosk-surrounded area and at the car park while ozone level at the kiosk-surrounded area and car park displayed no significant difference. The ratio between in kiosk/kiosk-surrounded area of 1.67 implied that the staffs mainly expose to ozone from the indoor source, namely, the photocopiers. For student, the ratio between the kiosk-surrounded area/the nearby car park of 1.50 indicated that the main exposure source of ozone was contribution from the photocopying kiosk. For outdoor, ozone was generated by reaction between the hydrocarbon and nitrogen dioxide emitted from vehicle exhausts. However, low level ozone found in the car park attributed to the fact that ozone was diluted by ambient air. Additionally, the levels of ozone precursors were low due to slight traffic on campus.

Keywords: ozone, photocopier, indoor/outdoor ratio, exposure.

1. Introduction

People commonly spend an average of 87% of their time in enclosed buildings [1] and around two-thirds of the day inside their residences [2]. Tightly sealed buildings are an additional concern for the health of those who live and work inside. Skolnick [3] reported that a population living in the tight energy-efficient buildings contracted upper respiratory diseases at rates 46 to 50% higher than a compared group living in better ventilated houses. Modern office equipment, such as faxing machines, ink-jet and laser printers, scanners, and photocopiers, result in human exposure to indoor air pollutant. Headache, eye and nose irritation and dry skin are common syndromes found in office workers. Studies of Wolkoff et al. and Wolkoff about effects of indoor air pollution on human health implied that office equipment not only increased contaminant levels in the offices but also caused an adverse health effects and a nuisance to employees [4,5]. A number of earlier research revealed that the levels of air pollutants in the office became more intense owing to the use of office equipment. Lee et al. reported that ozone level in the office was so high that it could cause harmful consequences to human health [6]. Jerrette et al. analyzed the risk of death for ozone. They found that for every 0.01ppm increase in ozone level, there is a 4 percent increase in risk of

death from respiratory causes, primarily pneumonia and chronic pulmonary obstructive pulmonary disease [7].

Most photocopying machines use the xerographic method that makes copies on plain paper. A charged photoconductive drum receives light reflected from the original, creating a charged latent image that attracts toner particles. These particles are transferred onto paper and fused by heat or pressure. The toner consists of black carbon particles in a resin binder [8]. Ozone is generated from the reaction of charged ions and electrons with atmospheric gases in electrophotographic process of the copier and from the corona wire (coil that serves a positive charge in the surface of the drum of the copier). Ozone trapped in the ink destroys a charge and surface coating of the drum in the toner cartridge [6].

Ozone can initiate a variety of human health problems including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. Ground-level ozone can also reduce lung function and inflame the linings of the lungs. Repeated exposure may permanently scar lung tissue [9]. Children are at the highest risk from ozone exposure as they frequently play outdoors. Ozone exposure can probably exaggerate asthma in children. Asthmatic people or people with respiratory diseases will normally undergo health effects earlier and at lower ozone levels than less-sensitive individuals [10]. Working with photocopier for long-term could develop an autoimmune disease due to ozone exposure. The symptoms are thromboembolic phenomena, joint and kidney involvement [8].

The highest concentration of ozone in the work atmosphere as determined by the American Conference of Governmental Industrial Hygienists (ACGIH) is not higher than 100μg/m^3 (0.05ppm), which is the standard most recently referred [11]. Another indoor air quality standard of ozone was established by the Occupational Safety and Health Administration (OSHA), which set at 200μg/m^3 (0.10 ppm) [6,12].

In this study, levels of ozone emitted from photocopier and its exposure sources of different groups of people were determined. Two groups of people were selected for this study: photocopying staffs and students around the photocopying kiosk. In addition, a total of three environments were selected for ozone monitoring including a photocopying kiosk, a kiosk-surrounded environment and a nearby car park. The ozone levels were used to calculate I/O ratios. The purposes were to find out the major exposure source of ozone of the two groups. I/O ratio >1 indicates that the major sources of air pollutant are indoor sources, and I/O ratio <1 implies the predominance of outdoor sources. I/O ratio was also used to identify the source of exposure to pollutants in primary school children in Athens [12]. However, worldwide studies on ozone levels emitted from photocopiers were continually conducted in air-tight chambers. The ozone levels in photocopying workplace remain largely unknown.

2. Materials and Methods

Sampling

Ozone in air was sampled at three environments: (i) a photocopying kiosk (W·L·H = 4·3·2 meters), locating in Science Building, Faculty of Science, Silpakorn University, (ii) a kiosk-surround area and (iii) a nearby car park. In the kiosk, two photocopiers are in service. Two exhaust fans were installed but only one is operated. Two sampling sets were fixed at 1.5 meter height above ground in each environment. The in-kiosk sampling sets were situated between the two photocopiers. The second sets were placed at two meters away from the kiosk's opening. At the car park, air samplers were located at four meters away from the kiosk to measure ozone level in ambient air. Air containing ozone was drawn by personal air pump (Gillian, Model Programmable GilAir-5) through a midget impinger containing 10mL absorbent [14]. Samples were collected every 2 days from November 2010 to February 2011. Total number of samples was 135 (45 samples for each site). Fig. 1 illustrates the sampling layout.

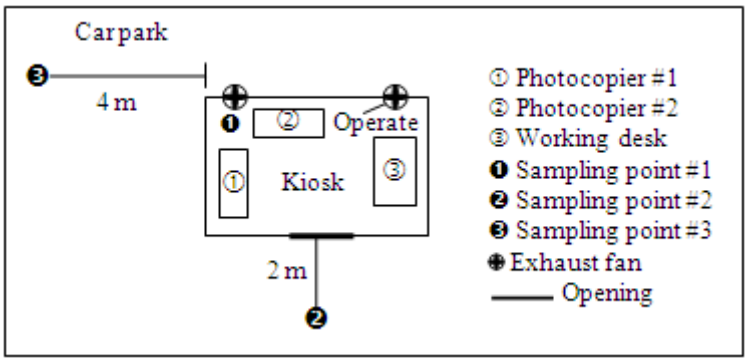

Fig. 1: Sampling layout.

Analysis

Ten milliliters of absorbing solution were pipetted into the impinger. The flow rate of the personal air pump was 2liter/min. Sampling period of this study lasted 8 hours starting from 9am to 5pm, which was a servicing period, in the photocopying kiosk, the kiosk-surrounded environment and the nearby car park. The sampling temperature was controlled below 25°C by ice box to prevent the evaporation of absorbing reagent. After sampling, samples were analyzed by a method of APHA Intersociety Committee [14]. The absorbance of samples, standard solutions and blank were determined at 352nm by Spectrophotometer (JASCO, Model V-530). Ozone concentrations were calculated by the equation as followed [14], where M was standardization factor and V was standard air volume.

$$\text{ppm oxidant (expressed as ozone)} = (Abs_{sample}\text{-}Abs_{blank}) \cdot M/V$$

The advantages of this method were that a delay of several days was permissible between sampling and completion of analysis and that it was simple, accurate and precise. However, chlorine, hydrogen peroxide, organic peroxides, and various other oxidants would liberate iodine. The response to nitrogen dioxide was limited to 10% by the use of sulfamic acid in the procedure to destroy nitrite, thus minimizing any error due to the collection of nitrogen dioxide. The negative interferences from reducing gases such as sulfur dioxide and hydrogen sulfide were very serious (probably on a mole-to-mole equivalency). In addition, the procedure was very sensitive to reducing dusts and droplets that may be present on the glassware [14].

Calculation of I/O ratios

I/O ratios of photocopying staffs and students around the kiosk were calculated. The purpose was to identify the major sources of ozone exposure. Different environments were used for different groups as shown in Table 1.

Table 1: Indoor and outdoor environment for I/O calculation

	Environment	
	Indoor	**Outdoor**
Staffs	**In Photocopying kiosk**	**Kiosk-surrounded area**
Students	**Kiosk-surrounded area**	**Car park**

Statistical analysis of data

SPSS program was used for data analysis. The correlations of ozone levels between the photocopying kiosk and at the kiosk-surrounded area (indoor and outdoor environment for staffs) as well as the kiosk-surrounded area and the car park (indoor and outdoor environment for students) were tested. Additionally, Paired sample t-test was introduced to find out the difference of average ozone levels among three sampling sites at 95% ($\alpha = 0.05$) confidence interval. This type of t-test is a statistical technique used to compare mean values between two groups of population those are correlated [15].

3. Results and discussions

On average, level of ozone in the photocopying kiosk influenced by emission from photocopiers was 0.05±0.02ppm. The value of 0.05ppm comes close to the American Conference of Governmental Industrial Hygienists (ACGIH) Standard for workplace [11] that means several values were exceed the standard. This finding implied that ozone level in the kiosk possibly poses a risk to workers' health. In most other studies, levels of ozone released from the photocopiers were tested in the air-tight chamber. The results showed the range of 1.3-7.9ppm [16,17,18]. Previous studies investigating the prospective effects of long-term occupational exposures to ozone had reported headache, irritation of the nose and throat, chest constriction, rapid and shallow breaths and lung congestion in exposed workers [11]. The processes of airway injury, inflammation, and repair continue to occur during repeated exposure. Human population studies indicated that people who live in communities with high ozone levels had experienced a greater decrease in lung function over 5 years than people living in communities with lower background levels [19]. These studies suggested that long-term exposure to ozone may result in impaired lung function and cause structural changes to the lung. In this study, photocopying staffs works 8 hour/day and 5 day/week thus they were at risk to basic symptoms as mentioned earlier and respiratory problems. To improve the air quality in the kiosk, natural and/or mechanical ventilation should be provided. The opening at the opposite wall to an existing opening is required to enhance air movement. Moreover, both exhaust fans should be operated. The circulated air volume appropriate for the printing service room should not be below 15 times of room volume per hour [18]. For this reason, the circulated air volume of 360m^3/hour is obligated in the tested photocopying kiosk in this study.

When comparing ozone concentrations, ozone levels in the kiosk were found to be the highest, followed by the kiosk-surrounded environment and the car park (Table 2). Good correlation was found between levels of ozone in the kiosk and the kiosk-surrounded environment (R^2=0.74) whereas the ozone levels between the kiosk-surrounded environment and the nearby car park was poorly correlated (R^2=0.55) (Fig. 2). These findings implied the influence of photocopier emission to air quality at kiosk-surrounded environment rather than vehicular emission outside. The results from Paired sample t-test suggested the significance difference between the in-kiosk ozone level and the kiosk-surrounded environment and at the car park at 95% ($\alpha = 0.05$) confidence interval. The test results between ozone level at the kiosk-surrounded environment and the car park were not significantly different at 95% ($\alpha = 0.05$) confidence interval.

Table 2: Exposure level of ozone in three environments and I/O ratios

	Ozone level in ppm	**Correlations (R^2)**		**I/O Ratio**	
		Kiosk & surrounded environment	**Surrounded area & car park**	**Staffs**	**Student**
		0.74	**0.55**	**1.67**	**1.5**
Photocopying kiosk	**0.05±0.02**				
Kiosk-surrounded environment	**0.03±0.01**				
Car park	**0.02±0.01**				

I/O ratios of ozone for the two groups were 1.67 and 1.50 indicating an important contribution of indoor source. In case of staffs I/O (kiosk/kiosk-surrounded environment) ratio of ozone level was 1.67 representing that their exposures were predominantly from the emission of photocopiers. They exposed to high ozone levels which may cause several adverse health problems as mention above. It was observed that students' I/O

(kiosk-surrounded environment/car park) ratio of 1.50 designated indoor source (photocopiers) was prevalent. It could be stated that the air near photocopying service was contaminated by photocopier emission. Outdoor source, where ozone was generated from reaction of hydrocarbon and hydrogen dioxide in the ambient air, played relatively irrelevant role to student exposure. Compared to study of Poupard et al. relating to I/O ratios of ozone in the academic building without photocopying service, I/O ratios were ranged from 0.00-0.45. It was concluded from their study that, without photocopying machines, ambient ozone was predominant [22].

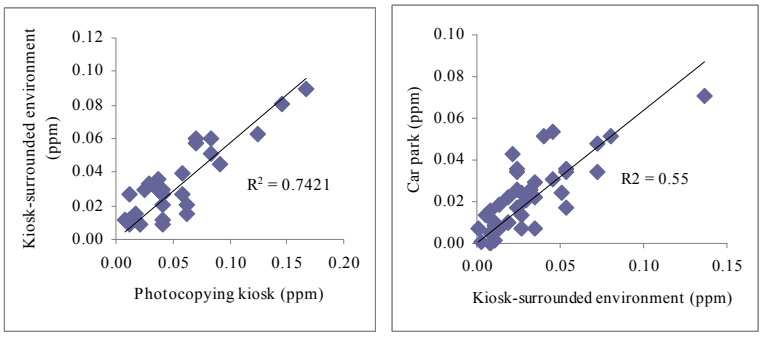

Fig. 2: Correlation of ozone levels.

Various reasons presented in this study definitely confirmed the contribution of photocopier emission to air quality in the building.

4. Conclusions

Indoor levels of ozone both in the photocopying kiosk and the kiosk-surrounded environment were a function of photocopier emission with higher levels found in the kiosk. Ozone is generated from an electrophotographic process and from the corona wire in the copiers. Long-term human exposure to ozone can cause basic symptoms such as eye and throat irritation, coughing and headache until lung malfunction and respiratory problems. From air monitoring, correlation test, Paired sample t-test and I/O ratios, it could be verified that photocopiers were the major source of ozone exposure to workers and people around the photocopying service. Photocopying staffs were at risk of several adverse health effects since the exposed ozone level was equivalent to the upper limit of ACGIH standard for workplace and they spend many hours per day and many days per week in this area. Enhancement of natural and/or mechanical ventilation could relieve the exposure level of ozone near the copying service area and its surrounded environment.

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