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ORIGINAL ARTICLE

Association of Exposure to Indoor Air Pollutants and Respiratory Health Symptoms among Photocopy Workers in Bandar Baru Bangi, Selangor

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ABSTRACT

Introduction: Indoor air quality (IAQ) has a significant impact on individual well-being, particularly in photocopy industry workers who are exposed to high levels of contaminants. Improper IAQ is linked to various health issues including respiratory symptoms. This study aimed to determine the association between exposure to indoor air pollutants and respiratory health symptoms among photocopy workers in Bandar Baru Bangi, Selangor. **Methods:** A cross-sectional comparative study was conducted between exposed and control groups consisted of 76 employees who worked in photocopy premises and 76 employees who worked in offices. A set of questionnaires adapted from the American Thoracic Society was used to collect data on respiratory health symptoms, history of exposure, and socio-demographic background of the employees. Area monitoring was performed using various direct reading devices to measure UFP, $PM_{2.5}$, PM_{10}, CO, CO_2, and TVOCs. **Results:** In all photocopy centers of exposed group, the mean of PM_{10} and $PM_{2.5}$ were at 344.16 μg/m^3 and 315.24 μg/m^3 ($p<0.001$), which exceeded the acceptable limit of respirable particulates by ICOP at 150 μg/m^3; UFP level at 9068.75 pt/cc ($p<0.001$); and TVOC at 2.32 ppm ($p<0.001$), below the limit of 3.0 ppm. High PM_{10} exposures was reported significantly associated with all respiratory symptoms at $p<0.001$ (cough OR=3.89 (95% CI=1.00–15.07); phlegm OR=4.82 (95% CI=1.19–14.60); wheezing OR=1.77 (95% CI=1.54–5.79); shortness of breath OR=2.13 (95% CI=0.82–5.55); chest tightness OR=0.37 (95% CI=0.14–0.98)); high $PM_{2.5}$ exposure was significantly associated with all symptoms except for wheezing (cough at $p<0.001$, OR=6.71 (95% CI=1.41–32.00; phlegm at $p<0.001$, OR=5.15 (95% CI=1.41–32.00); shortness of breath at $p<0.05$, OR=2.13 (95% CI=0.85–5.32); and chest tightness at $p<0.05$, OR=0.37 (95% CI=0.15–0.95); meanwhile high exposure to UFP had significant relationships with shortness of breath at $p<0.001$, OR=0.66 (95% CI=0.27–1.64) and chest tightness at $p<0.001$, OR=1.51 (95% CI=0.61–3.74) among respondents. TVOC also had significant relationships with shortness of breath at $p<0.001$, OR=1.25, 95% CI=0.47–3.35 and chest tightness at $p<0.001$, OR=1.04, 95% CI=0.23–1.68. Results also showed that symptoms of cough, phlegm and wheezing were influenced by the PM_{10} and $PM_{2.5}$ exposure at 49.4% (Nagelkerke R^2= 0.494), 60.1% (Nagelkerke R^2= 0.601) and 56.3% (Nagelkerke R^2=0.563), respectively. However, there were no significant factors that influenced the symptom of shortness of breath and chest tightness among the respondents. **Conclusion:** This study concluded that exposure to indoor air pollutants increased the risk of respiratory health symptoms among photocopy workers. This study suggests that regular photocopy machine maintenance and daily workplace housekeeping is required, whereas the photocopy workers should be fully trained in terms of technical, health and safety aspects.
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INTRODUCTION

People spend a significant amount of time indoors, whether it is at work or at home, and indoor air quality has a considerable impact on individual overall well-being (1). Indoor air quality (IAQ) is defined by the United State of Environmental Protection Agency (USEPA) (2) as the air quality inside and around structures and buildings that impacts people's health and comfort. Indoor air quality refers to the physical, biological, and chemical components of the air that flows through the areas where humans live and breathe. This underscores the importance of regular air quality testing and monitoring in buildings. Such measures can help identify potential health hazards and inform strategies to mitigate indoor air pollution (3, 4). In addition, USEPA added that indoor air pollution levels are usually 2-5 times higher than outdoor levels, and in some cases 100 times higher. This proved that indoor air could be more hazardous than outdoor air (2).

The occupational health impacts of the industrial workers due to indoor air pollutants in many industries around the world are of high concern. Various industrial activities where employees were potentially exposed to indoor air pollutants in the working areas may also affected by several factors such as the air ventilation, air filtration control, and indoor temperature and humidity (5-8). Printing/photocopy is one of the industries that potentially releases various amounts of contaminants, creating air quality as a major concern for their health. During operation, photocopier tend to emit toner particles, toxic gases such as volatile organic compound (VOC), ultrafine particles with a nanoscale size less than 0.1 micrometres (UFP), particulate matter with a diameter of 2.5 micrometres or smaller ($PM_{2.5}$), and particulate matter with a diameter of 10 micrometres or less (PM_{10}), ozone, nano particles and extremely low-frequency electromagnetic fields (9-11). These emissions are variable and depend on the few factors such as photocopier's model, cartridge age, toner, printer age, page type, mode of operation, printing and maintenance frequencies (12-15). A study conducted in copy centres in Portugal concluded that operation of laser printers can lead to high particulate matter and ozone concentrations indoors (16). Another local study carried out by Jalaludin (2015) found the levels of $PM_{2.5}$ and UFP were higher among the photocopier workers. This study also showed an increase in risk of getting lung function abnormality and respiratory illness among the operators in this industry (17).

Up until today, health studies on occupational exposure to emissions from photocopier are inconclusive and not comprehensive. Several studies have reported on the health impact of indoor air pollution in the printing industry emitted in occupational settings with symptoms like respiratory health illnesses including inflammation of the respiratory tract, upper respiratory tract infections, sick building syndrome, skin and eyes irritations, headache and non-allergic rhinitis (11, 18-19). A study by Betha et al. (2011) has identified photocopiers as the potential contributors of indoor air pollution and the presence of UFPs and VOCs in printer emissions, which together represent substantial health risks to the workers (20). Many researchers have reported on the effects of exposure to photocopier towards deoxyribonucleic acid (DNA) damage among operators in the printing centers (21-23). A study found that photocopier operators who were exposed to nanoparticles (NPs) experienced elevated levels of urinary biomarkers associated with oxidative damage, such as 8-hydroxydeoxyguanosine, 8-OHdG; 8-hydroxyguanosine, 8-OHG; and 8-isoprostane; 4-hydroxynonenal, HNE (23). In addition to causing upper airway and systemic inflammation, exposure to these particles has also been linked to autoimmune and respiratory disorders. The findings from this study suggested that photocopier operators may be at risk for systemic oxidative stress due to the damage inflicted on DNA, ribonucleic acid (RNA), and lipids by the NPs.

There is a gap in this study that needs attention to be covered and the fact that there are few numbers of research studies that associate with exposure to indoor air pollutants and respiratory health symptoms among photocopy workers. Research on the association between exposure to indoor air pollutants and respiratory health symptoms among photocopy workers has been conducted majorly by international researchers; however, there are a few numbers of local researcher who have conducted a research related to the relationship between exposure of indoor air pollutants and respiratory health symptoms among photocopy operators. Photocopy workers are largely adults who are not included in vulnerable groups such as children and elderly; thus, as a result, most researchers tend to overlook this vulnerable group. This study was carried out with the aim to determine the association between exposure to indoor air pollutants and respiratory health symptoms among photocopy workers in Bandar Baru Bangi, Selangor.

MATERIALS AND METHODS

This study was a cross-sectional comparative study conducted among adult workers to assess the association between exposures to indoor air pollutants with respiratory health symptoms. Indoor air pollutants from photocopy/printing premises measured in this study were $PM_{2.5}$, PM_{10}, UFP and TVOCs while the respiratory health symptoms experienced by the photocopy workers were cough, phlegm, wheezing, shortness of breath, and chest tightness.

Study Location and Population

This study was conducted at several photocopy/printing premises in Bandar Baru Bangi, Selangor. This township is situated in Hulu Langat District, in between Kajang and Putrajaya, in south-eastern Selangor, Malaysia. It is also located between Universiti Putra Malaysia (UPM) and Universiti Kebangsaan Malaysia (UKM). Bandar Baru Bangi is hectic, residential, modernistic, industrial and education city where most of the population is a committed full-time employment. It is known as a fast-growing area where it has a high population, the number of business premises is increasing due to high demand. This city is a strategic place to open photocopy/print business, this is because most of the customers come from university student, office workers, local people, schoolteachers, and school students. There are about twenty photocopy/print premises located in Bandar Baru Bangi.

The study population was selected based on the inclusion and exclusion criteria listed by the researchers, which included healthy male and female workers aged 20 to 60 years old, and had at least five years of working experience in the study location. A total of 152 respondents were participated in this study where 76 respondents were among the photocopy workers from several photocopy/printing premises as the exposed group and 76 respondents were among the office workers with no professional exposure to emissions from photocopiers which categorized as comparative group. Those with previous history of respiratory illnesses and who actively smoke and expose to second-hand tobacco smoke were excluded from both study groups.

Data Collection and Study Instrumentations

Questionnaire

A modified questionnaire based on standardised international questionnaire by the American Thoracic Society (ATS-DLD-78-A) for data on sociodemographic background and questionnaire about chronic respiratory symptoms such as experience of chronic phlegm, chronic cough, and chest tightness was used in this study. The questionnaires were translated from English to Malay. The researcher did a pilot testing on a similar target group before the data collection being conducted. A pre-testing questionnaire was administered to 10% of the target population to assess the validity and reliability of the questions provided. A total of 15 respondents participated in the pre-test and Cronbach alpha was obtained at 0.767. A consent letter was included to thoroughly explain the methodology used in this study to respondents to obtain permission and avoid unnecessary problem. Majority of questions constructed were close response questions and can easily be answered as well as does not take much time to answer. A quick interview with respondents was conducted upon collection of questionnaires to ensure that questionnaires were completed successfully.

Study Instruments

For the determination of indoor air pollutant levels, direct reading devices of P-Trak Ultrafine Particle Counter 8525, Optical Particle Sizer 3330, Q-Trak TSI IAQ-Calc 7545, and PbbRAE Portable VOC Monitor have been used for the UFP, $PM_{2.5}$, PM_{10}, CO, CO_2, and TVOCs, respectively. Exposures to PM_{10}, $PM_{2.5}$, UFP, and TVOC were measured four times for each respondent, with data were collected in the morning, afternoon, early evening, and late evening from 9 a.m. to 5 p.m. Before conducted the measurement, all of the devices were calibrated for the quality control and quality assurance (QA/QC). To eliminate measurement inaccuracies when taking measurements, all equipment was zero calibrated. The instrument was installed correctly in accordance with the Department of Occupational Safety and Health's Industry Code of Practice for Indoor Air Quality 2010 by placing at a breathing level height which about 75 cm to 120 cm above floor level, meanwhile the selected point locations must not closer than 50 cm from any vertical surface such as wall and windows as it could interfere the measurement. The data sampled by the equipment was uploaded to its software after the measurement was performed in order to determine the total average reading.

Statistical Analysis

Statistical Packages for Social Sciences (SPSS version 27) was used to analyse the data. The Kolmogorov-Smirnov normality test was applied, with a significant level ($p<0.05$) for normal distribution. The descriptive analysis variables of socio-demographic data were analysed with univariate analysis, and the nominal variables were analysed using bivariate analysis. Mann-Whitney U test was used to examine median differences in indoor air pollution exposure (PM_{10}, $PM_{2.5}$, UFP, TVOC, CO_2 and CO) between the exposed and control groups. To compare the respiratory health symptoms of the exposed and comparative groups, the Chi Square test was performed. Furthermore, to determine the association between exposure of indoor air pollutants (PM_{10}, $PM_{2.5}$, UFP, TVOC, CO_2 and CO) and respiratory health symptoms among respondents. After all confounders had been eliminated, multiple logistic regression (MLR) was performed to identify the factors that influence respiratory health symptoms. The confounders of the study were included socio-demographic data, history of illnesses and smoking status.

Ethical Consideration

Ethics approval was obtained from the Ethics Committee for Research Involving Human Subjects in Universiti Putra Malaysia with the reference number JKEUPM-2021-004. However, permission to conduct the study in the selected photocopy/printing premises was obtained from the employer of the premises. Informed consent was distributed to the respondents along with questionnaire distribution and the anonymity of the participants was always maintained.

RESULTS

Sociodemographic of Respondents

Table I summarizes the sociodemographic data of the respondents from exposed and control groups. Descriptive analysis and Mann-Whitney U test were carried out to determine the sociodemographic characteristics and relationship of respondents with the variables. All of the respondents (100%) were Malaysian and all of them were Malay. The exposed and compared groups both had 100% response rate in this study. In term of age, there was no significant difference between the photocopy workers and office workers. The exposed and control groups had median ages of 32 (range 25–45) and 35 (range 27–49),

Table I : Socio-demographic Characteristics of Respondents

	Exposed (N=76)		Comparative (N=76)		p value
	Median	**Range**	**Median**	**Range**	
Continuous					
Age (yrs)	32	25 – 45	35	27 – 49	0.069
Working experience (yrs)	6	5 – 20	8	5 – 25	**0.010***
Categorical			N (%)		
Gender					
Male	42 (55.3)		27 (35.5)		**0.023***
Female	34 (44.7)		49 (64.5)		

Descriptive analysis and Mann-Whitney U test;
*Significant at $p < 0.05$

Table II : Descriptive statistics of the Levels of Indoor Air Pollutants at Study Locations

Location		PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	UFP (pt/cc)	TVOC (ppm)	CO_2 (ppm)	CO (ppm)
A	Min	418.0	393.8	3270.0	2.5	112.0	0.0
	Max	822.5	793.5	13643.0	6.3	200.0	0.1
	Mean	**581.8**	**547.1**	8762.33	**3.93**	163.33	0.07
B	Min	165.1	149.1	8176.0	2.0	194.0	BDL
	Max	289.8	278.0	25181.0	3.0	395.0	BDL
	Mean	225.07	208.67	**16232.33**	2.33	**274.0**	BDL
C	Min	124.9	101.9	2369.0	1.0	105.0	0.1
	Max	593.6	532.4	8022.0	3.0	186.0	0.7
	Mean	401.87	357.03	4553.67	2.0	134.33	**0.43**
D	Min	153.1	132.5	3396.0	1.0	105.0	0.1
	Max	191.6	171.0	8838.0	1.0	178.0	0.4
	Mean	167.9	148.17	6726.67	1.0	148.67	0.27
E*	Min	134.0	111.2	857.0	BDL	89.0	BDL
	Max	140.3	116.9	2064.0	BDL	130.0	BDL
	Mean	**137.17**	**113.5**	1462.0	BDL	**106.33**	BDL
F*	Min	104.8	95.1	1359.0	BDL	90.0	BDL
	Max	120.1	111.6	3634.0	BDL	120.0	BDL
	Mean	112.43	101.33	**2131.37**	BDL	**106.33**	BDL

*Control group area; BDL=Below Detection Limit

respectively. However, there were considerable differences in working experience, with photocopy workers and the control group having medians of 6 years (range 5-20) and 8 years (range 5-25), respectively at $p<0.05$. In term of gender, 55.3% of photocopier workers are male and 44.7% are female, while 64.5% of female were dominating the comparative group. There was significant relationship between both groups in term of gender at $p<0.05$.

Comparison of Exposure to Indoor Air Pollutants based on Studied Locations

Table II shows the descriptive statistics of the levels of indoor air pollutants at each of the studied locations.

Overall, the concentration of PM_{10} exposure based on the locations of the study area ranged between 167.9 µg/m³ to 581.8 µg/m³ for the exposed group where the highest mean was recorded at Location A. The level of $PM_{2.5}$ in the exposed areas ranged between 148.17 µg/m³ to 547.1 µg/m³ where the highest mean was also recorded at Location A. As for the level of UFP, the highest mean detected at the Location B at 16232.33 (min 4553.67 µg/m³). The concentration of TVOC in the exposed areas ranged between 1.0 ppm to 3.93 ppm which the highest mean was recorded also from Location A. For the level of CO_2, Location B had the highest mean at 274.0 ppm (ranged 134.33 to 274.0 ppm), while Location C detected the highest mean of CO at 0.43 ppm (ranged below detection limit (BDL) to 0.43 ppm). Meanwhile, as for the control areas, the highest mean of PM_{10} was identified at Location E at 137.17 µg/m³ (ranged 112.43 to 137.17 µg/m³) which was four times lower compared to the exposed areas. Similarly, $PM_{2.5}$ exposure in the control areas was recorded higher at the Location E at mean level of 113.5 µg/m³ (ranged 101.33 to 113.5 µg/m³), which was also four times lower compared to exposed areas. UFP measurement of control areas ranged between 2131.37 pt/cc to 14.62.0 pt/cc where the highest mean was found in Location F, was six times lower compared to the exposed areas. As for the TVOC measurement, both control areas recorded a low reading below the detection limit, which was almost four times lower than the exposed areas. For the level of CO_2, both control areas recorded the same mean level at 106.33 ppm, which was one time lower than in the exposed areas. In term of CO measurement, both of the control areas had a reading below the detection limit.

Association of Exposure to Indoor Air Pollutants based on Studied Locations

Mann-Whitney U test was conducted to determine the relation between the exposure to indoor air pollutants with the exposed and control areas. The results of the analysis were presented in Table III. Based on the table, there were significant associations in the concentrations of PM_{10}, $PM_{2.5}$, UFP, TVOC, CO_2 and CO between exposed and control areas at $p<0.001$. The mean (range) for the PM_{10} in the exposed areas was 344.16 (124.9 – 822.5) µg/m³ while control areas at 124.8 (104.8 – 140.3) µg/m³, at $p<0.001$, Z=-9.977. The mean (range) for $PM_{2.5}$ in the exposed areas was recorded at 3.15.24 (101.9 – 793.5) µg/m³ while 107.42 (95.1 – 116.9) µg/m³ for the control areas, where correlation was found at $p<0.001$, Z=-8.810. As for the UFP levels in both studied locations, mean (range) concentration for exposed areas was 9068.75 (2369 – 25181) pt/cc and 1796.3 (857.0 – 3634.0) pt/cc for control areas, at $p<0.001$, Z=-9.083. TVOC levels for exposed and control areas were recorded at 2.32 (1.0 – 6.3) ppm and below the detection limit, at $p<0.001$, Z=-11.433, respectively. The level of CO_2 measured in the exposed areas was at 180.08 (105.0 – 395.0) ppm while 106.33 (89.0 – 130.0) ppm in the control areas, at $p<0.001$, Z=-9.528. For the CO level, exposed areas had the mean value of 0.175 (0.0 – 0.7) ppm while control areas had a reading below the detection limit, at $p<0.001$, Z=-6.887.

Prevalence of Respiratory Health Symptoms among Respondents

The reported respiratory health symptoms among the respondents from the exposed and control group are presented in Table IV. Chi-squared test was performed on the data to evaluate the differences in the respiratory health symptoms between both studied groups. Based on the results, there were significant differences in all reported respiratory health symptoms among the respondents at $p<0.001$ where the exposed group had the higher number of respondents for all the symptoms. For the symptom of cough,

Table III : Association of Exposure to Indoor Air Pollutants between Exposed and Control Study Locations

Variable	Exposed Area N=4		Control Area N=2		p-value	Z
	Mean	Range	Mean	Range		
PM_{10} (µg/m³)	344.16	124.9 – 822.5	124.8	104.8 – 140.3	**<0.001***	-9.977
$PM_{2.5}$ (µg/m³)	315.24	101.9 – 793.5	107.42	95.1 – 116.9	**<0.001***	-8.810
UFP (pt/cc)	9068.75	2369 - 25181	1796.3	857.0 – 3634.0	**<0.001***	-9.083
TVOC (ppm)	2.32	1.0 – 6.3	BDL	BDL	**<0.001***	-11.433
CO_2 (ppm)	180.08	105.0 – 395.0	106.33	89.0 – 130.0	**<0.001***	-9.528
CO (ppm)	0.175	0.0 – 0.7	BDL	BDL	**<0.001***	-6.887

Mann-Whitney U test; *significant at p<0.001; BDL=Below Detection Limit

Table IV : Prevalence of Reported Respiratory Health Symptoms among Respondents

Variable	Exposed group	Control group	x^2	p-value
	N = 76	N = 76		
	n (%)			
Cough			69.699	**<0.001***
Yes	72(94.7)	22(28.9)		
No	4(5.3)	54(71.1)		
Phlegm			85.872	**<0.001***
Yes	69(90.8)	12(15.8)		
No	7(9.2)	64(84.2)		
Wheezing			31.579	**<0.001***
Yes	34(44.7)	4(5.3)		
No	42(55.3)	72(94.7)		
Shortness of breath			29.610	**<0.001***
Yes	36(47.4)	6(7.9)		
No	40(52.6)	70(92.1)		
Chest tightness			32.097	**<0.001***
Yes	36(47.4)	5(6.6)		
No	40(52.6)	71(93.4)		

Chi-Square test; *Significant at p<0.001

72 (94.7%) of respondents from the exposed group reported having cough while only 22 (28.7%) from control group (p<0.001, x^2=69.699). For the symptoms of phlegm, 69 (90.8%) and 12 (15.8%) of respondents from the exposed group were reported to have the symptom, respectively (p<0.001, x^2=85.872). Meanwhile, 34 (44.7%) and 4 (5.3%) of respondents from exposed and control groups were recorded to have the wheezing symptom, respectively (p<0.001, x^2=31.579). Chest tightness symptom was reported by 36 (47.4%) and 5 (6.6%) in the exposed and control groups, respectively at p<0.001, x^2=32.097. Meanwhile, shortness of breath was reported by 36 (47.4%) and 6 (7.9%) in the exposed and control groups, respectively (p<0.001, x^2=29.610).

Association of Exposure to Indoor Air Pollutants with Respiratory Health Symptoms

The Chi-Square test was conducted to determine the association of exposure to indoor air pollutants with the respiratory health symptoms. The data was presented in odd ratio and 95% confidence interval. The indoor air pollutants were categorized based on the acceptable limit of the Industry Code of Practice on Indoor Air Quality 2010 Standard (ICOP IAQ 2010) (27) for the PM_{10} (150 μg/m³), $PM_{2.5}$ (150 μg/m³) and TVOC (3.0 ppm), while UFP based on the median value at 3515 pt/cc. The results of the analysis were presented in Table V.

Based on the findings, there were significant associations between the exposure to high PM_{10} and all reported respiratory health symptoms, with cough at p<0.001, OR = 3.89 (95% CI = 1.00 – 15.07), phlegm at p<0.001, OR = 4.82 (95% CI = 1.19 – 14.60), wheezing at p<0.001, OR = 1.77 (95% CI = 1.54 – 5.79), shortness of breath at p<0.001, OR = 2.13 (95% CI = 0.82 – 5.55) and chest tightness at p<0.001, OR = 0.37 (95% CI = 0.14 – 0.98). Based on the results also, exposure to high PM_{10} increases the probability of getting cough, phlegm and wheezing symptoms at 3 times, 4 times and one time higher among the exposed group, respectively. As for the exposure to high $PM_{2.5}$, the chi-square test results showed that there were significant associations with all of the reported respiratory health symptoms except for wheezing, where cough at p<0.001, OR = 6.71 (95% CI = 1.41 – 32.00), phlegm at p<0.001, OR = 5.15 (95% CI = 1.08 – 18.37), shortness of breath at p<0.05, OR = 2.13 (95% CI = 0.85 – 5.32) and chest tightness at p<0.05, OR = 0.37 (95% CI = 0.15 – 0.95). The results also indicated that exposure to high $PM_{2.5}$ level increases the probability of getting symptoms of cough and phlegm at 6 times and 5 times higher among the photocopy workers.

On the other hand, exposure to high UFP were significantly associated with the symptoms of shortness of breath and chest tightness only, where shortness of breath at p<0.001, OR = 0.66 (95%

Table V : Association of Exposure to Indoor Air Pollutants with Respiratory Health Symptoms among Respondents

Variable	PM_{10} <150 μg/m³	$PM_{2.5}$ <150 μg/m³	UFP <3515 pt/cc	TVOC <3.0 ppm
Cough				
OR	**3.89*** **	**6.71*** **	0.35	0.76
95% CI	1.00 – 15.07	1.41 – 32.00	0.35 – 3.55	0.75 – 7.69
p value	<0.001*	<0.001*	0.895	0.895
Phlegm				
OR	**4.82*** **	**5.15*** **	1.22	0.54
95% CI	1.19 – 14.60	1.08 – 18.37	0.25 – 5.87	0.11 – 2.66
p value	<0.001*	<0.001*	1.000	0.324
Wheezing				
OR	**1.77*** **	1.76	0.67	1.08
95% CI	1.54 – 5.79	0.96 – 5.79	0.27 – 1.66	0.40 – 2.88
p value	<0.001*	0.069	0.118	0.417
Shortness of breath				
OR	2.13	2.13	0.66	1.25
95% CI	0.82 – 5.55	0.85 – 5.32	0.27 – 1.64	0.47 – 3.35
p value	<0.001*	**0.006** **	<0.001*	<0.001*
Chest tightness				
OR	0.37	0.37	1.51	1.04
95% CI	0.14 – 0.98	0.15 – 0.95	0.61 – 3.74	0.23 – 1.68
p value	<0.001*	**0.003** **	<0.001*	<0.001*

Chi-Square test; N=152; OR=Odd Ratio; 95% CI=95% Confidence Interval; *Significant at p<0.001; **Significant at p<0.05; ***OR Significant if 95% CI > 1

CI = 0.27 – 1.64) and chest tightness at p<0.001, OR = 1.51 (95% CI = 0.61 – 3.74). Similarly, exposure to high TVOC were also significantly associated with the symptoms of shortness of breath and chest tightness, where shortness of breath at p<0.001, OR = 1.25 (95% CI = 0.47 – 3.35) and chest tightness at p<0.001, OR = 1.04 (95% CI = 0.23 – 1.68).

Main Factors that Influence the Respiratory Symptoms among Study Respondents

Multiple logistic regression was conducted to determine the main factors that influenced the respiratory health symptoms among respondents from both studied groups after controlling all of the confounders since these dependent variables showed increased in risk of symptoms with the concentration of indoor air pollutants. The results of the regression analysis are presented in Table VI. Based on the results, the symptoms of cough, phlegm and wheezing were significantly associated with the present of PM_{10} and $PM_{2.5}$ in the buildings at p<0.05. For cough, PM_{10} was associated at (B = -0.079, p = 0.007, AOR = 0.924, 95% CI = 0.87 - 0.98), while $PM_{2.5}$ at (B = -0.082, p = 0.005, AOR = 1.086, 95% CI = 1.02 -1.15), with Nagelkere R^2= 0.494. For the symptom of phlegm, PM_{10} was influenced at (B = -0.099, p = 0.001, AOR = 0.906, 95% CI = 0.85 - 0.96), while $PM_{2.5}$ at (B = 0.103, p = 0.001, AOR = 1.108, 95% CI = 1.04 - 1.28), with Nagelkere R^2= 0.601. Meanwhile, respondents who were exposed to the PM_{10} and $PM_{2.5}$ had a considerably higher probability of acquiring wheezing with PM_{10} at (B = -0.089, p = 0.001, AOR = 1.016, 95% CI = 0.97 - 1.07), while $PM_{2.5}$ at (B = 0.103, p = 0.012, AOR = 0.979, 95% CI = 0.93 - 1.03) with Nagelkere R^2= 0.563.

DISCUSSION

Sociodemographic of Respondents

Respondents from the exposed and control groups that participated in this study had quite similar range of ages at 25-49 years old. However, no statistically significant relationship was established between respondents' age. Similar finding was found in studies by Jalaludin (2015) and Karimi et al. (2016) where there was no significant difference in terms of age between exposed and control groups (17,24). However, gender variable was significantly difference between

Table VI : Logistic Regression for Factors that Influence Respiratory Health Symptoms after Controlling All Confounders

	β	S. E	p-value	AOR	95% CI	R^2
			Cough			
Constant	1.841	0.567	0.001	6.303	-	
PM_{10}	-0.079	0.029	**0.007***	0.924	0.87 - 0.98	
$PM_{2.5}$	0.082	0.030	**0.005***	1.086	1.02 - 1.15	0.494
UFP	0.000	0.000	0.791	1.000	1.00 - 1.00	
TVOC	-0.684	0.551	1.541	0.504	1.71 - 1.486	
			Phlegm			
Constant	2.718	0.612	0.000	5.150	-	
PM_{10}	-0.099	0.030	**0.001***	0.906	0.85 - 0.96	
$PM_{2.5}$	0.103	0.031	**0.001***	1.108	1.04 - 1.28	0.601
UFP	0.000	0.000	0.819	1.00	1.00 - 1.00	
TVOC	-0.849	0.559	0.128	0.43	0.14 - 1.28	
			Wheezing			
Constant	0.462	1.816	0.799	0.374	-	
PM_{10}	-0.089	0.019	**0.001***	0.906	0.97 - 1.07	
$PM_{2.5}$	0.072	0.043	**0.012***	0.978	0.93 - 1.03	0.563
UFP	0.000	0.000	0.146	1.000	1.00 - 1.00	
TVOC	-0.062	0.231	0.788	0.000	0.60 - 1.48	
			Chest tightness			
Constant	2.630	0.450	0.000	13.87	-	
PM_{10}	-0.029	0.018	0.093	0.97	0.94 - 1.01	
$PM_{2.5}$	0.028	0.019	0.137	1.03	0.99 - 1.07	0.169
UFP	0.000	0.000	0.620	1.00	1.00 - 1.00	
TVOC	-0.360	0.208	0.084	0.70	0.46 -1.05	
			Shortness of breath			
Constant	-0.043	0.877	0.829	10.73	-	
PM_{10}	-0.009	0.023	0.695	0.98	0.95 - 1.01	
$PM_{2.5}$	0.007	0.025	0.783	1.02	0.99 - 1.06	0.122
UFP	0.000	0.000	0.212	1.00	1.00 - 1.00	
TVOC	-0.114	0.221	0.638	0.72	0.48 - 1.08	

N=152; β=Regression coefficient; S.E=Standard Error; AOR=Adjusted Odd Ratio; 95% CI=95% Confidence Interval; Nagelkerke R^2;*Significant at $p<0.05$

both groups due to nature of work as photocopy workers have a higher number of male respondents while administrative staff was dominant by female. Meanwhile, according to Elango et al. (2013), working experience of respondents is important to evaluate the exposure of indoor air pollutants and respiratory health symptoms, thus occupational exposure was defined as minimum five years of employment in a xerographic unit. Results of median for the photocopy workers showed significant difference between working experience with the respondents. This finding was in line with several studies that found a significant difference in term of years of working with the workers (17, 24-26).

Comparison of Exposure to Indoor Air Pollutants between Studied Areas

The findings on the levels of indoor air pollutants are being compared with the 8-hour exposure of Industry Code of Practice on Indoor Air Quality 2010 Standard (ICOP IAQ 2010) (27) established by the Department of Occupational Safety and Health (DOSH) Malaysia. However, there is no direct acceptable limit of indoor emission for the PM_{10} and $PM_{2.5}$, these pollutants are compared with the respirable particulates permissible limit at 150 µg/m^3. Overall, all of the indoor air pollutants in the present study showed a higher reading of concentrations as compared to the control group. Based on the results, present study found that indoor PM_{10} concentration was three times higher in the exposed group than in the control group. Mean value of indoor PM_{10} concentration in exposed area was also exceeded the standard value by three times. A study conducted by Talib and Zainab (2021) observed that printing environment had the highest concentrations of $PM_{2.5}$ (44.50±1.08 µg/m^3) and PM_{10} (477.66±32.78µg/m^3) in the indoor areas of printing units and copy centers (28). The researchers suggested that higher levels of particulate matter in printing environment are linked to increased daily copying and poor ventilation. Another study by Elango et al. (2013) also found similar results where the levels of PM_{10} was above the standard limit at 106.7µg/m^3 (100.0 µg/m^3) in all the photocopier centers, compared to control group.

Meanwhile, indoor $PM_{2.5}$ concentration in present study was also three times higher in the exposed group than in the comparative group. Indoor $PM_{2.5}$ concentration in exposed areas also exceeded the standard value by three times, according to the ICOP IAQ 2010 (27). Several studies were conducted related to exposure to $PM_{2.5}$ in photocopy industry. A recent study conducted in Thailand found the highest concentration of $PM_{2.5}$ was in the offset printing, which due to the surrounded paper in the area (6). A local study found out the exposure of $PM_{2.5}$ was 5 times higher at 62.30 µg/m^3 among the photocopy workers compared to control group (29). Another local study conducted among photocopy operators in Selangor also showed 5 times higher of mean exposure to $PM_{2.5}$ as compared with the office workers (17). This study also suggested that greater exposure of suspended $PM_{2.5}$ may have influence by the reduced ventilation in enclosed indoor environment.

As for the indoor concentration of UFP in exposed area, the present study was 9 times higher than the control group. There is not yet establish of the acceptable limit of UFP by the DOSH Malaysia, thus this pollutant cannot be compared with the standard. Because of the nano-scaled size and low terminal setting velocities of UFP, ultrafine particles can suspend can suspend in the air for a considerable period of time, thus inhalation and deposition of such particles in the human respiratory tract could lead to various adverse health effects such as asthma and respiratory inflammation (30-32). Exposure to UFP printing particles has gradually become an emerging occupational and environmental health concern. Therefore, it is essential for the DOSH Malaysia to set a new standard of exposure to UFP for the workers in printing industry. Higher concentration of exposure to UFP in present study was likely due to the nature of work of the exposed group in handling the photocopying operations as their daily work task. This finding also is consistent with previous study by Lee et al. (2007) on measurement of fine and ultrafine particles formation in photocopy centers in Taiwan where the number of concentrations in indoor air were much higher than outdoor air (33). Another study by Tang et al. (2012) found a significant increase of fine particles and UFP which were identified in ambient workplace air during and after the printing process (34). Based on the evidences, these researchers conclude that laser printers and photocopiers could be a relevant source of fine particles and UFP in photocopy industry.

As for the TVOC level in the present study, exposed group posed as twice higher than the control group where control group had a reading below the detection limit. Using the DOSH Malaysia standard on the exposure to total volatile organic compounds in indoor air, the result (2.32 ppm) was still within the recommended value of 3.0 ppm. TVOC can be generated partly by evaporation of toners and inks with the heating of the machine during the operation process, as well as the dispersion of paper particles. A study conducted by Kiurski et al. (2018) found a positive correlation between TVOC emissions with the photocopy process (35). A local study carried out by Abdul Razak (2015) in a photocopy and printing service centre in Shah Alam had the highest mean of TVOC at 5.873 ppm exceeded the ICOP acceptable limit of 3.0 ppm (36). While a research by Vilcekova and Meciarova (2016) found TVOC concentration was varied from 1.9 ppm to 3.7 ppm, with a mean of 2.6 ppm. The researcher found out that variations in TVOC levels can be explained by the operation of specific printing equipment that generated turbulence in the indoor environment (37).

Meanwhile, the readings of CO_2 in this study were found below the recommended value established by the ICOP Malaysia at 1000 ppm (27). However, the exposed area posed a higher reading compare to control area which indicated poor ventilation system in the photocopy centres. According to Pang et al. (2021), CO_2 concentration has been considered as an indicator of building ventilation. The indoor CO_2 level depends on the outdoor air supply rate and the source strength that refers to the production rate of metabolic CO_2 (37). Increase in indoor CO_2 level indicate inadequate ventilation, which is often associated with poorer air quality (38). Exposure to indoor CO_2 has been linked to cause significant associations with neurological symptoms (headache, fatigue, stress, dizziness and insomnia), as well as irritation of the upper airways system. Lu et al. (2015) found an increase of 100 ppm in CO_2 to be significantly related with dry throat, tiredness, dizziness and dry cough among office workers in, which corelated with poor ventilation system of the building (39).

Carbon monoxide is one of the primary pollutants that has been emitted during the photocopy operations, which known as a compound that is emitted directly from the stack and/or process equipment (15, 40). In this study, the level of CO was higher in exposed area while control area had a below detection limit reading. A study conducted by Kiurski et al. (2016) found a strong loading of CO in one of the principal component elements which confirmed the fact that CO is produced during heating of photocopier in an inadequate air supply in the building (15). Thus, this can be concluded that the presence of CO in the photocopy centres in the present study was related to the heating process during the operation of photocopier.

Prevalence and Associations of Respiratory Health Symptoms among Respondents

Overall, all of the reported respiratory health symptoms have the higher probability of acquiring in the exposed group than in control group. Studies indicated that photocopiers emit varieties of indoor air pollutants including ozone, several volatile organic compounds (VOCs) and particulate matters (PMs). Thus, the generated pollutants from photocopy activity easily accumulate indoors, especially under conditions of inadequate ventilation. It is therefore feasible that individuals working in the photocopy centers may be exposed to high levels of indoor air pollutants, which eventually developed various health problems (32). Based on the several previous studies conducted in photocopy premises, exposure to indoor air pollutants had been significantly associated with the prevalence of respiratory health symptoms among the photocopy workers (17, 24, 29, 36). According to Elango et al. (2013) photocopier workers had greater rates of nasal obstruction ($p<0.05$) and breathing issues ($p<0.05$). Moreover, compared to control subjects, photocopier workers had more phlegm symptom ($p<0.05$). The authors found that occupational exposure in respondents with over 5 years of experience to photocopier emissions is linked to increased levels of oxidative stress and inflammation, which raises the risk of atherosclerosis and cardiovascular disease (25). This may due to the longer working experience where the workers started to show respiratory health symptoms and it is possible that it will causes chronic respiratory issues and other non-communicable diseases. Emission levels were significantly greater during periods of high demand printing activity, which including continuous printing activities, and were directly impacted by indoor variables such as air change rates, fluctuations in ventilation flow rates, and movement of workers into and out of the photocopy/printing premises, as compared to those control group who only use photocopy devices for office documentation (20).

The results of the present study demonstrated that the symptoms of cough, phlegm, wheezing, shortness of breath and chest tightness have significant differences in exposure to high levels of PM_{10} and $PM_{2.5}$ among respondents. Meanwhile, exposure to high levels of UFP and TVOC were associated with the symptoms of shortness of breath and chest tightness. These findings are in line with a study conducted by Karimi et al. (2016) where the researchers found a significant difference in respiratory symptoms (cough and wheezing) between two groups after controlling the confounding variables. The likelihood of photocopy and printing workers of getting both symptoms were 2 times higher when exposed to indoor air pollutants (24). Other related studies also have reported a positive correlation between the use of a photocopiers and occurrence of respiratory symptoms, including airway inflammation and eye irritation (41-43). On the other hand, according to Tang et al. (2012), the size of the workplace, the size of the papers, the size of the printers and the number and type of machines also are the main factors of increased in the levels of indoor air pollutants which can caused respiratory health symptoms and other possible non-communicable disease (34).

Main Variables that Influence the Respiratory Health Symptoms among Respondents

The factors that influence the respiratory health symptoms after all the confounders in the present study were found correlated with the exposure to PM_{10} and $PM_{2.5}$ in the workplace area. Symptoms of cough, phlegm and wheezing which were reported among the respondents were significantly influenced by these two indoor air pollutants. A study carried out by Nandan et al. (2020) found that inhaled particulate matter from photocopiers had increased the risk of skin, eye, and nose irritation, as well as reduced lung function and increased oxidative stress, which elevates the risk of cardiovascular disease (45). According to a study by Tang et al. (2012), which the aim was to assess the exposure to particulate matter released from laser printers and photocopiers found that there were numerous factors that influence the distribution of particulate matter been emit by photocopier, including the printer’s use history, the type of paper used, the amount of air flow and exchange rate in the room (34). Study by Talib and Zainab (2021) suggested that poor ventilation and lack of air fans in the photocopy/printing premises, are responsible for the increased exposure of particulate matter to the exposed group, especially, photocopy/printing premises involved with numerous machinery and equipment ranging from offset printing machines, cutting machines, thermal machines, and many other machines of various sizes that differ according the demands of the job (28).

CONCLUSION

Photocopy workers have higher risk of developing respiratory health symptoms as the findings significantly showed that exposure to indoor air pollutants (PM_{10}, $PM_{2.5}$, UFP and TVOCs) were significantly higher among photocopy workers compared to the control group. The higher readings of CO_2 and CO in the exposed area indicated a poor ventilation in the buildings. In this study, cough, phlegm, wheezing, shortness of breath and chest tightness symptoms were reported higher among photocopy workers compared to control group. Photocopy workers that exposed to high concentrations of PM_{10} and $PM_{2.5}$ have higher possibility to shown respiratory health symptoms such as cough and phlegm. Findings from this study concluded that occupational exposure to pollutants emitted from the photocopiers significantly associated with respiratory health symptoms in photocopy workers. However, limitation of present study related to the number of exposure measurement with the potential health effects is needed to be mentioned as this is may influence the outcome of this study.

For recommendations, this study advises to improve workplace ventilation to eliminate hazardous indoor air pollutants from inks and chemical vaporization. Moreover, daily workplace cleanliness is required to minimize particle exposure, and any equipment malfunction should be repaired as soon as possible, as photocopier leakage may produce harmful indoor air pollutants. Finally, photocopy workers at photocopy/printing premises especially workers who exposed to indoor air pollutants for prolonged time should be trained on how to operate equipment and toners properly, as well as given with necessary personal protection equipment.

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REFERENCES

1. Tran, V. V., Park, D., & Lee, Y.-C. (2020). Indoor air pollution, related human diseases, and recent trends in the control and improvement of indoor air quality. International Journal of Environmental Research and Public Health, 17(8), 1-27.
2. USEPA. (2014). United States Environmental Protection Agency. Indoor air quality. Retrieved January 15, 2022, from https://www.epa.gov/
3. Zubir, N., Jalaludin, J., & Rasdi, I. (2022). Indoor Air Quality and Psychosocial Factors Related to Sick Building Syndrome among Office Workers in New and Old Buildings of a Public University in Klang Valley, Malaysia. Malaysian Journal of Medicine & Health Sciences, 18.
4. Zainal, Z. A., Hashim, Z., Jalaludin, J., Lee, L. F., & Hashim, J. H. (2019). Sick Building Syndrome among Office Workers in relation to Office Environment and Indoor Air Pollutant at an Academic Institution, Malaysia. Malaysian Journal of Medicine & Health Sciences, 15(3). 126-134.
5. Jodeh, S., Chakir, A., Massad, Y., & Roth, E. (2020). Assessment of $PM_{2.5}$, TVOCs, comfort parameters, and volatile organic solvents of paint at carpenter workshop and exposure to residential houses in Deir Ballout in Palestine. International Journal of Environmental Science and Technology, 1-10.
6. Pongboonkhumlarp, N., & Jinsart, W. (2022). Health risk analysis from volatile organic compounds and fine particulate matter in the printing industry. International Journal of Environmental Science and Technology, 19(9), 8633-8644.
7. Lazović, I. M., Stevanović, Ž. M., Jovašević-Stojanović, M. V., Živković, M. M., & Banjac, M. J. (2016). Impact of CO_2 concentration on indoor air quality and correlation with relative humidity and indoor air temperature in school buildings in Serbia. Thermal Science, 20(suppl. 1), 297-307.
8. Luo, N., Weng, W., Xu, X., Hong, T., Fu, M., & Sun, K. (2019). Assessment of occupant-behavior-based indoor air quality and its impacts on human exposure risk: a case study based on the wildfires in Northern California. Science of the total environment, 686, 1251-1261.
9. Yang, C.-Y., & Haung, Y.-C. (2008). A cross-sectional study of respiratory and irritant health symptoms in photocopier workers in Taiwan. Journal of Toxicology and Environmental Health, Part A, 71(19), 1314-1317.
10. Pirela, S., Molina, R., Watson, C., Cohen, J. M., Bello, D., Demokritou, P., & Brain, J. (2013). Effects of copy center particles on the lungs: a toxicological characterization using a Balb/c mouse model. Inhalation toxicology, 25(9), 498-508.
11. Khatri, M., Bello, D., Gaines, P., Martin, J., Pal, A. K., Gore, R., & Woskie, S. (2013). Nanoparticles from photocopiers induce oxidative stress and upper respiratory tract inflammation in healthy volunteers. Nanotoxicology, 7(5), 1014-1027.
12. Wensing, M., Schripp, T., Uhde, E., & Salthammer, T. (2008). Ultra-fine particles release from hardcopy devices: sources, real-room measurements and efficiency of filter accessories. Science of the total

environment, 407(1), 418-427.
13. Morawska, L., He, C., Johnson, G., Jayaratne, R., Salthammer, T., Wang, H., Uhde, E., Bostrom, T., Modini, R., & Ayoko, G. (2009). An investigation into the characteristics and formation mechanisms of particles originating from the operation of laser printers. Environmental science & technology, 43(4), 1015-1022.
14. He, C., Morawska, L., & Taplin, L. (2007). Particle emission characteristics of office printers. Environmental science & technology, 41(17), 6039-6045.
15. Kiurski, J. S., Oros, I. B., Kecic, V. S., Kovacevic, I. M., & Aksentijevic, S. M. (2016). The temporal variation of indoor pollutants in photocopying shop. Stochastic environmental research and risk assessment, 30, 1289-1300.
16. Vicente, E. D., Ribeiro, J. P., Custódio, D., & Alves, C. A. (2017). Assessment of the indoor air quality in copy centres at Aveiro, Portugal. Air Quality, Atmosphere & Health, 10, 117-127.
17. Jalaludin, J. (2015). PM2.5 & UFP Exposure and Its Asscosiation with Respiratory Health Illness among Photocopy Workers in Selangor. Asia Pacific Environmental and Occupational Health Journal, 1(1) 36-43.
18. Su, C., & Shu, Z. (2010). Investigation of sick building syndrome (SBS) and related risk factors in people working in office environment. Journal of Environment and Health, 27(3), 238-241.
19. Jaakkola, M. S., Yang, L., Ieromnimon, A., & Jaakkola, J. J. (2007). Office work exposures and respiratory and sick building syndrome symptoms. Occupational and Environmental Medicine, 64(3), 178-184.
20. Betha, R., Selvam, V., Blake, D. R., & Balasubramanian, R. (2011). Emission characteristics of ultrafine particles and volatile organic compounds in a commercial printing center. Journal of the Air & Waste Management Association, 61(11), 1093-1101.
21. Khisroon, M., Khan, A., Hassan, N., Zaidi, F., & Farooqi, J. (2020). Biomonitoring of DNA Damage in Photocopiers' Workers From Peshawar, Khyber Pakhtunkhwa, Pakistan. Journal of occupational and environmental medicine, 62(9), 527-530.
22. Kasi, V., Elango, N., Ananth, S., Vembhu, B., & Poornima, J. (2018). Occupational exposure to photocopiers and their toners cause genotoxicity. Human & Experimental Toxicology, 37(2), 205-217.
23. Zhang, Y., Bello, A., Ryan, D. K., Demokritou, P., & Bello, D. (2022). Elevated urinary biomarkers of oxidative damage in photocopier operators following acute and chronic exposures. Nanomaterials, 12(4), 715.
24. Karimi, A., Eslamizad, S., Mostafaee, M., Momeni, Z., Ziafati, F., & Mohammadi, S. (2016). Restrictive pattern of pulmonary symptoms among photocopy and printing workers: a retrospective cohort study. Journal of Research in Health Sciences, 16(2), 81.
25. Elango, N., Kasi, V., Vembhu, B., & Poornima, J. G. (2013). Chronic exposure to emissions from photocopiers in copy shops causes oxidative stress and systematic inflammation among photocopier operators in India. Environmental Health, 12, 1-12.
26. Kitamura, H., Terunuma, N., Kurosaki, S., Hata, K., Masuda, M., Kochi, T., Yanagi, N., Murase, T., Ogami, A., & Higashi, T. (2014). A cohort study on self-reported respiratory symptoms of toner-handling workers: cross-sectional and longitudinal analysis from 2003 to 2008. Biomed Research International, 2014.
27. DOSH. (2010). Department of Occupational Safety and Health, Ministry of Human Resources, Malaysia. Industry Code of Practice on Indoor Air Quality 2010 (ICOP IAQ 2010). https://www.dosh.gov.my/index.php/chemical-management-v/indoor-air-quality.
28. Talib, A. H., & Zainab, A. (2021). Measurement of some Air Pollutantsin Printing Units and Copy Centers Within Baghdad City. Baghdad Science Journal, 18(1 (Suppl.)), 687.
29. Bahruddin, N. A., Jalaludin, J., & Praveena, S. M. (2014). Exposure to PM 2.5, Ultrafine Particle and Lung Function Among Photocopy Workers in Selangor. From Sources to Solution: Proceedings of the International Conference on Environmental Forensics 2013.
30. Su, C., & Shu, Z. (2010). Investigation of sick building syndrome (SBS) and related risk factors in people working in office environment. Journal of Environment and Health, 27(3), 238-241.
31. House, R., Rajaram, N., & Tarlo, S. (2017). Case report of asthma associated with 3D printing. Occupational Medicine, 67(8), 652-654.
32. Chan, F., Rajaram, N., House, R., Kudla, I., Lipszyc, J., & Tarlo, S. M. (2017). Potential respiratory effects from 3-D printing. In B58. Occupational lung disease: case studies, epidemiology, and mechanisms (pp. A3861-A3861). American Thoracic Society.
33. Lee, C.-W., & Hsu, D.-J. (2007). Measurements of fine and ultrafine particles formation in photocopy centers in Taiwan. Atmospheric Environment, 41(31), 6598-6609.
34. Tang, T., Hurraß, J., Gminski, R., & Mersch-Sundermann, V. (2012). Fine and ultrafine particles emitted from laser printers as indoor air contaminants in German offices. Environmental Science and Pollution Research, 19, 3840-3849.
35. Kiurski, J. S., Aksentijević, S. M., & Mandarić, S. D. (2018). Statistical approach for characterization of photocopying indoor pollution. Air Quality, Atmosphere & Health, 11, 867-881.
36. Abdul Razak, N. A. H. (2015). Employee exposure to total volatile organic compounds in photocopy

and printing service centre.
37. Pang, L., Zhang, J., Cao, X., Wang, X., Liang, J., Zhang, L., & Guo, L. (2021). The effects of carbon dioxide exposure concentrations on human vigilance and sentiment in an enclosed workplace environment. Indoor air, 31(2), 467-479.
38. Seppanen, O. A., & Fisk, W. J. (2004). Summary of human responses to ventilation.
39. Lu, C.-Y., Lin, J.-M., Chen, Y.-Y., & Chen, Y.-C. (2015). Building-related symptoms among office employees associated with indoor carbon dioxide and total volatile organic compounds. International Journal of Environmental Research and Public Health, 12(6), 5833-5845.
40. Rackes, A., & Waring, M. S. (2013). Modeling impacts of dynamic ventilation strategies on indoor air quality of offices in six US cities. Building and Environment, 60, 243-253.
41. Vilcekova, S., & Meciarova, L. (2016). Monitoring of indoor environmental quality in a printing company–Case study. People, Buildings and Environment.
42. Guo, H., Lee, S., Chan, L., & Li, W. (2004). Risk assessment of exposure to volatile organic compounds in different indoor environments. Environmental research, 94(1), 57-66.
43. Kleinsorge, E. C., Erben, M., Galan, M. G., Barison, C., Gonsebatt, M. E., & Simoniello, M. F. (2011). Assessment of oxidative status and genotoxicity in photocopier operators: a pilot study. Biomarkers, 16(8), 642-648.
44. Wolkoff, P., & Nielsen, G. D. (2001). Organic compounds in indoor air—their relevance for perceived indoor air quality? Atmospheric Environment, 35(26), 4407-4417.
45. Nandan, A., Siddiqui, N. A., & Kumar, P. (2020). Estimation of indoor air pollutant during photocopy/printing operation: a computational fluid dynamics (CFD)-based study. Environmental geochemistry and health, 42, 3543-3573.