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Effect of Toner Coverage Percentage and Speed of Laser Printer on Total Volatile Organic Compound (TVOC)

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Good indoor air quality (IAQ) is essential to enhance human productivity and health. Emissions due to a laser printing in an office environment have been observed as one of the contributors to the poor IAQ. Of the various types of laser printers available in Malaysian market nowadays, this experiment chooses one famous laser printer to investigate the influence of toner coverage on the emission rates within 1 m^3 acrylic chamber. Total volatile organic compound (TVOC), carbon dioxide (CO_2) and temperature were monitored in 100 pages printing job with different percentages of toner coverage. Toner coverage significantly influenced laser printer speed to 30 pages/min, 20 pages/min and 15 pages/min. Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS) were used in identifying the elemental composition from the sample toner powder collected from the laser printer cartridges. This study showed that TVOC concentration increased rapidly at the beginning of printing process at maximum value of 0.68 ppm and its concentration started to decay at 30 pages of printing for all percentages of toner coverage. Meanwhile, 50 % of toner coverage resulted in not only the highest temperature of 300.7 K but also the highest CO_2 concentration which started to decay as it reached 50 pages of printing job. This study clearly shows the printer speed and the coverage of printing job could significantly influence the emission rates of compounds that reduce the quality of indoor environment.

1. Introduction

In the last decades, the emissions from laser printer to the indoor environment have been given wide concern. Printer is one of the common electronic office equipment attached with computer to help people in daily activity (Destaillats et al., 2008). With the availability of various types of printer around the world, their usage have become potential source of indoor pollutants (Kagi et al., 2007), such as volatile organic compound (Destaillats et al., 2008) , ozone (Wang et al, 2012) , and particles (Saraga et al., 2011) that may cause sick building syndrome (SBS) (DOSH, 2010). Usually a printer is located on a closer to human, as it help in daily activity. Pollutants are emitted immediately once the printing job starts until the end of printing process (Xerox Corporation, 2013). Most laser printers nowadays use xerography techniques or dry printing techniques which were introduced by Xerox in 1960s (Duke et al., 2002). The toner or black powder commonly used in printing process is located at photoconductor drum. The sheet of paper is passed through the drum, while the image will then pass onto the paper. The heat and pressure are being used by printer to ensure the toner powder sticks to the paper. However, in laser printing, the documents will be recreated using laser beam and transfer it to the charging roller (Health and Safety Department University of Edinburgh, 2010). VOCs, which is the primary contaminant emission, are vaporized by the laser printer fuser when heated (He et al., 2010) at certain temperature (Duke et al., 2002). As such, the fuser roller temperature is the primary parameter influencing the emission of laser printer (Morawska et al.,

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2009). Previously, the chamber experiment only considering 5 % of toner coverage have been conducted by several researchers in order to evaluate particles and chemical emissions from laser printer. Their experiments were carried out following the procedures as specified in ECMA 328 (2013) standards (Schripp et al., 2008). However, this experimental study have considered different percentages of toner coverage and identified the emissions from typical laser printer in 1 m^3 acrylic chamber. This paper reports a chamber study examining the TVOC emission during printing process at different percentages of toner coverage, as well as other IAQ parameters such as temperature and CO_2 (He et al., 2007).

2. Experimental Set-up

For this study, the selected laser printer was based on popular monochrome laser commonly used in Malaysian office environments, which is Canon LBP 6000. The objectives of the chamber experiment include investigating toner coverage of laser printer to the speed of laser printer in page per min, measuring TVOC emission from the laser printer with different percentages of toner coverage, and monitoring IAQ parameters such as temperature and CO_2 emitted from laser printer depending on laser printer speed and toner coverage.

2.1 Design of Experiment

The investigation and monitoring work were carried out inside 1 m^3 acrylic experimental chamber. The chamber was also equipped with stirring fan in order to ensure homogeneous inside atmosphere during experiment (He et al., 2010). The paper weighted 80 g/m^2 was used for printing process. This study considered four different percentages of toner coverage such as 25 %, 50 %, 75 % and 100 %. The printed area was set up accordingly before being printed by the laser printer. Under those circumstances, the different percentages of toner coverage would significantly affect the speed of laser printer (Byeon and Kim, 2012).

2.2 Experimental Procedure

Two devices were employed to monitor TVOC emission from the laser printer namely Gray wolf Sense TG-502 TVOC probes and TSI IAQ-Calc 8762-M-UK.

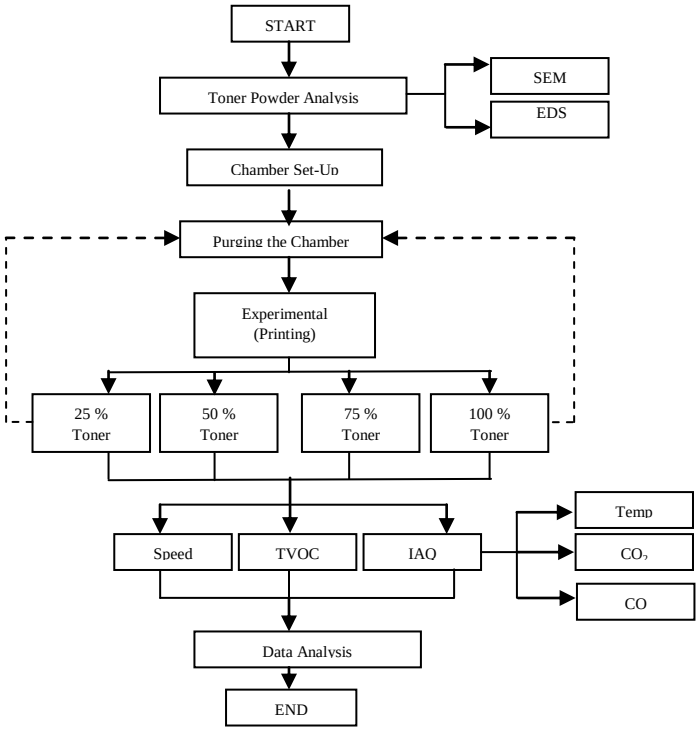


Figure 1: Experimental chamber flowchart

Before carrying out the chamber experiment, the sample toner powder of the laser printer were initially collected and analysed using Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS) in order to identify the elemental composition of the toner powder. The elemental

analysis of toner powder has been previously studied by Barthel et al. (2011) to identify potential sources of aerosol during printing and significantly showed the presence of elements that are inorganic and solid form such as Calcium (Ca), Titanium (Ti), and Iron (Fe). Figure 2 shows the experiment flowchart and steps to be followed in this study. The chamber were located in the Thermal Environmental Laboratory of UTHM. The room temperature was set at 296.15 K with relative humidity in the range of 50 - 60 %. The laser printer was placed at the centre of the chamber and measurements were taken for 100 pages of printing job as suggested by Morawska et al. (2009).

3. Result and Discussion

The results of this study are divided into four parts and discussed accordingly. The first part deliberates on the SEM and EDS analysis from the sample toner powder collected from the toner cartridges. Then, it discusses the relationship between the different percentages of toner coverage and the printing speed. Third part elaborates on TVOC emission from laser printer due to different percentages of toner coverage. Finally, the discussion on the emissions of other IAQ parameters, namely CO_2 and temperature, as observed and measured during printing process (Barthel et al., 2011).

3.1 SEM and EDS

SEM and EDS analysis were conducted to identify the elemental composition of the toner powder. Figures 3 (a) and (b) portray the 1000x SEM and 5000x SEM images of the toner powder, respectively. SEM/EDS analysis of the toner powder found that it mainly composes of 71.93 % mass of Carbon (C), 26.8 % of mass of Oxygen (O), and 0.74 % of mass of Silicon (Si). Other chemical compounds found in this particular toner powder include Sulphur (S), Zirconium (Zr) and Platinum (Pt) with 0.14 %, 0.18 % and 0.14 % of masses, respectively. The emission of VOC and aerosol are primarily coming from the evaporation of these elemental compounds (Sharma et al, 2013) due to certain heat from fuser of laser printer (Wang et al., 2011).

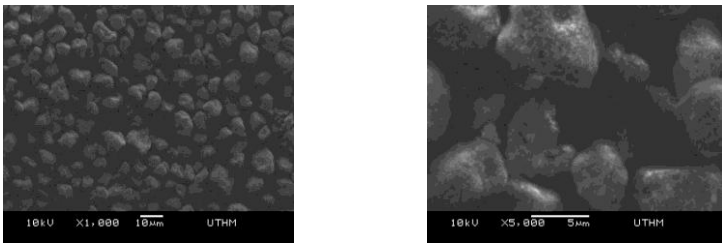
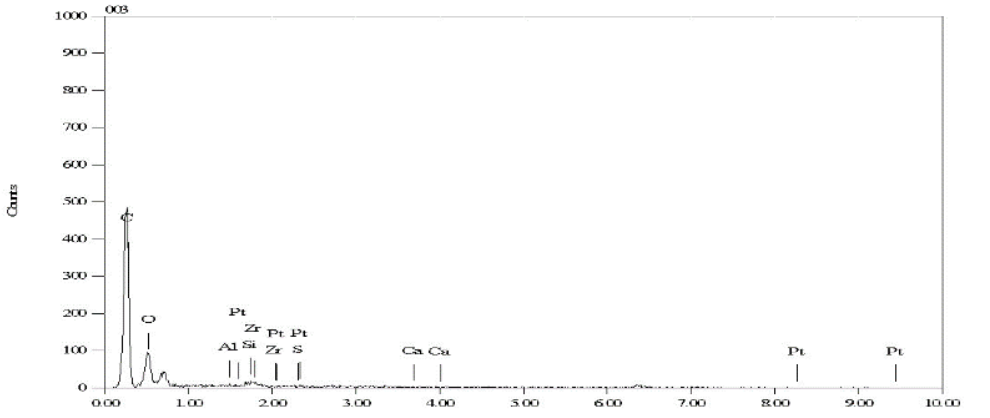


Figure 2: (a) 1000x SEM image of toner powder (b) 5000x SEM image of toner powder



Element		(keV)	mass%	Error%	Åt%	Compound	mass%	Cation	K
C K	*	0.277	71.93	0.13	77.78			109.4156	
O K		0.525	26.80	0.86	21.76			30.3871	
Al K		1.486	0.06	0.64	0.03			0.1045	
Si K		1.739	0.74	0.73	0.34			1.3726	
S K		2.307	0.14	0.79	0.06			0.2634	
Ca K									
Zr L		2.042	0.18	3.22	0.03			0.2615	
Pt M		2.048	0.14	4.26	0.01			0.1662	
Total			100.00		100.00				

Figure 3: Element characterization of toner powder using EDS

3.2 Printing Speed and Toner Coverage

Toner coverage are significantly influenced the speed of laser printer. The speed of laser printer were measured during experiment. 25 % of toner coverage showed the highest speed of printing that is 30 pages/min. Whereas, 50 % of toner percentage coverage have reduced about 33.3 % of laser printer speed to 20 pages/min, and 75 % and 100 % of toner percentages coverage have decreased 50 % of laser printer speed corresponding with 15 pages/min.

3.3 TVOC Emission

This experiment collected TVOC emission concentration correspond to 1,000 printed pages (Wang et al., 2011). Figure 4 shows the result of TVOC for the samples taken only during printing process, thus neglecting the decay concentration. At the beginning of the printing, the printing task started to measure the concentration of TVOC when its rate was at or below than 0.25 ppm referring to direct measurement. TVOC amount for all percentages of toner coverage demonstrated a rapid increase in VOC concentration during the earlier phase of printing process typically ranging from 5-10 pages (Morawska et al., 2009), and started to decay afterwards (Koivisto et al., 2010). As expected, printing phase with the highest percentage of toner coverage that is 100 % depicted the highest TVOC emission from the laser printer. With 100% toner coverage, maximum value of 0.64 ppm was captured at the earlier printing phase. Whereas, for 75 %, 50 %, and 25 % toner coverages, the captured maximum values were 0.6 ppm, 0.48 ppm, and 0.25 ppm, respectively.

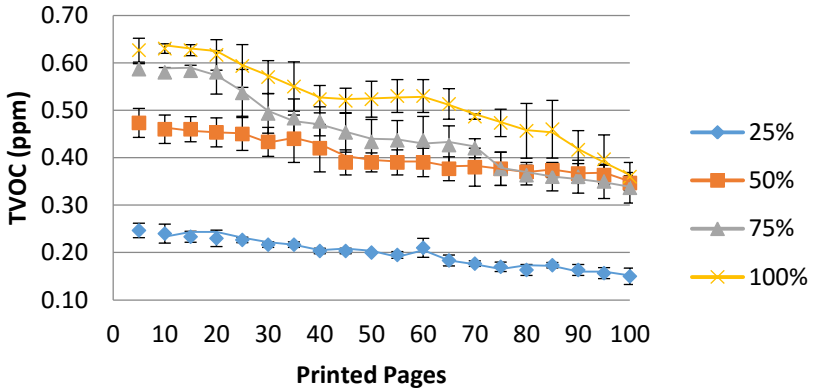


Figure 4: TVOC Emission from laser printer due to different toner coverages

3.4 Temperature Increment and CO_2 Emission

Along with TVOC, others IAQ parameter such as temperature and CO_2 have also been monitored and measured in order to have a better understanding of laser printer emission. Figure 6 illustrates the temperature changes as the number of printed pages gradually reach 100 pages during the printing process. As mentioned earlier, the surrounding room temperature was set to be 296.15 K with relative humidity ranging from 50 to 60 %. In this experiment, it can be clearly seen from Figure 5 that for 50 % of toner coverage which correspond to 20 pages/min of printing speed, the temperature increases most rapidly as compared to that of the others throughout the printing process. In general, all printing phase of different percentages of toner coverage show the gradual rise of temperature. Apparently, the measured temperatures in this experiment have significantly demonstrated that the increasing in temperatures during the printing process, for all the different percentages of toner coverage, was mainly caused by the speed of the laser printer. The percentage of toner coverages would reduce the speed of laser printer, hence the temperature produced by laser printer would increase depending of the printing job and fuser roller temperature.

CO_2 is a colourless gas that normally appears in our surrounding environment. Figure 6 presents the CO_2 emission from the laser printer due to the different percentages of toner coverage. The CO_2 concentration were measured regularly at 10 printed pages interval from the beginning of printing job until the number of printed pages reached 100 pages. It can be seen clearly from Figure 7 that the laser printer emitted CO_2 rapidly from the beginning of the printing process, and then started to decay gradually as the number of printed pages reached 50 pages. The 50 % of toner coverage has emitted the highest value of CO_2 as the number of printed pages were in the range of 30 - 70 pages of printing process. These situations apparently delineate the higher laser printer speed. The 75 % and 100 % of toner coverages; however, presented the slowest speed of printing, hence reducing the emission of CO_2. In addition, the emission of CO_2 started to decay (Byeon and Kim, 2012) as the number of printed pages reached 70 pages (Koivisto

et al., 2010). The effect of laser printer fuser temperature previously discussed by He et al. (2010) had indicated that fuser roller temperature were claimed to be the major contributing factor that affect the operation and emission of laser printer.

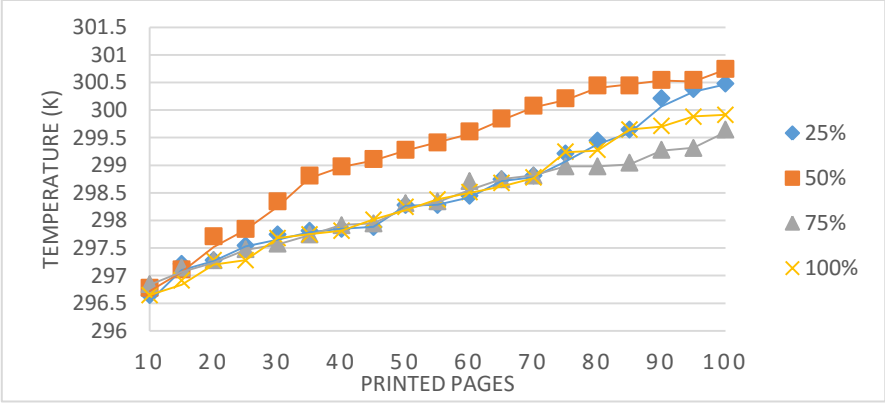


Figure 5 : Temperature increment during printing process at different toner coverages

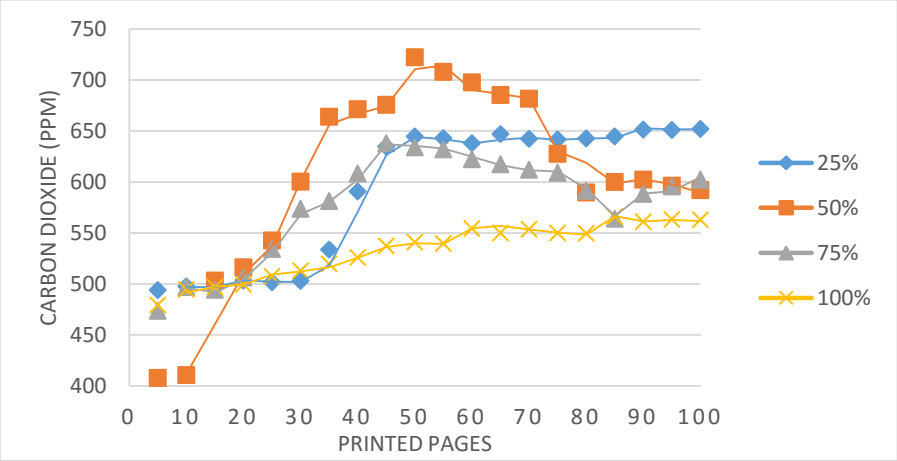


Figure 6: CO_2 emission from laser printer

4. Conclusions

In this paper, the chamber experiment have been discussed as an attempt to have a better understanding of contaminants emission from typical laser printer. The experimental results indicated that percentage of toner coverage significantly affect the printing speed, hence influencing the emission from laser printer. Therefore, industrial printing machine that have high speed machines may have greatest emission rates since it relates to the company economy growth. Typical laser printer may influenced by toner coverage and it's slow the roller fuser. Toner powder has been analysed using SEM and EDS in order to determine the element characterization. It was found that carbon (C) is the major compound in the toner powder with 71.93 % of mass. Furthermore, TVOC and other IAQ parameters have also been discussed. All percentages of toner coverage have shown a rapid increase in TVOC concentration during the early phase of printing job with maximum values typically within the range of 5 - 10 printed pages. The temperature were influenced by the speed and printing job. Therefore, toner coverage would slow down the speed of laser printer, thereby resulting in the increment of temperature. It is also important to note that this paper is neither aimed at quantifying nor comparing emission rates from different printers (Wolkoff et al., 1993). However, this paper concentrates on discussing the effects of different percentages of toner coverage on the speed and emission rates of laser printer. Printer identified as factor to contribute to IAQ problem, hence air monitoring is an ideal way to sustain good IAQ (Sironi et al., 2014). Further study will carried out to investigate the emission rates with different toner coverages and models of printer.

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