INDOOR AIR POLLUTION IN OFFICE ENVIRONMENT DUE TO VOC EMITTED FROM ELECTRONIC EQUIPMENT

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Abstract - Indoor air quality, especially in the modern office environment, is an important parameter in relation to the health and well being of those who occupy these office spaces. Volatile organic compounds or VOCs evaporate under the temperature and pressure conditions prevailing in indoor environments leading to their increased concentration indoors as compared to outdoors. Recent studies have recognized electronic equipment as prominent emitters of VOCs. Emission characterization for printers and photocopiers has established these equipment as potential contributors to VOC contamination indoors.

Keywords - Volatile organic compounds (VOC), Electronic equipment, Office environment, Indoor air quality.

I. INTRODUCTION

Emitted particles present indoor in an office environment are a combination of particles generated from various sources, including laser printers which emit paper fibers, organic vapors and inorganic gases [1]. Printers and photocopiers have been found to emit VOCs, ozone and ultrafine particles. Studies conducted on photocopiers are scanty as compared to those done with printers. Recent studies indicate emissions from laser printers are primarily aerosol condensates of volatile organic compounds (VOCs) or semi-volatile organic compounds (SVOCs). Microanalysis of printer aerosols collected onto transmission electron grids have confirmed that the emissions are almost entirely composed of SVOCs, with only trace quantities of some inorganic particles [2].

II. VOC EMISSIONS

2.1. Emission Levels

Printer emissions vary with type of printers and within models of printers and up to three times higher emission rates have been encountered with color laser printers [3]. Particle emission levels are known to be printer specific and affected by printing conditions including the number of pages printed, cartridge model, cartridge age and toner coverage. During a specific working day, level of exposure to printer emissions depends upon factors such as closeness to the printer, room ventilation, printer model, printer age, toner coverage, type of paper, and the number of print runs during the day [1]. Comparison of TVOC emissions from various types of office printers using a dynamic environmental chamber reveals that the TVOC emission rates of laser printers are the highest and about 6 times that of ink-jet printers [4]. Tests conducted on 3 printers and 4 photocopiers concluded that all of them emitted VOCs although with differences in individual compounds and their concentrations [5]. Some patent literature investigated 62 printers and categorized 60% of them as non-emitters, 40% as emitters and 27% as high particle emitters [1].

2.2. Sources of Emissions

Emissions from office printers results from operation (toner, ink, and paper) and off-gassing from components (e.g., plastic casings or circuit boards). Also, the emissions of idle mode from all equipment are found to be relatively lower compared with emissions from operation [4].The chemical emissions in printers and photocopiers can result from circuit boards, inks and toners, papers and plastic construction materials [5]. It is understood from the literature that VOCs are evaporated from toner, paper etc. due to very high temperatures found around the fuser rollers. The sources of specific VOCs are different. Styrene is emitted from the toner used in printing while o, m, p-xylene are emitted from the printer's materials, as these compounds are generated when printers are not only normally printing but also idling [6]. Tests run on printer paper, samples of toner powder, fuser rollers, and a sample of lubricating oil by placing them in a ceramic container and heating in a furnace revealed that emissions for each material tested depended on the temperature of the material, with the concentrations of particle number and TVOCs negligible until some threshold temperature was attained [2]. It was also found that the particles were volatile and of secondary nature, being formed in the air from VOCs originating from both the paper and hot toner. High-temperature fuser region is the possible source of evaporating VOCs and the emissions take place from the polymer coating of the toner powder on the page, and residue from previous printings [7].

2.3. Specific VOC Emissions

From the research several VOCs including xylene, styrene, and ethyl benzene have been identified as printer emissions. Aromatic compounds (toluene, m-xylene, p-xylene, ethyl benzene, and styrene) are the

dominant substances in printers due to their low thresholds [4]. Higher mass concentrations noted in a study for xylenes were up to 40.5 μgm^{-3}, ethyl benzene up to 41.3 μgm^{-3}, trimethylbenzene up to 45.6 μgm^{-3} and toluene up to 37.7 $\mu g\ m^{-3}$ [5].The maximum possible VOC emissions estimated by another study results to be about 42.8 µg per printed page and among specific VOCs m, p-xylene had the highest concentration, approximately 160 $\mu g/m^3$, and o-xylene and styrene were the second highest, with concentrations of approximately 100 $\mu g/m^3$ [7]. Concentrations of toluene and styrene were found to decrease during peak printing hours and hence it was hypothesized that it was due to ozone formation and subsequent reaction with VOCs [8].

Table 1.VOCs emission data from various studies

S.NO.	Wang et al.(2011) [7]	Lee et al.(2001) [4]	Betha et al. (2011)[8]	Kowalska et al. (2015) [5]
1.	Toluene	Toluene	Toluene	Toluene
2.	Ethylbenzene	Ethylbenzene	Ethylbenzene	Ethylbenzene
3.	m; p-xylene	m; p-xylene	m-Xylene p-Xylene	Xylenes
4.	Styrene	Styrene	Styrene	Styrene
5.		Benzene	Benzene	Benzene
6.	o-Xylene	o-Xylene	o-Xylene	
7.		Freon12	Freon 12	
8.		Methyl chloride	Methyl chloride	
9.		Freon114	Freon 114	
10.		1,3-Butadiene	1,3-Butadiene	
11.		Freon11	Freon11	
12.		1,1-Dichloroethene		
13.		Methylene chloride	Methylene chloride	
14.		Freon113	Freon 113	
15.		Carbon tetrachloride	Carbon tetrachloride	
16.		Trichloroethene	Trichloroethene	
17.		Tetrachloroethene		
18.	1,3,5-Trimethylbenzene	1,3,5-Trimethylbenzene		
19.		1,4-Dichlorobenzene		1,4-Dichlorobenzene
20.	1,2,4-Trimethylbenzene	1,2,4-Trimethylbenzene		
21.		1,2-Dichlorobenzene		1,2-Dichlorobenzene
22.		1,2,4-Trichlorobenzene		1,2,4-Trichlorobenzene
23.	n-Butyl acetate			Butyl acetate
24.		Hexachlorobutadiene		
25.		1,3-Dichlorobenzene		
26.		Chloroform		
27.			1,1,1 -Trichloroethane	
28.			3-Methylpentane	
29.			a-Pinene	
30.			b-Pinene	
31.			2-Methylpentane	
32.			Isoprene	
33.				Trichloroethylene
34.				Tetrachloroethylene
35.				Chlorobenzene
36.				Trimethylbenzene
37.				α-Methylstyrene
38.				Decamethylcyclopentasiloxane
39.				Naphtalene
40.				TVOC
41.	1-Ethyl-2-methylbenzene			
42.	1-Ethyl-3-methylbenzene			
43.	Decanal			
44.	n-Dodecane			
45.	n-Hexadecane			
46.	Nonanal			
47.	n-Pentadecane			
48.	n-Tetradecane			
49.	n-Tridecane			

CONCLUSIONS

The literature evaluated for this brief review indicates the majority of particulates emitted from printers and photocopiers are likely to be aerosols of VOCs and SVOCs. Most of the studies have focused on the size characterization of particles and the formation mechanism of these particles. Research is required to identify the different VOCs being emitted from these devices which ultimately react in the presence of heat and ozone to form ultrafine particles. It is also recognized that the full chemical nature of printer and photocopier emissions and their toxicity is unknown. Also, not all the chemical components of these emissions have been characterized. Given the myriad of printing and photocopying devices and the different operating conditions, the emission identification and characterization is very challenging. However, monitoring of indoor air quality in working spaces is required to limit the exposure of workers.

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