Particle Measurement of Hardcopy Devices

M. Wensing[1], G. Pinz[1], M. Bednarek[1], T. Schripp[1], E. Uhde[1] and T. Salthammer[1,2]

[1]Fraunhofer Wilhelm-Klauditz-Institute, Material Analysis and Indoor Chemistry
Bienroder Weg 54E, D-38108 Braunschweig, Germany
email: michael.wensing@wki.fhg.de http://www.wki.fhg.de
[2]University of Applied Sciences, Salzdahlumer Str. 46/48, 38102 Wolfenbuettel, Germany

Summary: *The present work describes the investigation of the particle emissions of hardcopy devices (laser printers and multi-function devices) in the current printer operation. The measurements took place under standardized climatic boundary conditions (temperature, humidity and air exchange) in a 1 m^3 glass emission test chamber. As measuring instruments a Condensation Particle Counter (CPC) as well as an optical particle counter were used. The results of these investigations show that within the range of 7 nm to 20 µm particle emissions are detectable. The results point on the fact that here beside toner particles also aerosols generated during the printing process can be responsible.*

Keywords: *hardcopy devices, particle emission, VOC, SVOC, chamber measurement*
Category: *particulate matter*

1 Introduction

Like other electronic devices (TV sets and video recorders) [1] also hardcopy devices such as laser printers, copiers and multi-function devices can emit volatile and semi-volatile organic compounds (VOC/SVOC) [2], and in addition, ozone and dust during operation. In the context of the assignment of the German environmental label “blue angel” ("Blauer Engel") these emissions are measured and evaluated on the basis of test chamber investigations [3]. Here, the dust emissions are determined gravimetrically so far without closer characterization of the particle size [4, 5]. However, the quantitative emission of particles is often so small that no ponderable dust emissions can be measured.

The present work describes test chamber investigations of hardcopy devices where alternatively optical measuring methods are used allowing the collection (counting) of particles starting with a size of 7 nm. The meaning of such measurements is the following: On the one hand with this analytical technique a wide size spectrum of particles including so called ultra-fine particles (UFP, particles size < 0.1 µm) could be detected [6], on the other hand the question if particles from toners contribute to the emitted spectrum of particles should be possible to be answered.

2 Methods

The investigations of 10 different hardcopy devices (see table 1) took place in accordance with the assignment basis for the "blue angel" under defined climatic conditions (temperature, humidity and air exchange) [4, 5] in a special 1 m^3 glass test chamber. The influence of particle deposition on the chamber walls was not studied in the present paper. During the printing phase a sample document with a surface coverage of 5 % black was printed out. For the printing process normal white paper (80 g/m^2) was used. The air exchange in the test chamber during and after the printing phase was $N = 3\ h^{-1}$.

For the particle counting two different measuring instruments were used to monitor the progression of the particle numbers during the printing operation. The first device was a Condensation Particle Counter (CPC) model 3022A (TSI), measuring range starting from a particle size of 7 nm up to 3 µm with a sampling rate of 1.5 l/min.. By use of diffusion nets it could be differentiated between particles > 7 nm and > 103 nm employing the CPC. For this purpose two printing operations each were investigated, the CPC was operated once with and without diffusion nets.

At the investigation of the device No. 11 (multi-function device) the CPC was used in combination with an EC (electrostatic classifier) to form a SMPS (scanning mobility particle sizer) allowing the determination of the ultra-fine particle size distribution (< 0.1 µm) in one printing operation. This investigation took place separately from the “blue angel” (“Blauer Engel”) sampling.

The second measuring device was an optical particle counter (OPC) type 1.108 (Grimm) allowing the differentiation of 15 different size fractions of particles between > 0.3 µm and > 20 µm. The sampling rate was 1.2 l/min.

On the basis of the determined particle concentrations the rates for the particle emission were calculated with the following equation, see also [7]:

$$SER_P = \frac{C_P * n * V * t_T}{t_{Pr}} \quad (1)$$

SER_P: calculated particle emission rate [#P h^{-1}]

Cp : mean particle concentration [#P m^{-3}]

n : air exchange rate [h^{-1}]

V : volume test chamber [m^3]

t_T : total sampling time [min]

t_{Pr} : printing time [min]

Table 1 offers an overview on the investigated devices. All of them are new devices the particle emission of which was determined parallel to the "blue angel" measurement.

Table 1. Overview hardcopy devices; type, printing time, printed pages.

No	Typ	printing time [min]	printed pages [number]
1	LP	15	250
2	LP	15	250
3	LP	14	250
4	LP	18	500
5	MFD	12	253
6	MFD	10	250
7	MFD	12	250
8	MFD	10	500
9	LP	10	500
10	LP	10	250

LP: laser printer; MFD: multi-function device

3 Results

Table 2 shows a compilation of the measured particle numbers for the different particle sizes (> 7 nm, > 0.1 µm und > 0.3 µm) for the devices Nos. 1 – 10. Presented is the mean particle concentration for the individual particle size fractions during the printing operation and the so-called trail phase. Figure 2 presents exemplarily a typical course of the particle concentration for all particles > 7 nm in the test chamber during a printing operation of 18 minutes (device No. 4). For all devices the fraction of the particles > 0.3 µm represents by far the smallest portion. All tested devices showed an optically assessable particle size distribution (> 0.3 µm) with the maximum particle concentration being in the size fraction 0.3 -0.4 µm. Figure 1 comprises the emission rates per hour calculated for the two particle sizes (> 7 nm und > 0.1 µm) according to equation (1). The majority of the detected particles is part of the fraction of the ultra-fine particles. In Figure 3 for device No. 11 the course of the ultra-fine particle concentration is presented during the printing operation of 25 and two times 100 pages. Figure 4 shows the course of the UFP for device No. 11 during the printing operation of 1 and 25 pages. Using SMPS the maximum of particles at the start of a printing operation was determined at a size of 20 nm and at the end of the printing at 40 nm. See also [8] regarding the time-related change of the particle sizes during the printing operation.

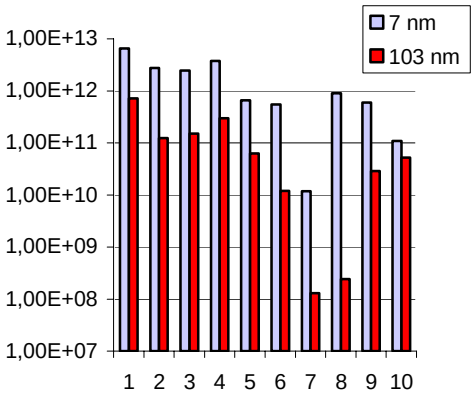

Figure 1. Calculated particle emission rates SER_P [#P h^{-1}] of different sizes: > 7 nm, > 0.1 µm.

Table 2. Measured particles numbers of different sizes: > 7 nm, >0.1 µm and > 0.3 µm.

No	Particles > 7 nm [#P/cm^3]	Particles > 0.1µm [#P/cm^3]	Particles > 0.3 µm [#P/cm^3]
1	343,000	38,000	1.13
2	145,000	6,000	0.79
3	123,000	8,000	0.97
4	140,000	11,000	8.94
5	28,000	3,000	1.15
6	20,000	400	1.14
7	500	6	not measured
8	33,000	9	2.47
9	22,000	1,000	1.46
10	5,000	2,000	not measured

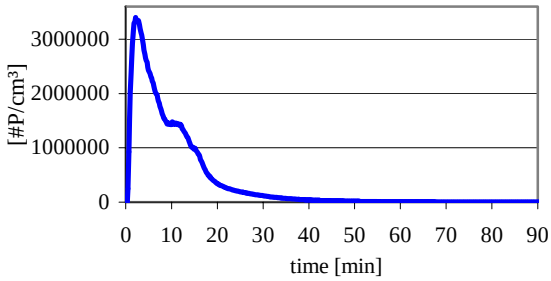

Figure 2. Device No. 4: particle concentrations over time for particles > 7 nm.

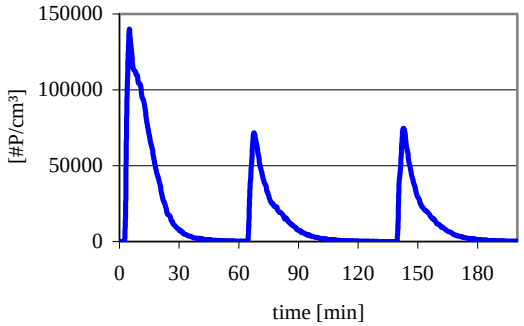

Figure 3. Device No. 11: particle concentrations over time for the UFP fraction (> 7 nm < 0.1 µm) during the printing operation of 25, 100 and 100 pages.

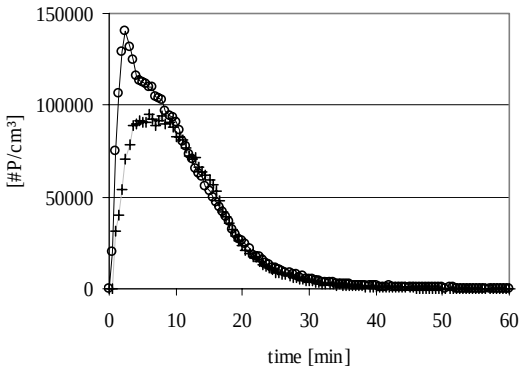

Figure 4. Device No. 11: particle concentration over time for the UFP fraction (> 7 nm and < 0.1 µm); printing of 1 page (“ + “) and 25 pages (“ o “).

4 Discussion and Conclusion

In the present paper measuring data of particle counting devices for the emission of particles > 7 nm in the operation of hardcopy devices are presented within the framework of dynamic test chamber investigations. Figure 2 shows a typical time/concentration course during a printing operation for particles with a diameter > 7 nm. Immediately when beginning the printing operation the particle concentration in the test chamber increases. But before completion of the printing, which lasted in the example shown 18 min, the particle concentration already decreased again, to finally decrease to the initial value before the printing started. This course of the particle concentration in the present investigations turned out to be typical and points on the fact that the emission does not run continuously over entire printing process. In this respect the calculated emission rates according to equation (1) (Figure 1), which takes a temporally constant emission for basis, will describe the true emission behaviour only insufficiently.

To localize the source of the detected particles (toner, paper etc.?) the knowledge of the size distribution is of interest. Table 2 shows the averaged particle concentration for the three size classes 7 nm, 0.1 µm and 0.3 µm over the duration of the respective measurement. From all examined devices emissions of so-called ultra-fine particles (particle < 0.1 µm) occur, which constitute apparently even the main part of the emission. In contrast particles > 0.3 µm, represent only a very small portion of the entire particle emission. This size fraction is of special interest concerning the source of particles, since the typical size of toner particles as a function of the employed type of toner is within the range of 5 – 10 µm. Concerning the kind of the particle distribution for particles between 0.3 µm and 20 µm for all devices examined here it was without exception found that the toner size fraction of the total emission plays practically no role during printing operation. The same applies probably also to particle emissions by abrasion of the paper. These results confirm also earlier findings for black/white laser printers [9] and colour laser devices [10], where no toner dusts were detected in during printing operation.

In the course of the investigations it turned out that emissions of particles in the size range of toner particles did not play a role. For all devices the so-called ultra-fine particles (< 0.1 µm) were detected as main portion of the emission; these emissions were examined more closely by the example of device No. 11. In addition, the effect that very short-term particle emissions were observed at the beginning of each printing operation was (see figure 2) investigated more detailed. In Figure 3 the concentration vs. time course of the ultra-fine particle fraction is shown for three sequential printing operations with 25, 100 and 100 pages, respectively. It can be recognized clearly that the initial printing of 25 pages causes a considerably higher particle concentration in the test chamber compared to the following printing operations of 100 pages each. This effect was reproducible both with repeated measurements on a subsequent day with the same device as well as with another multi-function device in a second test series. The effect could be caused by a longer idle phase of the device (without

printing operation) after which a brief printing operation is obviously sufficient to initiate a considerable particle emission.

For this printer it also seems that the printing duration and/or the number of printed pages has no considerable influence on the height of the initial emission. This is pointed out in Figure 4, the printing of 1 and 25 pages with device No. 11 generates quite comparable emissions of ultra-fine particles and indicates no linear correlation between the number of printed pages on the one hand and the number of emitted particles on the other hand. As a possible cause for the occurrence of these emissions toner emissions can very likely be excluded due to the particle size of the detected particles and also because of the missing page relation.

It can be assumed that the ultra-fine particles measured in the experiments are generated by condensation processes of VOC/SVOC emissions of the device [1], which lead to small droplets/particles and are registered by the particle counters [11]. Especially emissions of volatile/semi-volatile compounds from plastic construction parts of the printer, which are initiated by operational heating processes within the device, may add to the particle generation effect. As soon as the printing operation starts, it comes to a short emission causing a release of particles. Further studies of a manufacturer of hardcopy devices indicate that emissions of siloxane oligomer components from a heated press-roller contribute as a major source to the detected ultra-fine particles.

It probably takes a certain time until those compounds have migrated again to the heated zones before a repeated printing operation will generate the same number of particles. If print jobs are separated by only brief pauses (Figure 3) the particle concentrations were found to be lower than during the initial print job.

Up to now only few data about particle emissions of hardcopy devices are available. Therefore the interpretation of the results is tentative and further investigations are required in order to better understand the origin, composition and temporal dynamics of the ultra-fine particle emissions of the hardcopy devices described here. Recent measurements indicate that other printer types show a considerable relation between the number of pages printed and the amount of ultra-fine particles released. Finally, it would also be interesting to find out how the particle emissions are related to the age of the entire device or certain consumable like toner cartridges.

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