Bibliography

This bibliography lists selected publications relating to use of TSI's particle measurement instruments in office hardcopy devices emissions research. Recent research suggests that office devices like photocopiers, laser printers and multifunctional devices are often a significant source of ultrafine particles (particles less than 100 nm in diameter). These tiny particles are associated with adverse health impacts. With renewed concern about airborne particles in indoor environments, and specifically in office environments, this area of research is a hot application for TSI instruments.

Latest research studies are listed below.

He, C.; Morawska, L.; Taplin, L. 2007, "Particle Emission Characteristics of Office Printers," *Environmental Science and. Technology,* 41 (17), 6039 -6045, 2007. [DOI :10.1021/es063049z S0013-936X(06)03049-5]

Abstract
In modern society, printers are widely used in the office environment. This study investigated particle number and $PM_{2.5}$ emissions from printers using the TSI SMPS, TSI CPC 3022, and 3025A TSI P-Trak and DustTrak. The monitoring of particle characteristics in a large open-plan office showed that particles generated by printers can significantly ($p = 0.01$) affect the submicrometer particle number concentration levels in the office. An investigation of the submicrometer particle emissions produced by each of the 62 printers used in the office building was also conducted and based on the particle concentrations in the immediate vicinity of the printers, after a short printing job, the printers were divided into four classes: non-emitters, and low, medium, and high emitters. It was found that approximately 60% of the investigated printers did not emit submicrometer particles and of the 40% that did emit particles, 27% were high particle emitters. Particle emission characteristics from three different laser printers were also studied in an experimental chamber, which showed that particle emission rates are printer-type specific and are affected by toner coverage and cartridge age. While a more comprehensive study is still required, to provide a better database of printer emission rates, as well as their chemical characteristics, the results from this study imply that submicrometer particle concentration levels in an office can be reduced by a proper choice of the printers.

Kagi, N; Fujii, S; Horiba, Y; Namiki, N; Ohtani, Y; Emi, H; Tamura, H; Kim, Y.S**.** 2007, "Indoor Air Quality for Chemical and Ultrafine Particle Contaminants from Printers," *Building and Environment,* Volume 42, Issue 5, May 2007, Pages 1949-1954 [DOI:10.1016/j.buildenv.2006.04.008]

Abstract
There are various emission sources of chemical contaminants, such as volatile organic compounds (VOCs) and ozone and particulate matter. This report is a study into the indoor air of a room containing either a laser printer/ink-jet printer, and the air contaminations were monitored for VOCs, ozone and ultrafine particle. The result confirmed an increase in the concentration of ozone and ultrafine particle numbers in the printing processes of the printer. The emission of VOCs and ozone were measured by the use of a test chamber. The chamber concentrations of styrene, xylenes and ozone were increased in printing process of the laser printer, and pentanol was detected from the ink-jet printer. The results suggest that an office or residential printer may be a source of indoor air contamination. It is necessary for emission from printers to monitor not only VOCs and particle but also ultrafine particles and other contaminants in indoor air.

Wensing, M; Pinz, G; Bednarek, M; Schripp, T; Uhde, E; Salthammer, T. 2006, "Particle Measurement of Hardcopy Devices," *Proceedings of Healthy Buildings*, Lisboa, Portugal, Vol. II, 461-464

Abstract
The present work describes the investigation of the particle emissions of hardcopy devices (laser printer and multi-fuctional devices) in the current printer operation. The measurements took place under standardized climatic boundary conditions (temperature, humidity and air exchanges) in a 1 m^3 glass emissions 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 nm particle concentrations are detectable. The results point on the fact that here beside toner particles also aerosols generated during printing processes can be responsible.

Uhde, E; Wensing, M.2006, "Characterization of Ultra-fine Particle Emissions from a Laser Printer," *Proceedings of Health Buildings2006,* Lisboa, Vol.II, 479-482

Abstract
A laser printer for home and office use has been tested regarding emissions of sub-micrometer particles. Total concentration of ultra-fine as well as particle size distributions were measured in a small chamber. Toner coverage, paper type, and the number of pages printed were varied. Particle number concentration around 1.8x 10^6 cm^{-3} were measured. The printer released particles with a mean size of 90-120 nm. Smaller particles were detected during the first minutes after starting a printer job. The dependence of the page coverage and the number of printed pages was found to be weak.

Niwa, A; Norcio, L; Biswas, P. 2004, "Aerosol emissions from laser printers," poster # 8PC2*, American Association for Aerosol Research Conference 2004, Atlanta, GA*

Abstract
There is a renewed concern about aerosols in indoor environments, and specifically in office environments. In this study, emissions from laser printers was investigated. The objective was to understand the source of the particles, and understand some of the mechanistic details of the formation and emission process. In the first part of the study, particle measurements were performed at various locations around the printer. In addition, different temporal measurements were conducted to cover the warmup and printing cycles. Largest particle concentrations were observed at the back and location where the paper exits the printer. Highest particle concentrations were observed during the warmup cycle followed by the printing cycle. Measurements of size distributions were obtained by a SMPS, with and without a diffusion denuder in line, and no significant differences were observed. The size distributions showed peaks around 20 to 50 nm. These particles were collected on an electron microscope grid in an electrostatic sampler, and spherical particles were observed by SEM (Scanning Electron Microscopy). The measured data was analyzed, and the qualitative understanding was that the particles were being formed during the "toner fixing" process. The toner fixing process involves heating the paper, and resulted in VOCs (volatile organic compounds) emissions from the toner particles. It was conjectured that the organic compounds were then nucleating to form particles. To further understand this process, a flow reactor was designed and constructed to study particle formation when toner particles are heated. The temperature range was from 150 to 220 C to cover the range of the fixing process. Preliminary results showed that the particulate emission increased with temperature, with a jump in concentrations after 180 C. The peak of the size distributions was between 20 and 50 nm, and matched that measured in the vicinity of the laser printer. Additional results on the composition of the particles and a mechanistic pathway of formation will be discussed.