Toxicological investigation of laser printer emissions –
Effects on human cells

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Introduction
Laser printer emissions have recently received much interest due to increasing health-related effects at the office workplace. The aim of the present study was to establish an in vitro test system to reveal the potential risk of laser printer emissions to human health. For this purpose, human lung epithelial A549 cells or peripheral mononuclear blood cells (PMBC) were exposed to laser printer emissions on transwell inserts in a Vitrocell® air-liquid interface exposure system. Physical properties such as temperature, humidity, particulate matter (PM1.0, PM2.5, PM10), ultrafine particles (diameter range between 10 – 1000 nm), ozone and chemical properties such as total organic carbons (TOC), volatile organic compounds (VOC), total volatile organic compounds (TVOC) of laser printer emissions were studied. Furthermore, biological effects including cytotoxicity and genotoxicity of laser printer emissions on human lung cells (A549) and release of cytokines of peripheral mononuclear blood cells (PMBC) had also been studied.

Results & Conclusions
The physical and chemical results showed that each tested printer had its own specific emission profile (Tab 1). Mean PM10, PM2.5, PM1.0 and ultra fine particle emissions were 0.06 – 4.27, 0.12 – 1.04, 0.35 – 1.09 µg/m³ and 14 – 368232 Particles/cm³, respectively. The major detected volatile compounds were 2-butanone, hexanal, hexamethylcyclotrisiloxane, styrene, o-xylene, ethylbenzene, m,p-xylene, benzaldehyde and ethylacetate. Exposure of A549 cells for 1 h to laser printer emissions caused an increased induction of micronuclei which was detected for two out of the five tested laser printers compared to cells exposed to filtered, clean air, whereas cell viability (WST-1-assay) and cell proliferation (CBPI) were not affected. The micronuclei number of the two positive printers were 20.8 ± 3.03 (n = 5) and 24.8 ± 2.77 (n = 5), respectively. Compared with clean air 6.83 ± 1.33, the two printers showed significant increased micronuclei frequencies (p < 0.001, student’s t-test). Furthermore, exposure of A549 cells for 1 h to the emissions of laser printer D resulted in enhanced IL-2, IL-10 and IL-12 levels after 24 h of incubation. We were able to show that our emissions test chamber/in-vitro exposure system is suitable for assessment of toxic effects of laser printer emissions on primary or cultured human cells. Our results indicate that laser printer emissions can cause pro-inflammatory and genotoxic effects in human cells in vitro. Further experiments have to be performed to analyse various types of laser printers and to evaluate the agents which are responsible for the observed toxic effects.

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Material & Methods
The atmosphere was generated in a conditioned emissions test chamber (volume 1 m³, temp. 21°C, rel. humidity 50%, air exchange 1 h⁻¹) where the laser printer were placed. TOC was measured by a photoacoustic detector using propane as reference. Ozone was measured by a chemiluminescent analyzer. PM1.0, PM2.5 and PM10 were measured by an aerosol spectrometer. Ultrafine particles were measured by a condensation particle counter (CPC). VOC and TVOC were analysed according to ISO 16000-9 using sorbent tube thermal desorption (TD) and gas chromatography (GC) coupled to mass spectrometry (MS). After exposure experiments of 1 h at a constant flow of 5 mL/min cell cultures were tested in a Vitrocell® air-liquid interface exposure system for different biological responses like cell viability (WST-1 assay), release of cytokines as a marker of pro-inflammatory changes and for induction of micronuclei (CB-MNv4+test) as a marker of genotoxicity.

Tab 1: Overview of emissions of TVOC, fine and ultra fine particles as well as cell viability and micronucleus induction in A549 lung epithelial cells after 1h exposure to different laser printer emissions.

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![Graph](graph-url)

![Table](table-url)