

Health hazards caused by emissions of laser printers and copiers?

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Abstract

Laser printers and copiers are suspected to emit toner dust and volatile organic compounds and thereby to represent a health hazard. This article summarizes the present state of knowledge about emissions of laser printers and copiers and the present quality standards. There are no data showing an excess exposure of consumers working with laser printers and copiers to inhalable fine dust and volatile organic compounds. Toxicity studies show that toners consist of low-toxicity poorly soluble particles. In experimental animals, accumulation of toner particles in the lung following long-term inhalation exposure to high toner concentrations may cause chronic inflammation and lung fibrosis. Chronic in vivo inhalation studies with rats and hamsters did not show increased lung tumor rates. However, intratracheal instillation of very high toner doses produced significantly increased lung tumor rates in rats. Since there is no significant exposure of consumers to toners using copiers and laser printers these effects are unlikely to occur in humans. Case reports show that inhalation exposure to toner may be associated with symptoms of the upper and lower airways in sensitive subjects. Presumably, these symptoms are related to individual hypersensitivity reactions. Most of these reports suffer from severe shortcomings (inadequate documentation of medical history and exposure; inadequate evaluation of causal relationships).

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1 Introduction

Personal computers, printers, copiers and fax machines are part of the everyday environment of thousands and millions of people. They are used in numerous offices, laboratories and industry workplaces, in shops and hotels, in medical practices and schools as well as in many private households. Thus the question whether harmful substances are released when operating these devices and to what extent they are released is an important issue of public interest since millions of people worldwide would be affected.

In Germany in particular, a public debate on the release of harmful substances from office devices has developed. The question uppermost in mind is whether operating laser printers and copiers emit toner dust and volatile organic compounds (VOC) and whether this leads to an exposure of office workers and consumers to harmful substances. Test and computer magazines as well as TV programmes have repeatedly been reporting “alarming” test results and have produced a feeling of insecurity in many consumers.

Among the health effects associated with operating laser printers are persistent rhinitis, sore throat, cough, asthma as well as inflammations of the eye or skin. Moreover, it has been claimed that toners may be carcinogenic and may cause inflammations [1; 2].

To make the discussion more objective, comments and information brochures have been published by different institutions, e.g. Bundesanstalt für Arbeitsmedizin and Arbeitsschutz (BAuA, Federal Institute for Occupational Safety and Health) [3], Bundesinstitut für Risikobewertung (BfR, Federal Institute for Risk Assessment) [4; 5], Umweltbundesamt (Federal Environmental Agency) [6], Hauptverband der gewerblichen Berufsgenossenschaften (HVBG) and Berufsgenossenschaftliches Institut für Arbeitsschutz – BGIA (Federation of Institutions for Statutory Accident Insurance and Prevention and BG-Institute for Occupational Safety and Health) [7], Berufsgenossenschaft Druck und Papierverarbeitung, and Verwaltungs-Berufsgenossenschaft (Institutions for Statutory Accident Insurance and Prevention in the Printing and Paper Processing Industry, and in the Administrative Sector) [8] as well as various other institutions [9 to 11].

The objective of the present article is to summarize and evaluate the scientific data on the effects of laser printer and copier emissions, especially toner dust, on cells and organisms. Furthermore, cases of illnesses reported in medical literature that are attributed to exposure to toners are critically discussed.

2 Material emission from laser printers and copiers

Laser printers and copiers can emit small amounts of dust, volatile organic compounds (VOC) and ozone [11 to 17].

In contrast to older devices where the imaging drum is electrostatically charged with a corona wire, modern laser printers and copiers emit considerably smaller amounts of ozone as most of them usually employ the transfer-roller-technology. With this technology, practically no ozone is generated. Ozone filters are not necessary for these devices.

Dust emitted by laser printers and copiers may consist of paper dust as well as of toner dust. Due to physical and technical reasons, a significant release of toner dust from laser printers and copiers during printing is not to be expected since the toner dust is released from the closed toner cartridge via a very narrow slit. This slit is very close to the surface of the passing, electrostatically charged paper. The toner particles are attracted by the electrostatically charged paper and can therefore not be emitted. After the toner has been fused and fixed in the fuser and after the excess toner has been wiped off, toner dust cannot be emitted from the printed paper.

Toners consist of very small particles of a thermoplastic polymer, usually a styrene-acrylate copolymer, that are fixed on the paper by fusing. The toner is heated up to 170 °C [12]. Black toners contain carbon black or iron oxide as pigments. Colour toners contain various organic pigments. In addition to these main constituents, toners contain various additives such as wax and silica, partly also small amounts of specific metal salts to control the electromagnetic properties.

The diameter of toner particles is about 2 to 10 µm. Toner dust belongs to the group of respirable fine particles, which upon inhalation are deposited predominantly in the tracheobronchial and alveolar region. A minor fraction may also be deposited in the nose, the larynx and the pharynx.

VOC may be released during the fusing of the toner and during the heating of the paper. Other sources can be plastic materials and electronic components of printers or copiers. VOC emissions from these sources, however, usually decrease rapidly within a few days after a new printer or copier has been installed and operated for the first time. Besides VOC, also semi-volatile organic compounds (SVOC) such as phenols and cresols, phthalates, phosphorous esters and siloxanes have to be considered. They are used as plasticizers, flame retardants and release agents in specific device components and materials and are released into the ambient air under the influence of heat.

Short-term emissions of toner dust may occur when changing a toner cartridge or when cleaning or repairing a laser printer or copier. Persons who frequently do this kind of work may be exposed to toner dust at higher levels. For prevention, these persons should take adequate precautions so that the inhalation of toner dust is avoided.

3 Quality standards for laser printers, copiers and toners

According to the award criteria of the environmental label “Blue Angel” [18], the following requirements apply to printers, copiers and multifunction devices:

- Toners and inks must not contain hazardous substances.
- Regarding the contamination with heavy metals related to manufacturing, the ALARA principle applies.
- Pigments that can release carcinogenic aromatic amines are not permitted.
- In accordance with a given test method, device emissions are to be determined by a testing institute qualified for this test and must be presented. Given emission rates for volatile organic compounds, benzene and styrene in particular, for ozone and for dust must not be exceeded.
- Out of informative reasons, emission test results for colour devices when printing with a colour print master must also be presented.

Another ecolabel for environmentally sound and safe printers and toners is the BG-PRÜFZERT-label with the additions “tested safety, ergonomic, low-emission” and “tested for toxins” respectively [19; 20], which is awarded by the Testing and Certification Body of the Expert Committee Administration of the Professional Association of the Administrative Sector. The criteria defined in the principles for testing refer to device emissions [19] and to harmful constituents of toners [20].

Emission measurements of laser printers and copiers are conducted according to the ECMA standard 328 [21]. Based on this standard, the Bundesanstalt für Materialforschung und -prüfung (BAM, Federal Institute for Materials Research and Testing) has developed a testing procedure to measure the emissions of hard copy devices [22]. This procedure applies for devices that are tested for emissions within the scope of the environmental label “Blue Angel”. In parallel with this procedure, the Berufsgenossenschaftliche Institut für Arbeitsschutz (BGIA, BG-Institute for Occupational Safety and Health) in cooperation with the Fraunhofer Wilhelm-Klauditz-Institute (WKI) developed a dynamic test chamber procedure to determine material emissions from IT work equipment and devices [14]. This test procedure mostly corresponds with the emission test chamber method that was developed in the 1990ies to characterize and quantify VOC emissions from building material and from indoor fixtures and commodities.

Product testing is conducted in air-conditioned test chambers under standardized conditions, with high purity air passing through the chambers. The test procedures specify requirements with regard to climatic parameters, volume of the test chamber, air exchange rate, duration of conditioning, ready, printing and follow-up phase, etc. Considering test chamber volume and air exchange rate, specific emission rates for each device are calculated based on the substance

concentrations measured in the test chamber air. These emission rates are stated in the units $\mu\text{g}/(\text{device h})$ or $\text{mg}/(\text{device h})$.

The device-specific dust emission rates of today's laser printers usually are between 0.5 and 2.5 $\text{mg}/(\text{device h})$ [23]. Since airborne particles are usually measured by determining the dust amount intercepted by filters gravimetrically, it is not possible to distinguish between paper dust and toner dust. With these measurements, it is not possible to quantify the relative fraction of paper dust and toner dust either.

The maximum emission levels used for awarding the German environmental label "Blue Angel" are shown in **Table 1**. The emission levels refer to the printing phase only. They are based on the guide values of the Indoor Air Hygiene Commission of the German Federal Environmental Agency and on other values of assessment with a model room according to DIN EN 13 419 [24] and a use factor of 0.1. According to this use factor, actual printing time is, at most, 10% of the time of a continuous printing operation theoretically possible in one day. This would correspond to a printing volume of about 1,000 pages a day for a desktop device with 16 to 17 pages per minute. When determining the maximum emission rates, it was taken into consideration that the target values defined for indoor air would not be reached by one single printer only as other emission sources also contribute to indoor air exposure.

Table 1:
Permitted limit values for the emission rates (SER_U) of TVOC, benzene, styrene, ozone and dust according to award criteria of the environmental label for printers (RAL-UZ 85) and multifunction devices (RAL-UZ 114) [18].

Substance	SER_U printing phase ($\text{mg}/(\text{device h})$)	SER_U tabletop units ready mode ($\text{mg}/(\text{device h})$)	SER_U floor-mounted units ready mode ($\text{mg}/(\text{device h})$)
TVOC	10	1	3
Benzene	0.05		
Styrene	1		
Ozone	2		
Dust	4		

The emission rates measured under the defined test conditions are only partly suitable for calculating the concentrations of dust, VOC and ozone that can occur in a room during the operation of a laser printer or copier. The reason for this is that these concentrations depend on

numerous other conditions that can merely be controlled. The measured emission rates are rather device-specific parameters, which may be used to compare the emissions of various devices.

The levels of harmful substances in toners measured according to the BG-PRÜFZERT standard “Toners for Laser Printers and Copiers” [20; 25] cannot be used to predict the emission behaviour of printers, copiers and multifunction devices. It is also not possible to predict the indoor air concentrations of harmful substances in offices and private rooms on the basis of toner analyses. Nevertheless, the levels of hazardous constituents and impurities in toners should be as low as possible according to the ALARA principle.

4 *In vitro* toxicity studies of toners

For *in vitro* studies, toners and toner extracts are incubated with bacteria cells and mammalian cells in culture media under qualified conditions. The following *in vitro* tests were used in particular:

- studies with bacteria (*salmonella typhimurium*) to determine mutagenic or genotoxic effects (Ames test)
- studies with alveolar macrophages from rats and guinea pigs to determine cytotoxic and inflammatory effects
- studies with fibroblasts.

The results of these studies [26 to 29] do not indicate that toners and toner extracts are cytotoxic and mutagenic and that reactive oxygen compounds are produced. For very high toner concentrations ($\geq 10 \mu\text{g}$ toner dust/ 10^6 cells), it has been noted that TNF_α (mediator of inflammation) as well as the cytoplasmatic enzyme lactate dehydrogenase (indicator of cell wall damage) have increasingly been released from alveolar macrophages.

5 *In vivo* acute toxicity studies of toners

Lin and *Mermelstein* [30] studied the acute toxicity of 16 Xerox toners in rats and rabbits. Oral toxicity was tested by administering toner doses of 5 to 35 g/kg body weight (!) to rats by gavage. Acute inhalation toxicity was tested by exposing the animals for 4 hours to toner concentrations of 0.17 to 10.29 g/m³. Acute dermal toxicity was tested by administering toner to the shaven back skin of the rabbits via a patch. According to the test results, there are no indications of acute oral, inhalative and dermal toxicity of the tested toners. The effect of the test toner on the eye was also tested within the scope of these studies: Draize eye irritancy tests in rabbits yielded negative results.

Guinea pig maximization tests did not show any signs of skin sensitization in guinea pigs.

Data on acute dermal and oral toxicity and on acute inhalation toxicity are given in the material safety data sheets (MSDS) of different commercially available toners. The inhalative LC50 (rat, 4 hours) is generally stated as $> 50 \text{ mg/m}^3$, the oral LD50 (rat) as $> 2000 \text{ mg/kg}$ and the dermal LD50 (rat and rabbit) as $> 2000 \text{ mg/kg}$.

In summary, it can be concluded that toner dust has a very low acute toxicity when administered by inhalation or by the oral or dermal route of exposure. According to criteria of the EU Directive 67/548/EEC, Annex VI, it is not required to classify toners as toxic or harmful if swallowed, in contact with skin or by inhalation.

6 Subchronic and chronic inhalation toxicity

Detailed studies in rats and Syrian golden hamsters on subchronic and chronic inhalation toxicity of toner dust were carried out in the 1980s and 1990s by *Muhle, Bellmann, Creutzenberg* et al. at the Fraunhofer Institute of Toxicology and Aerosol Research in Hannover (Germany). The results of these studies are described in several publications [31 to 35].

All inhalation toxicity studies were carried out with a Xerox test toner specially produced for these experiments. It contained a larger fraction of respirable particles than commercial toners. The test toner consisted of a styrene-1-butyl-methacrylate-copolymer. The pigment was high-purity carbon black with a mass fraction of 10%. The median aerodynamic diameter (MMAD) of the particles was $4.0 \mu\text{m}$. According to the criteria of the American Conference of Governmental Industrial Hygienists (ACGIH), up to 35% of the test toner consisted of respirable particles. The fraction of monomeric constituents and other VOC was smaller than 0.1% of weight. Extracts of the toner as well as extracts of the carbon black used for the production of the toner did not show any mutagenic activity in the Ames test. Titanium dioxide was used as an inert reference dust, cytotoxic silica dust of the type DQ12 was used as positive control.

The results of the studies may be summarized as follows:

- Subchronic and chronic inhalation exposure to toner concentrations up to 64 mg/m^3 does not lead to overt and significant toxic effects of a general nature (systemic toxicity).
- In rats, chronic exposure to toner concentrations $\geq 4 \text{ mg/m}^3$ leads to an accumulation of particles in the lung as well as to persistent inflammatory processes and slight to moderate fibrotic changes in the lungs of rats. In hamsters, these effects were only observed at significantly higher concentrations ($> 20 \text{ mg/m}^3$).
- In rats, which are much more sensitive than hamsters, a concentration of 4 mg/m^3 can be regarded as the lowest-observable-effect-level (LOEL).

- Since chronic exposure to toner concentrations of 1 mg/m³ is not associated with significant biological effects in rats, this concentration can be regarded as the no-observable-effect-level (NOEL). In hamsters, concentrations > 6 mg/m³ are the NOEL.
- Neither in rats nor in golden hamsters, an increased lung tumor rate was detected.

The particle accumulation in the lung tissue of the experimental animals is attributed to a damage and overload of the lung clearance mechanisms and is called "lung overloading". This is not an effect specific to toner dust but is generally observed when high concentrations of other, slightly soluble dusts are inhaled.

Presently, it is not possible to assess if the results obtained for the Xerox test toner, especially the concentration-response-relationships, can be transferred to other toners or if such a transfer is acceptable. Nevertheless, the following arguments support the conclusion that other comparable toners have similar characteristics of toxicity:

- The toners nowadays in use consist of polymer particles of similar particle size distribution and similar specific gravity.
- The biological effects produced by the inhalation of toner dust are primarily related to particle properties (insolubility and persistence in the biological environment; particle size distribution, specific gravity). In contrast, the chemical composition of the polymer matrix, of the employed pigment and of other ingredients as well as the presence of impurities caused by manufacturing seem to be of no relevance.
- Presently, it is not possible to assess if and to what extent particle surface properties can evoke biological effects.

7 Biological effects after intratracheal instillation of toners

Möller et al. [29] report on a study in which 3 mg of a commercially available black toner (suspended in a physiological saline solution) was instilled in the trachea of rats. At the same time, the Xerox test toner was analysed which had been used in the *in vivo* inhalation study. A bronchoalveolar lavage was conducted 7 days after the instillation. Different biochemical and cellular parameters were measured in the bronchoalveolar lavage fluid. Compared to the control, a distinct inflammatory response was verified. Both toners only differed slightly.

Within the scope of a detailed study, Pott and Roller [36] analysed 19 granular bio-durable particles without any known essential specific toxicity (GBP) regarding their carcinogenic effect in rats. The particles were administered to female Wistar rats (age 8 to 10 weeks) as a suspension by means of intratracheal instillation in weekly intervals. The animals were then observed over their entire lifetime and the number of animals with lung tumors was determined.

Among the examined dusts in this study was the Xerox test toner, which had been tested and evaluated as non-carcinogenic in the in vivo inhalation experiments of *Muhle, Bellmann, Creutzenberg*, et al. [31 to 35].

The toner dust was administered by intratracheal instillation directly into the lung of the experimental animals in 10 or 20 single doses of 6 mg each per animal. The applied total doses were about 400 and 800 mg/kg of body weight (!) respectively. The examination showed that a large number of the experimental animals developed primary lung tumors. Details can be gathered from the research report [36], which has only been published on the internet so far.

8 Experiences and studies in human beings

Descriptions and characterizations of adverse health effects and diseases connected with toner dust mostly exist in form of non-assessable lay reports and press articles which are primarily published on the internet. So far, there have only been a small number of well-founded, medical examination reports and scientific examinations that are available to experts. Most of the case studies published in scientific literature suffer from inadequate or totally missing exposure estimations while medical histories of basic diseases and pre-damages of concerned people have only insufficiently been established.

Lin and Mermelstein [30] report on the results of a study during which 16 different Xerox toners were administered to the skin of 100 test subjects (patch test). No skin irritations or sensitization reactions on the skin were detected.

Rabe and Haase [37; 38] tested biopsy specimens of 18 persons who declared to be especially sensitive to toner dust with the so-called "Alergocell" method. It is reported that the biopsy specimens of these persons showed "obvious mast cell and/or eosinophil degranulations, i.e. positive reactions in different dimensions" when being tested with the "patient-specific toner and/or with single toner stimulation solutions". The results of this examination are insufficiently documented and cannot be assessed as the validity of the test method is disputed.

Gallardo et al. [39] described the case history of a 44-year-old woman who slightly smoked cigarettes and had worked in a copy shop for 6 years. A slight lung fibrosis was determined in the transbronchial lung biopsy specimen, which had been extracted thoracoscopically. Iron and silicon could be detected both in the toner and in the lung biopsies. The authors concluded that the female patient suffered from a siderosilicosis. However, this is difficult to understand as a) exposure is not clear, b) iron and silicon can also be found in healthy lungs, c) (semi) quantitative specifications are missing, d) details on the amount of iron and silicon in control subjects are missing.

Armbruster et al. [40] described a 39-year-old non-smoker with a granulomatous pneumonitis and mediastinal lymphadenopathy, who had worked in a newspaper agency for 18 months. The

histological examination of the lung and lymph-node biopsy specimens resulted in non-necrotizing granulomas with epithelioid cells and giant cells. Besides, the X-ray energy dispersive microanalysis of the toner dust as well as the lung and lymph-node biopsy specimens showed copper peaks, leading the authors to the diagnosis of granulomatous pneumonitis and mediastinal lymphadenopathy due to photocopier emissions. For the same reason as described for *Gallardo et al.* [39], this casuistic description is also doubtful in its causal-analytical assessment. Maybe the man suffered from a sarcoidosis.

In an epidemiological study, *Rybicki et al.* [41] found a significantly increased odds ratio of 1.74 (95 CI 1.23-2.46) for the existence of sarcoidosis if the interviewed persons “had ever used a photocopier”. The odds ratio of persons who had ever exchanged toner cartridges or who had been employed in photocopier maintenance services was 2.88 (1.83-4.54). Sarcoidosis is an inflammatory general disease which causes formation of microscopically small connective tissue nodes, so called granulomas, which are formed in the whole body and impair the particular organ functions. In most cases, the lymph-nodes are swollen. The lung is concerned in almost all cases. It is unknown what causes this disease. An aetiological connection with dust exposure is not known. It is therefore very doubtful if a causal relationship between toner dust exposure and increased sarcoidosis risk can be assumed.

At present, the relationship between the use of toners and adverse health effects is examined in a pilot study financed by the BfR [5]. In a first step, the study conducted by Prof. Dr. V. *Mersch-Sundermann* of the Institute for Indoor Air and Environmental Toxicology of the University of Gießen is supposed to provide information whether the operation of laser printers and copiers can influence indoor air in a way that damages health.

A connection between an increased internal exposure to harmful substances and the intensive use of copiers and laser printers could not have been demonstrated yet, according to a study of *Einsiedler et al.* [42]. The authors conducted a human-biological monitoring study concerning 11 metals and solvent constituents contained in toners with male and female employees of offices and copy shops. An excessive exposure of the organism to heavy metals and solvent constituents beyond the general background exposure could not be detected.

9 Diseases caused by toners?

According to a press release of the Bundesinstitut für Risikobewertung (BfR, Federal Institute of Risk Assessment) [5], 72 notifications of adverse health effects attributed to toners were registered between the year 2000 and March 2005 by the “Poison and Product Documentation Centre”. Symptoms mostly reported are running noses, irritations of the conjunctiva and pharyngeal mucosa as well as asthma-like cough. The attending physicians attribute the

symptoms to exposure to toners. It is not documented whether and to what extent a careful clarification of the causal relationship was conducted in these cases.

In “Cases of Poisoning Reported by Physicians in 2002” [43], “an allergic rhinitis and obstructive respiratory disease caused by toner dust from laser printers and copiers” is reported for a 48-year-old patient, which was recognized as an occupationally related disease. After printers and copiers had been installed at his workplace, the patient increasingly had infections of the upper and lower respiratory tract, breathing difficulties, cough and paranasal sinusitis. In November 1990, bronchial asthma was diagnosed. A nasal provocation test with toner dust led to an immediate reaction of the nasal mucosa with sternutation, coryza, swollen nasal mucosa and limited nasal breathing. Besides, the patient had bronchial symptoms like cough and increased production of sputum and dyspnea. The symptoms last for 4 days. There was a selective increase of eosinophil leukocytes in the differential blood count which was interpreted as an indication of an allergic reaction. When contact with laser printers and copiers was avoided, discomfort was relieved. As the devices and rooms where the affected person had worked were not cleaned and maintained properly, “the extraordinary exposure to toner dust at the workplace” was regarded as “the exclusive reason for the existing allergy”.

The Berufsgenossenschaften (Institutions for Statutory Accident Insurance and Prevention for Trade and Industry) have recognized three cases of illness in connection with exposure to toner dust as occupational disease so far. For reasons of data protection, the occupational medicine evaluations of these cases cannot be discussed in detail. Generally, it has to be noted however that not every disease developed at work can be defined as an occupational disease. An occupational disease is rather restricted to specific conditions: According to §9 (SGB, German Social Security Code VII), occupational diseases are diseases insured persons suffer from after executing an activity that is covered by the insurance (acc. to §2, 3 or 6 of SGB VII). The German Federal Government defines those diseases as occupational diseases that according to findings of the medical science are caused by specific influences, which a particular group of persons is much more exposed to due to their insured activity than the general population. Moreover, accident insurance institutions have to recognize a disease as an occupational disease even if it is not defined in statutory regulation or does not fulfil the requirements stated therein. This is provided that, according to the latest findings of medical science, the requirements for a definition according to paragraph 1, sentence 2 (definition of occupational disease, see above) are fulfilled at the time of the decision.

Positive evaluations of correlation the authors know of have basically two severe deficiencies: On the one hand, the exposure situation is described insufficiently. If, as mentioned above, there is almost no release of toner dust during printing operation because of physical and technical reasons, then it has to be proven at first that exposure to toner emissions as required according to accident insurance law is given at all for office work. The authors know nothing

about such evidence ever having been provided at all. On the other hand, the provocation tests with toner dust conducted by some experts for sick office employees are hardly reasonable as they do not reflect real exposure situations in the least and do not follow the relevant recommendations of scientific medical societies [44; 45].

If there are obstructive respiratory diseases connected with a distinct unspecific hypersensitivity, deterioration due to inhalation of toner dust is imaginable under extremely unfavourable – rather historic – conditions. An objectification is difficult [46]. Longitudinal lung function measurements with and without exposure would be helpful to assess single cases. If possible, we conduct provocation tests that simulate workplace situations and place the sick persons in a test chamber together with the office devices in question. With intensive printer operation (high degree of black page coverage, if applicable cheap recycling paper), we then examine whether the unspecific respiratory sensitivity, which is determined before and after the exposure, changes significantly compared to a control day. So far, none of the exposure tests have shown a positive result.

According to the existing findings, it can be excluded that interstitial lung diseases can be caused by exposure to emissions from copiers and laser printers.

10 Summary and evaluation

Toners consist of very small particles of thermoplastic polymers, by which pigments are bound. The particle diameter ranges from 2 to 10 μm with a median of ca. 5 μm . Toners are to be classified as fine dust (analogue PM 10) but not as nano-particles.

Polymer particles are not soluble in aqueous solutions and for this reason inert in biological solutions and textures. They are biologically inert to a large extent. Their toxicity is to be categorized as marginal. Therefore, toners can be classified as belonging to the group of “granular bio-durable particles without known significant specific toxicity” (GBP). These kinds of dusts are called “low toxicity poorly soluble particles” (LTPSP) in Anglo-American literature.

As animal experiments show, long-term inhalation of high toner concentrations ($\gg 1 \text{ mg/m}^3$) can lead to an overload of the lung clearance mechanisms and to an accumulation of toner particles in the lung. This can cause inflammatory processes and increased formation of connective tissue (fibrotic changes). As the use of laser printers and copiers is not linked with a relevant inhalation exposure to toners, these kinds of effects are not to be expected in connection with the use of laser printers and copiers.

Long-term inhalation studies in rats and golden hamsters do not indicate a carcinogenic potency of toners. However, lung tumours were induced in rats after intratracheal instillation of large amounts of toner (400 to 800 mg/kg body weight). Probably, this is a high-dose effect on the basis of a massive chronic inflammation which does not occur with small doses. Thus, a linear

extrapolation of dose-response-relationships to small doses is not reasonable. Moreover, the question arises whether the rat lung is an adequate model to prove the carcinogenicity of bio-inert, non-toxic dusts [47]. As lung tumours cannot be induced by exposing mice and hamsters with comparable dust doses, it can be assumed that the rat lung is an especially sensitive model.

So far, there have been no scientifically established indications that the operation of modern laser printers and copiers in offices and households leads to an increased health-relevant exposure caused by toners and VOC. Human biomonitoring examinations did not indicate an increased internal exposure to harmful substances for persons who work intensively with laser printers and copiers.

No convincing evidence has been provided for allergenic effects of toners so far. The above mentioned case studies indicate that people with an existing, in most cases elsewhere developed unspecific nasal or bronchial hypersensitivity can develop symptoms like sternutation, rhinitis, cough and/or whistling breathing and rhonchus when inhaling even small amounts of toner. It is unlikely if these are indeed specific allergic reactions. Supposably, it is an unspecific hypersensitivity that can also occur when inhaling other dusts. A precise clarification is only possible when provocation tests are used that are conducted according to the guidelines of the scientific medical societies [44; 45].

Reports on occupational diseases in connection with toner suffer from methodological weaknesses (insufficient documentation of medical history and exposure; inadequate examination and evaluation of the causal relationship between occupational influence and disease symptoms) which are so severe that they are not convincing when critically examined.

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