7 Workplace

It is essential that indoor workplaces correspond with the needs and attributes of the people who work in them. Otherwise, both the workplace design and the work equipment used can prompt complaints from employees. The following section gives advice on how to investigate and assess workplace design and the work equipment selected, including laser printers/copiers and display screen equipment.

7.1 Workplace design

S. Neumann, Hamburg

The Arbeitsstättenverordnung (Ordinance on Workplaces) [1], particularly its annex, and the Technical Rules for Workplaces [2] specify key requirements concerning the design of indoor workplaces.

The Bildschirmarbeitsverordnung (Ordinance on Display Screen Work) [3] sets out the general health and safety requirements for work using display screen equipment, transposing the European Display Screen Directive [4] into national law for the Federal Republic of Germany. DGUV Information 215-410, formerly BGI 650 "Bildschirm- und Büroarbeitsplätze" (Display screen and office workstations) [5] defines the ordinance's requirements in more detail. As a general rule, people who work with display screen equipment (DSE) should be offered regular eye and eyesight tests, carried out by a person with the necessary capabilities (DGUV Principle G37 [6]). The German statutory accident insurance institutions have also published various brochures [7 to 16] providing information and guidance on specific topics in the area of office workplace design.

7.1.1 Investigation and assessment of the workplace

A special questionnaire, S7, dealing with workplace environment and work equipment, is available on the internet (www.dguv.de, webcode e650356). It was developed on the basis of the above-mentioned DGUV directives, ordinances and informative publications on office workplace design. The questionnaire can be used to investigate whether particular health complaints can be attributed to non-ergonomic workplace design.

The S7 questionnaire does not include lighting, noise or indoor climate because they are covered at length in Section 6.3 and in Chapters 8 and 9. Occupational safety aspects, such as prevention of tripping hazards, are also not included.

Some of the questions on the questionnaire indicate potential solutions. For instance, the questions concerning furniture, hardware, software and positioning of work equipment give guidance on workplace design.

7.1.2 Reduction of musculoskeletal strain

The following recommendations are intended to help reduce musculoskeletal strain:

- the strain caused by poor or uneven posture (e.g. twisted posture or prolonged periods in a seated position) or repetitive movements (e.g. prolonged use of a keyboard) should be reduced by shortening the period spent on such activities. This can be done by combining different tasks, giving the employee additional tasks or ensuring sufficient breaks;
- favourable posture and changes in posture should be promoted by ensuring individually adjustable and ergonomic workstations.

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7.2 Laser printers and copiers

T. von der Heyden, Sankt Augustin

Laser printers and copiers have become an indispensable part of modern office life, used by millions of people every day. However, reports of potential health hazards due to laser printers purportedly causing exposure to toner dust have provoked public concern on more than one occasion. It was this concern that, more than a decade ago, prompted the Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA; Institute for Occupational Safety and Health of the German Social Accident Insurance, formerly known as BGIA) to conduct numerous projects on this topic in cooperation with the Verwaltungs-Berufsgenossenschaft (VBG; German Social Accident Insurance Institution for the administrative sector). The aim of this work was to identify the emissions released by laser printers and copiers and to assess whether they were potentially harmful to health [1 to 3]. In addition to the IFA's activities in this field, the Landesgewerbeanstalt Bayern (LGA Bayern; Bavarian state trade agency) emission-tested various devices and toners between 2000 and 2007 [4]. The findings of this research remain valid today since printer technology has not undergone any significant change since then. They show that laser printers and copiers do not emit significant amounts of dust or gas (see the sections on the individual substance categories).

In the interests of environmental and user protection, the "Environmental Label Jury" has developed award criteria, referred to as RAL-UZ 122 [5] and RAL-UZ 171 [6], for office equipment that has a print function (printers, copiers and multifunctional devices (MFDs)) (Figure 7). As well as general requirements, e.g. recyclability and power consumption, and toner substance requirements, a major part of the awarding process involves emission testing. Chamber tests are carried out to determine the quantities of dust, ultrafine particles (UFPs), ozone, TVOCs, benzene and styrene emitted. The emissions are assessed on the basis of the current guideline values for environmental or indoor emissions, which are far lower than the applicable occupational exposure limits (OELs).

Generally speaking, the equipment is only tested in combination with the toner and paper sold for the specific device in question. In practice, however, the toner used often comes from a different manufacturer or in a recycled toner cartridge and has not been tested in conjunction with the device. The former Fachausschuss Verwaltung (Expert Committee for the Administrative Sector) has therefore created an additional DGUV Test certification mark for toner powder, which indicates that the product has been pollutant-tested (Figure 8) [7]. The intention is that this will assist buyers of toner cartridges when judging quality and comparing products. Toners bearing this mark meet strict requirements concerning the metals, volatile organic compounds and other substances they contain as well as particle size.

Figure 7:
"Blue Angel" for office equipment with a printing function (printers, copiers and MFDs)

Figure 8:
Special DGUV Test "pollutant tested" mark

Paper is a source of emissions too. Due to the design parameters for laser printers, the paper is briefly heated to roughly 150 to 200 °C, which can cause it to give off certain substances. The award criteria for the Blue Angel RAL-UZ 14 eco-label [8] for recycled paper (Figure 9), which include numerous environmental aspects, also consider potential emissions of volatile organic compounds if the paper is of a type intended to be used with electrophotographic printers or copiers (known as copying paper).

In situations where laser printers are used a great deal or several devices are operated simultaneously, it is always recommendable to place them outside the office.

Figure 9:
"Blue Angel" for recycled paper

7.2.1 Dust

The research conducted by the BGIA (now IFA) and LGA Bayern did not reveal any significant toner dust emissions. The RAL-UZ 122 and RAL-UZ 171 award criteria give an emission rate of 4.0 mg/h of dust (usually paper dust) as the maximum permissible value during the printing phase.

7.2.2 Metals

Most black toners have an iron content of 25 to 33%, in the form of iron oxide. The research carried out at the BGIA detected parts-per-thousand levels of titanium, strontium, copper and zinc compounds.

The copper and titanium content of colour toners is usually low. The IFA (formerly BGIA) also found chromium, iron, zinc, tin and strontium in various colour toners. The cobalt and nickel content (substances that are particularly problematic because of their sensitising effect) of the toners was either zero or trace.

For a toner to be awarded the "pollutant tested" mark, it must comply with the maximum content levels shown in Table 10 for the various metals contained in toner powder, which are specified in the "Grundsätze für die Prüfung und Zertifizierung von Tonerpulver schwarz und farbig für Laserdrucker und Kopiergeräte" (Code of rules for testing and certifying black and colour toner powders for laser printers and copiers) [7].

The award criteria for the Blue Angel eco-labels RAL-UZ 122 and RAL-UZ 171 go even further. They stipulate that toners must not contain any substances whose constituent parts include mercury, cadmium, lead, nickel or chromium(VI) compounds. The exception is nickel complexes with a high molecular weight, which may be used as pigments. Contamination with heavy metals, such as cobalt or nickel oxides, caused by the manufacturing process must be kept as low as technically possible and economically viable [5; 6].

Table 10:
Limit values for metals in toners in accordance with the requirements for the DGUV-Test “pollutant tested” mark

Metal	Limit value in mg/kg
Cadmium	5.0
Cobalt	25
Nickel	70
Lead	25
Mercury	2.0
Chromate (in the form of chromium)	1.0
Organotin compounds (in the form of tin)	5.0

7.2.3 Ozone

Modern laser printers do not usually emit ozone. In fact, today’s black and white laser printers mostly use ozone-free technology, which means they do not need an ozone filter. Black and white and colour devices that do produce ozone only emit negligible quantities, at a level that can be regarded as not harmful to humans, provided the ozone filter is intact and working properly. It is therefore imperative that maintenance be carried out regularly, including filter replacement where necessary. If this is not done, the ozone concentrations can increase to a much higher level. This is particularly an issue with old devices [1; 4]. In accordance with the award criteria for the Blue Angel RAL-UZ 122 and RAL-UZ 171 eco-labels, black and white devices must not exceed an ozone emission rate of 1.5 mg/h during printing and colour devices must not exceed 3 mg/h. When judging the ozone concentrations produced by laser printers during printing, it is important to bear in mind that ozone breaks down into oxygen on walls and other surfaces. The half-life for this process is approximately 30 minutes. In other words, once half an hour has passed, the amount of ozone is only half of what it was originally. If ozone is continuously emitted (from equipment or the outside air), the ozone formation and breakdown processes balance each other out.

7.2.4 Volatile organic compounds (VOCs)

All laser printers and copiers emit volatile organic compounds (VOC) during printing and copying. This is due to technical factors and practically impossible to avoid with today’s technology. Consequently, when assessing laser printers it is not important to determine whether they emit VOC but rather to establish the nature and quantity of the compounds released. The award criteria for the Blue Angel eco-labels RAL-UZ 122 and RAL-UZ 171 specify the following maximum values for total volatile organic compound (TVOC) emissions:

- 10/18 mg/h
  (black and white/colour device) during printing

The award criteria for the special DGUV-Test “pollutant tested” mark specify a maximum TVOC content of 1,000 mg/kg for toners.

The criticism surrounding these devices mainly concerns benzene, which can be emitted during printing and is classified as a carcinogen [9]. Though many black and white and colour laser printers do not give off any benzene at all, some have been found to do so. The LGA Bayern investigated benzene emissions from laser printers extensively, focusing on:

- Benzene content in toners
  Based on 585 toners examined, the mean value was 3 mg/kg and the median was < 0.1 mg/kg.

- Benzene emission rates from laser printers and copiers
  Based on 266 devices examined, the mean value was 0.09 mg/h and the median was 0.04 mg/h.

When the LGA Bayern began conducting these investigations, in 2000, benzene was detected frequently. In the years thereafter (up until 2007), it only found the substance on rare occasions. Both the LGA Bayern investigations and the IFA’s activities in this field have proved that most devices do not emit any benzene or only emit insignificant quantities of the substance, usually equivalent to the general level of benzene pollution in the environment.

The award criteria for the RAL-UZ 122 and RAL-UZ 171 Blue Angel eco-labels set a maximum benzene emission rate of 0.05 mg/h during printing. The award criteria for the DGUV-Test “pollutant tested” mark for toners specify a maximum benzene content of 1 mg/kg.

The Senatskommission zur Prüfung gesundheitsschädlicher Arbeitsstoffe (Senate Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area) of the Deutsche Forschungsgemeinschaft (DFG; German Research Foundation) has classified styrene, which is also emitted from such products, as “carcinogen category 5”. This means that its *“intensity (...) is considered so low that no significant contribution to the risk of cancer to humans is anticipated provided the MAK value is adhered to”* [10]. The measurements carried out by the BGIA found the concentrations to be lower than two hundredths of the OEL. A few devices, however, did exceed the indoor air guide value I (30 µg/m³) specified by the Umweltbundesamt (UBA; Germany’s Federal Environment Agency) [11].

The LGA Bayern also examined styrene emissions. The mean value for the styrene emission rate for the 266 devices in the period 2000 to 2007 was 0.9 mg/h and the median was 0.27 mg/h.

The award criteria for the Blue Angel eco-label specify a maximum styrene emission rate of 1.0/1.8 mg/h (black and white/colour device) during printing. To be awarded the DGUV-Test “pollutant tested” mark for toners, toners must not exceed a styrene content of 40 mg/kg.

The devices also emit varying quantities of other volatile organic compounds, such as toluene, xylenes, ethylbenzene and trimethylbenzenes. However, all of the concentrations measured were several orders of magnitude below the current occupational exposure limits.

7.2.5 Overall assessment

The following conclusions can be drawn from the investigations described above:

- Modern laser printers and copiers do not emit significant amounts of toner dust during printing. Consequently, there is no reason to assume a heightened health risk due to toner dust being absorbed through the respiratory system. If there is a possibility that, for example, toner dust might be emitted into the air when refilling cartridges, appropriate exhaust systems must be installed.

- If cartridges are replaced as prescribed, the toner does not usually come into contact with skin. If contact with the toner cannot be ruled out for certain devices, protective gloves should be worn when replacing the cartridge. Should contact with the skin occur despite this precaution, the toner must be removed from the skin using cold water and soap. Employees who potentially have frequent contact with toner (during servicing or recycling tasks) should always wear protective gloves to rule out any chance of direct contact with toner.

- Nowadays, laser printers do not pose a problem in terms of ozone formation since many devices already have completely ozone-free technology. Where devices do produce ozone, it is crucial that the ozone filter is maintained as prescribed. Spent ozone filters can cause the ozone values to increase. People who are very sensitive to ozone should certainly look for devices with ozone-free technology. If a laser printer is to be replaced anyway, preference should be given to devices with ozone-free technology.

- All laser printers emit VOC to varying degrees. The concentrations measured are several orders of magnitude lower than the occupational exposure limits in force. With the exception of the indoor guideline value I for styrene, which is occasionally exceeded, they also comply with the considerably more stringent environmental and indoor guideline values. The emitted quantities of the carcinogenic substance benzene corresponded to the general level of benzene pollution in the environment. Nonetheless, as it is not possible to specify a threshold value for the carcinogenic effect of benzene, it is up to device and toner manufacturers to enhance today's technology to ensure that future products to not emit any benzene.

7.2.6 References

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7.3 Display screen equipment

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The display screen equipment (DSE) used at computer workstations largely falls into one of two categories. The first is liquid crystal display (LCD) equipment, often called “thin film transistor” (TFT) or “flat” screens. The second is cathode ray tube (CRT) equipment though these products only account for a fraction of new purchases today.

Although DSE work in itself does not expose workers to adverse conditions, it can lead to health problems. The causes include tasks requiring high levels of concentration, prolonged, tiring tasks, eyesight problems, poor lighting, glare and non-ergonomic workstation design. These can provoke symptoms such as fatigue, eye problems, headache, muscle tension, back problems, etc. (see the relevant sections of this report). To prevent these symptoms, DSE workstations must conform to health requirements, as set out in the Bildschirmarbeitsverordnung (Ordinance on Display Screen Work) [1]. DGUV Information 215-410, formerly BGI 650, “Bildschirm- und Büroarbeitsplätze – Leitfaden für die Gestaltung” (Display screen and office workstations – A guide to workstation arrangement)[2] gives specific guidance on how to implement the ordinance.

7.3.1 Radiation emission from display screen equipment

Depending on the type of DSE, electric and magnetic fields are generated within the equipment, as are various types of radiation. As Chapter 10 of these recommendations explains in detail, both CRT and LCD screens only cause very low emissions of electric, magnetic and electromagnetic fields. The amounts of other types of radiation emitted (see below) are also small. There is therefore no reason to be concerned about radiation emissions from DSE posing a risk to health. This is true of all DSE workstation scenarios, including multiple-monitor set-ups within one room, monitors installed at opposite workstations and pregnant women performing DSE tasks.

In contrast to LCD display screen equipment, CRT equipment is often subject to interference from electromagnetic fields, e.g. from the building’s power distribution system. This can lead to flickering and changes in brightness and colour. CRT screens are particularly prone to this problem because even low-strength magnetic fields cause interference in them. For instance, a magnetic flux density of approximately 0.4 µT (caused, for example, by a passing electrically powered train) is sufficient to cause interference in sensitive equipment.

When electromagnetic fields have an impact on CRT equipment in the workplace, employees are often concerned that the fields might be harmful to humans too. However, such concerns are unfounded since interference can be caused even when the field strength is far lower than the threshold values specified for human protection.

Unlike with LCD screens, electrostatic field strengths of up to 7,000 V/m can occur at a distance of 30 cm from the surface of a CRT screen [3]. More modern CRT screens generate lower field strengths. The DGUV regulation 16, formerly BGV B11, “Elektromagnetische Felder” (Electromagnetic fields) [4] stipulates that the electrical field strength in static fields must not exceed 20,000 V/m. This value is complied with when working at CRT monitors. Charge can cause dust particles to be drawn in from the air if it is not directed away, as is the case with modern equipment.

Ionising radiation

Extensive research by the Physikalisch-Technische Bundesanstalt (PTB; Germany’s national metrology institute) and measurements performed by the Karlsruhe Nuclear Research Centre (now part of the Karlsruhe Institute of Technology; KIT) show that exposure to ionising radiation at CRT screens is usually around two orders of magnitude lower than the level of natural radiation to which all humans are constantly exposed [3; 5]. This research also measured the radiation behind the monitors – an especially important aspect when several people work in one office and are consequently very close to the back of the monitor opposite them. Even in these cases, however, the additional exposure caused by X-rays emitted from the DSE was far below the level of natural radiation exposure.

Owing to the imaging technology they use, LCD screens do not generate any ionising radiation.

Optical radiation

Optical radiation is subdivided into ultraviolet radiation (UV), visible radiation (light) and infrared radiation (IR).The radiation in the visible spectrum is the desired form since screens’ display functions use visible light.

All three types of radiation mentioned above are generated inside CRT equipment when the electron beam from the tube hits the fluorescent layer. IR radiation is also produced as a result of heat build-up in the tube’s cathode.

Almost all of the UV radiation generated in CRT monitors is absorbed by the glass of the tube so the intensity measurable outside on the screen’s surface is very low [6]. For instance, the maximum irradiance measured in the UV-A range is lower than 10 mW/m^2 [7]. The UV-B radiation values are three to six orders of magnitude below that. The UV-A exposure for an eight-hour work shift is less than 288 J/m^2, comparable with the eye exposure threshold values of 10,000 J/m^2 recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [8 to 10]. Consequently, UV radiation emission from CRT screens does not pose a risk for humans.

The intensity of the visible radiation emitted by CRT monitors in order to display information is considerably lower than the level that is potentially harmful to the eyes.

IR radiation emission from CRT display screen equipment is also negligible [6].The measured irradiance is 200 mW/m^2 [7] whilst the limit values recommended by the ICNIRP is 100,000 mW/m^2 [11]. Health risks from IR radiation emission are therefore unlikely too.

Besides the desired visible radiation, LCD screens emit UV and IR radiation. However, the UV and IR intensity is low and roughly equivalent to that of conventional fluorescent tubes. This means that LCD screens are not harmful to users either, be it through the visible radiation or UV and IR radiation emissions.

7.3.2 Display screen robustness to lighting

Display screens have optically transparent surfaces that reflect part of the light that falls on them. This reflection is either spectral (e.g. in the case of untreated screen surfaces) or diffuse (e.g. in the case of roughened screen surfaces).

Unwanted reflection is disadvantageous in DSE work because it reduces the contrast between the individual characters on the screen, making it more difficult to distinguish between them. Moreover, users have to concentrate harder in order to comprehend the information on the screen properly. The stronger the reflection, the more adverse the effect on the user, which is why screens should always have an anti-glare surface. It is therefore essential that buyers of display screen equipment ensure the equipment has good anti-glare properties. This is particularly true of notebooks, which are often used in lighting conditions that are less than ideal.

In the past, the reflective properties of display screens were divided into three reflectance classes, for positive and negative display, in accordance with DIN EN ISO 9241-7 [12] and DIN EN ISO 13406-2 [13]. The current standard, DIN EN ISO 9241-307 [14], no longer includes these reflectance classes. Instead, it specifies the test conditions under which display screen reflection should be measured (Table 11). Accordingly, today's Geprüfte Sicherheit (GS; tested safety) certificates include the following statements:

Light source with large aperture = 200 cd/m²

and

Light source with small aperture = 2,000 cd/m²,
equivalent to former reflectance class I

A display screen with these anti-glare properties can be used without hesitation in any office environment and is therefore unconditionally recommended.

Since screens' reflective properties depend on the display mode, there might be different figures given for positive and negative display. If not, the equipment either comes with positive or negative display only or it has the same reflective properties regardless of the display mode.

In addition to these anti-reflection measures, another step that can be taken is to display dark characters on a light background (positive display). This reduces the disruptive effect of any reflections that cannot be completely avoided as well as lessening the restrictions on the positioning of equipment within the work environment.

It should also be noted that colour difference, i.e. the difference between two colours, becomes more difficult to discern with increasing illumination of the screen from the ambient lighting. This is particularly true with screens that offer good anti-glare properties. The same applies to luminances and contrasts, though to a lesser degree. It is for these reasons that manufacturers now state the on-screen illuminance for which the product is suitable. Technical data sheets and GS certificates indicate the intended screen illuminance in lux. This parameter refers to the maximum permissible illuminance on the screen from the ambient lighting. The actual illuminance on a given screen can be measured at the workstation in question using a luxmeter (with the probe turned outwards).

To ensure that screens can display distinguishable colours even at workstations close to windows, it is recommended to use screens with a declared intended screen illuminance of at least 1,500 to 2,000 lux. Although reflective screens are not as sensitive to high illuminances, their higher reflectance makes them unsuitable for office environments (see above).

As filters added in front of screens often result in poorer display, they should only be used once all factors have been carefully considered. For instance, it should be possible to adjust the screen brightness to compensate for any reduction in brightness caused by attaching a filter.

Table 11:
Reflectance classes as per DIN EN ISO 9241-307 and former reflectance classes as per DIN EN ISO 13406-2;
large AP = large aperture, small AP = small aperture

Reflectance classes as per DIN EN ISO 9241-307, Luminance from directed reflected light sources in cd/m²	Suitable environment	Former reflectance class as per DIN EN ISO 13406-2
$L_{large\ AP} = 200$ and $L_{small\ AP} = 2\ 000$	Screens of this type can be used in any office environment.	I
$L_{large\ AP} = 200$ or $L_{small\ AP} = 2\ 000$	In unfavourable lighting conditions or locations close to windows, unwanted reflections may appear on these screens.	II
$L_{large\ AP} = 200$ or $L_{small\ AP} = 2\ 000$	The reflection on these screens is usually so disruptive that they are not suitable for office work in normal office environments.	III

7.3.3 References

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