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6.3 Office lighting

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6.3.1 General aspects

Lighting requirements for workplaces are set out in the Arbeitsstättenverordnung (Ordinance on Workplaces) [1] and the Technical Rule for Workplaces ASR A3.4, "Lighting" [2]. DGUV Information 215-442, formerly BGI 856, "Office lighting" [3], adds more specific detail and recommendations.

This section outlines the salient requirements of ASR A3.4 and the DGUV Information 215-442 as well as providing guidance on how to assess lighting systems (see Section 6.3.5). The S4 questionnaire can also be downloaded from the internet (www.dguv.de/ifa, webcode e650356) as an aid.

6.3.2 Daylight

Daylight plays an important role in indoor lighting. An adequate supply of daylight, combined with as little obstruction of the outside view (undistorted and unaltered) as possible, has a positive impact on employees' sense of wellbeing and thus on morale and productivity.

Consequently, it is important that office rooms have adequately sized windows. This can be said to be the case if

- the area of the transparent window surfaces is equal to at least one tenth of the room's floor area or
- the daylight factor[2] at the workstations is at least 2%.

In addition, the proportions and balustrade heights must be such that, as far as possible, they do not obstruct employees' view of the outside environment. Where circumstances allow, the workstations should therefore be positioned near the windows, not in the middle of the room.

At the same time, the windows must be fitted with suitable, adjustable solar protection solutions (see DGUV Information 215-444, formerly BGI 827, "Sun protection in offices" [4]) so as to minimise glare and illuminance[3] caused by daylight shining on display screens.

Daylight alone is not enough to ensure good quality lighting (particularly adequate illumination) throughout the entire working day, whatever the season. This is true even if the workstations are positioned directly next to the window and make optimum use of the daylight. As a result, artificial lighting has to be used. The quality parameters described below refer to artificial lighting but the aims they serve in terms of protection can also be applied to daylight. It should be pointed out, however, that employees appreciate the positive effects of daylight and the

[2] The daylight factor is the ratio of the illuminance at a given point inside to the illuminance outside without any obstruction. The sky must be overcast [2].

[3] Illuminance is a unit of measurement for the light that hits a given surface. It is measured in lux (lx) [2].

fact that they can see outside. So they are willing to accept more extreme levels of glare, light colour, luminance variance, etc. caused by natural light and actually find them agreeable.

6.3.3 Lighting quality parameters

Lighting quality affects humans in two ways. Firstly, it influences vision, determining how quickly and precisely a person can discern detail, colour and shape. And secondly, it can boost or reduce activity and performance levels. Poor lighting can cause visual strain, leading to headaches, watery or stinging eyes or spots before the eyes.

The following lighting (or "photometric") quality parameters are particularly important when endeavouring to achieve an adequate standard of lighting for visual tasks at display screens:

- Level of illumination
- Luminance distribution
- Direct glare limitation
- Reflected glare limitation for display screens and other equipment
- Daylight glare limitation
- Light direction and shadiness
- Light colour and colour rendering
- Flicker-free lighting

Strain on employees can largely be avoided by ensuring these quality parameters are applied. The employees' eyesight must also be taken into account.

Level of illumination

Artificial lighting must provide an adequate level of illumination. For display screen and office workplaces, this requires a horizontal illuminance[4] of at least 500 lx. The same level is required for the work area "meetings". Surrounding areas must have a horizontal illuminance of at least 300 lx.

The illumination level is determined not only by the horizontal illuminances but also by the vertical illuminances[5] and the evenness of the illuminance distribution across the surface being assessed.

Since the illuminance values are minimum requirements, lighting systems must be serviced as soon as the specified minimum value is reached (see also Section 6.3.4, "Maintenance").

Luminance distribution

Luminance is the photometric parameter that quantifies brightness. To achieve unhindered vision, the luminance ratio in the field of vision must be balanced. This is the case if the ratio between the luminance

- in the work area (e.g. a sheet of paper) and the immediate surroundings (e.g. desk) is 3 : 1 ("task-to-surround ratio") and
- on large surfaces in the working environment (e.g. walls) and the work area (e.g. a display screen) is 10 : 1.

The differences in luminance should not be too slight as this gives rooms a monotonous look.

A room's boundary surfaces can be deemed to be adequately bright if the colour scheme is such that the reflectance is between

- 0.7 and 0.9 on the ceiling,
- 0.5 and 0.8 on the walls and
- 0.2 and 0.4 on the floor.

The recommended reflectance range for work planes, furnishings and equipment is 0.2 to 0.7. The recommended gloss level is matt to satin matt (60 ° reflectometer reading ≤ 20).

Direct glare limitation

Unwanted direct glare can occur in a room or in employees' field of vision due to bright surfaces (e.g. luminaires, windows or illuminated surfaces) and steps must be taken to limit it. The discomfort glare from luminaires is evaluated using the UGR (Unified Glare Rating) method [5]. The lower the UGR, the less the glare. In rooms with display screens and office workstations, the UGR must not be higher than 19, irrespective of the level of illumination.

Reflected glare limitation

Reflected glare, caused by high luminances being reflected on glossy surfaces, also has to be limited. It is therefore important to ensure that only LCD screens with good anti-glare properties are used at display screen workstations. Reflected glare on other work equipment can be avoided by complying with the recommended gloss levels (see "Luminance distribution"). It is also important to use matt paper and document wallets. Other factors that can help prevent reflected glare are the type of lighting (see "Lighting type") and the positioning of the luminaires.

Daylight glare limitation

To minimise daylight-induced direct and reflected glare, it is important that workstations are positioned in such a way that, as far as possible, employees' line of vision runs parallel to the main window area. Installing display screens in front of windows can result in direct glare due to significant differences in

[4] Horizontal illuminance E_h is the illuminance on a horizontal surface, e.g. a bench [2].

[5] Vertical illiminance E_v ist the illuminance on a vertical surface [2].

luminance between the screen and the surroundings. Windows close behind users can reduce the legibility of the display.

In addition, suitable, adjustable solar protection solutions must be affixed to the windows in order to limit glare and excessive illuminance caused by daylight.

Light direction and shadiness

Efforts should be made to ensure a good level of shadiness at the workplace. The lighting must be designed to provide adequate shadiness so as not to impair spatial perception. On the other hand, highly directed light should be avoided too as it creates sharp-edged and long shadows.

Light colour and colour rendering

Lamps with a light colour of warm white or neutral white should be used for display screen workstations. Lamps with a daylight white light colour should not be used unless the illuminance is relatively high (≥ 1,000 lx).

Lamps must have a colour rendering index R_a of at least 80 if they are to provide good colour rendering.

Flicker-free lighting

Where artificial lighting is used, unwanted flickering can occur. Flickering leads to impaired vision and fatigue. It can be prevented by using electronic ballasts.

6.3.4 Maintenance

Lighting systems must be serviced regularly and repaired as necessary. To ensure this requirement is met, a properly qualified lighting planner should draw up a service plan for each lighting system. Service plans specify the intervals for cleaning and replacing lamps, cleaning luminaires and redecorating the room's surfaces. The service plan must be followed once the system is in operation so as to make sure the illuminance does not drop below the specified maintenance value.

If the illuminance falls below the required minimum, the lighting system must be serviced. During the course of a lighting system's useful life, the illuminance decreases as the lamps, luminaires and room age and accumulate dirt. Consequently, a higher mean illuminance value (planning value) must be assumed when planning the system.

6.3.5 Assessing lighting systems

It makes sense to check the plans and calculations during the actual planning phase to verify that the system complies with the requirements concerning lighting quality parameters. It is almost always extremely difficult to modify a lighting system that has already been installed.

Another key point is that the service plan drawn up by the planner should be adhered to and the lamps and luminaires cleaned, the lamps replaced and the rooms redecorated as specified in the plan (see Section 6.3.4, "Maintenance"). This ensures that the illuminances do not drop below the specified maintenance values.

Despite these measures, it can sometimes be necessary to carry out an assessment of an existing lighting system. This is done, for example,

- to narrow down the potential causes of non-specific health problems,
- if employees have health complaints that could be due to inadequate lighting,
- if there is concern that the requirements pertaining to the lighting quality parameters of the lighting system have not been complied with or
- if the intervals set out in the service plan are to be extended.

A qualified person (e.g. an OSH professional, occupational physician or technical inspector) can carry out an indicative assessment of whether the illuminance requirements are met.

If a detailed assessment is needed to establish whether the lighting quality parameters comply with the requirements, an assessor should be brought in to conduct the measurements described in DIN 5035-6 "Beleuchtung mit künstlichem Licht – Messung und Bewertung" (Artificial lighting – Measurement and evaluation) [6]. It is also recommended that an assessor be brought in and, where necessary, measurements be carried out if a complaint is to be made about the lighting system to, for example, the person(s) who planned or installed it or to the lessor of the premises.

Indicative assessment of illuminance

Illuminance should be measured at intervals of approximately 20 to 50 cm, depending on the size of the room or work area, with the gaps between each measurement as evenly spaced out as possible. The luxmeter used should be at least class C (for screening measurements).

The measurements are performed

- at a height of 0.75 m for horizontal illuminance E_h and
- at a height of 1.20 m for the mean vertical illuminance $\overline{E}_v$

The mean of each illuminance value is calculated based on the individual measurements. The mean vertical illuminance can be measured using a cylindrical sensor or determined by measuring and averaging vertical illuminances (e.g. in four directions, each 90 ° to each other) at one point.

The following must be considered when measuring illuminance:

- extraneous light must be eliminated as far as possible, i.e. the measurements must be conducted after dark, without daylight and with solar protection closed;

- no shadow, e.g. from the person measuring or from tall items of furniture or furnishings in the room, should fall on the luxmeter's sensor;
- the lamps must be operating stably, i.e. the lighting system must have been powered up at least 20 minutes prior to the measurement being conducted;
- the air temperature must be in the usual temperature range, e.g. 20 to 26 °C for offices; and
- the operating voltage must be as close to the rated voltage as possible.

Ensuring correct light colour and colour rendering

When lamps are replaced, it is important to ensure that their light colour and colour rendering, as well as their power consumption, are as set out in the plans. The light colour and colour rendering of the fluorescent lamps used are indicated by a three-digit code which the manufacturer applies to the lamps. The first digit refers to the colour rendering properties and the second and third digits indicate the light colour.

6.3.6 References

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6.4 Materials

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Materials, furniture, and cleaning and care products can have a major impact on indoor air quality since they are potential sources of gaseous or particulate emissions. The best known examples are formaldehyde, which is mostly emitted by chipboard and wood preservatives.

The information available on the materials and products used is usually sparse, if it exists at all. This tends to make it difficult to determine which harmful substances in the indoor air might have caused employees' health complaints. This section therefore has two objectives, as follows:

- Firstly, it sets out to show which substances are typically emitted as particulate matter or gas from certain materials (wood panels, adhesives, carpet, cleaning agents, etc.). These potential emissions can then be compared with any substances that might already have been detected in the indoor air, thus helping to identify the sources and/or eliminate the causes. Having said that, it is generally not possible to attribute a health complaint to one specific source without conducting further investigation.
- Secondly, it seeks to help provide effective ways of preventing health complaints by taking action early, while construction and furnishing are still underway, and to devise appropriate prevention strategies. To prevent disorders developing, action should be taken directly at the source. A large share of the many volatile organic compounds (VOC) that pollute indoor air comes from continuous emitting large-surface sources, such as furniture, building components and carpets. The fewer pollutants the materials emit into the indoor air, the better the quality of that air will be. Consequently, the process of choosing which materials are to be used in a building is particularly important. But recognising and selecting low-emission products is not always easy. This section aims to provide guidance for such situations.

6.4.1 General aspects

In order to prevent health complaints of occupants, new-build, reconstruction and refurbishment projects should only use construction chemicals (carpet adhesives, paints, varnishes, etc.) that cause minimum indoor air pollution. If emissions occur despite this strategy, it can be useful to heat the room and ventilate it to let in plenty of fresh air. In many cases, the emission rate falls to a very low value after a few months. However, some materials, among them chipboard, can continue to emit significant quantities of substances for longer – even up to several years.

Measures and procedures intended to improve indoor air quality by ensuring appropriate materials are selected do not necessarily go hand in hand with an improvement in the health and safety of the construction workers who work with the materials. For instance, for reasons of safety, (wood) flooring contractors must be advised to use low-solvent or, better still, solvent-free products instead of highly volatile adhesives with high solvent