ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 *2009. No. 2(90)*
ELEKTRONIKA IR ELEKTROTECHNIKA

HIGH FREQUENCY TECHNOLOGY, MICROWAVES
T191
AUKŠTŲJŲ DAŽNIŲ TECHNOLOGIJA, MIKROBANGOS

Lighting of Workplaces and Health Risks

K. Reinhold, P. Tint
Department of Work Environment and Safety, Tallinn University of Technology,
Kopli 101, 11712 Tallinn, Estonia, phone: +372- 620-3960; e-mail:karin.reinhold@tv.ttu.ee; piia.tint@tv.ttu.ee

Introduction

The lighting ergonomics gives possibilities to avoid the under or over-lighting of workplaces. Well-designed lighting decreases the amount of occupational accidents and diseases of eyes. Wellbeing connected with all-day work in front of video display terminals (VDT) is very much depended on lighting sources choice.

Workplace risk assessment can be defined as a systematic procedure for analyzing workplace components to identify and evaluate hazards and safety characteristics [1]. It is crucial to be able to identify the main hazards present in the work environment at source and evaluate their magnitude, nature and characteristics.

This study provides a basis for the determination of risk levels for lighting in the work environment in manufacturing and implements the flexible risk assessment method by using the results of measurements in five (printing, clothing, wood, plastic and mechanical) industries.

Methods

The study includes of the following activities:

1. The simple/flexible risk assessment method that was worked out by the authors in 2002 (Fig. 1) is used [2]. The method is based on two-step model that could be enlarged to a six-step model, and uses (no/yes) or (corresponds to the norms/does not correspond to the norms) principle. In this study, the five-step simple/flexible risk assessment method is used.

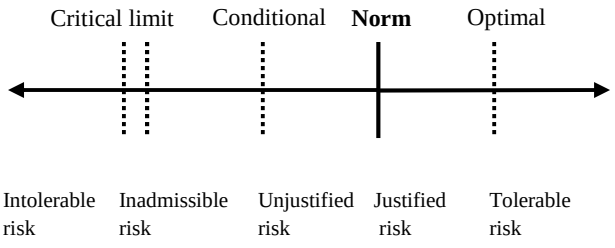

Fig. 1. Five-step simple/flexible risk assessment method

2. Eighteen case studies in companies of different industries were performed. The details of the companies are shown in Table 1. The case studies were conducted in the time period of 2003-2008.
3. To perform the measurements of lighting of workplaces, standard method DIN 5035-6:2006 "Artificial lighting. Measurement and evaluation" were used.

Theoretical estimation of poorly organized lighting using the simple/flexible risk assessment method

Poor lighting usually means weak luminosity. However, for good lighting practice it is essential that in addition to the required illuminance, qualitative and quantitative needs are satisfied as well. The following variables determine a good visual work environment: well-balanced luminance distribution, suitable illuminance value, absence of glare, correct direction of light, high colour rendering index of the luminaries, suitable choice of the colour appearance of a lamp, absence of flicker and availability of daylight [3, 4, 5, 6, 7]. CEN Standard EN 12464-1:2002 [8] suggests an illuminance of 300...500 lx for usual office work. The demand for stronger lighting rises with the worker's age as the ageing of the eye produces the reduction of visual acuity, contrast sensitivity and accuracy in identifying some colours [7]. The required value of illuminance in the clothing industry varies from 300 to 1500 lx, in the printing industry from 500 to 2000 lx, in the plastic industry from 50 to 1000 lx etc (EN 12464-1:2002). The value 1500 lx, for instance, is required for embroidering and quality inspection in the clothing industry and colour inspection in the printing industry. Usually, natural and artificial lightings are combined.

In the case of excessively high luminance contrast or glass (mirror) surfaces in industrial buildings or working with computers, disability or discomfort glare may develop. The glare caused by bright light sources shall be avoided by suitable shielding of lamps or shading of windows by suitable blinds or louvers [9]. The survey by Froehner and Reuter [10] showed that workers are more likely to change the settings of window covers (blind, lamellas) when glare occurs and the illumination seems to be too high than when the illumination is at low levels (less than 300 lx). High brightness reflections in the visual task may alter task visibility, usually detrimentally. Veiling

reflections and reflected glare could be reduced by arrangements of luminaries and workplaces, suitable surface finish (matt surfaces), luminance restriction of luminaries etc (EN 12464-1:2002). In the production rooms, the visual comfort of an individual is influenced by the distribution of luminance across the immediate field of vision. The ideal ratio for distribution across the work area is usually taken as 10:3:1 [7]. Therefore, the worker is not allowed to work only with a local lighting source, but the surroundings have to be lighted additionally with general lighting sources (at least 10% of the total lighting of the room), otherwise the probability of accidents arises. In the case of visual work, the illuminance uniformity *f* (expressed as shown in formula 1) and its immediate surroundings shouldn't be less than 0.5 (EN 12464-1:2002). Large spatial variations in illuminance around task area may lead to visual stress and discomfort [11].

$$f = \frac{E_{\min}}{\overline{E}} , \qquad (1)$$

where E_{min} – the illuminance at once of the measuring points and $\bar{E}$ is the mean illuminance.

Fluctuating luminaries can be even more disturbing than static contrasts. Flicker can cause visual disturbance [12] and increase the risk of occupational accidents in factories since it can have a stroboscopic effect [7, 11]. It is important for visual performance and the feeling of comfort that colours in the environment of objects are rendered naturally. Lamps which have the colour rendering index (R_a) less than 80 shouldn't be used in interiors where employees work or stay permanently. Those are, for instance, low pressure sodium lamps as surface colours of objects seen in the light output from such a lamp are seriously distorted (Smith 2000). In some work operations such as colour inspection and quality control the colour rendering index of the lamps shouldn't be less than 90 (EN 12464-1:2002). Incandescent lamps and some fluorescent tubes have broad emission spectra and therefore the best colour rendering properties [7]. The symptoms that indicate on the health damages caused by poor lighting are fast tiring, headache, asthenopic symptoms (eyestrain, tired, soft and dry eyes), ocular surface related symptoms such as watery eyes and irritated eyes, decrease of concentration abilities and stress. Specific disturbances of the eyes are degeneration of sharpness of vision (e.g. blurred vision, double vision) and accommodation abilities (e.g. slowness of focus change) [13, 14].

Considering data from scientific literature and international standards [3, 13, 15; EN 12646-1:2002; ISO/CIE 8995-1:2002] and using the simple/flexible risk assessment method, the connections between risk levels, values of illumination, glare, flicker, colour rendering index and health complaints can be interpreted in the office rooms as shown in Fig. 2.

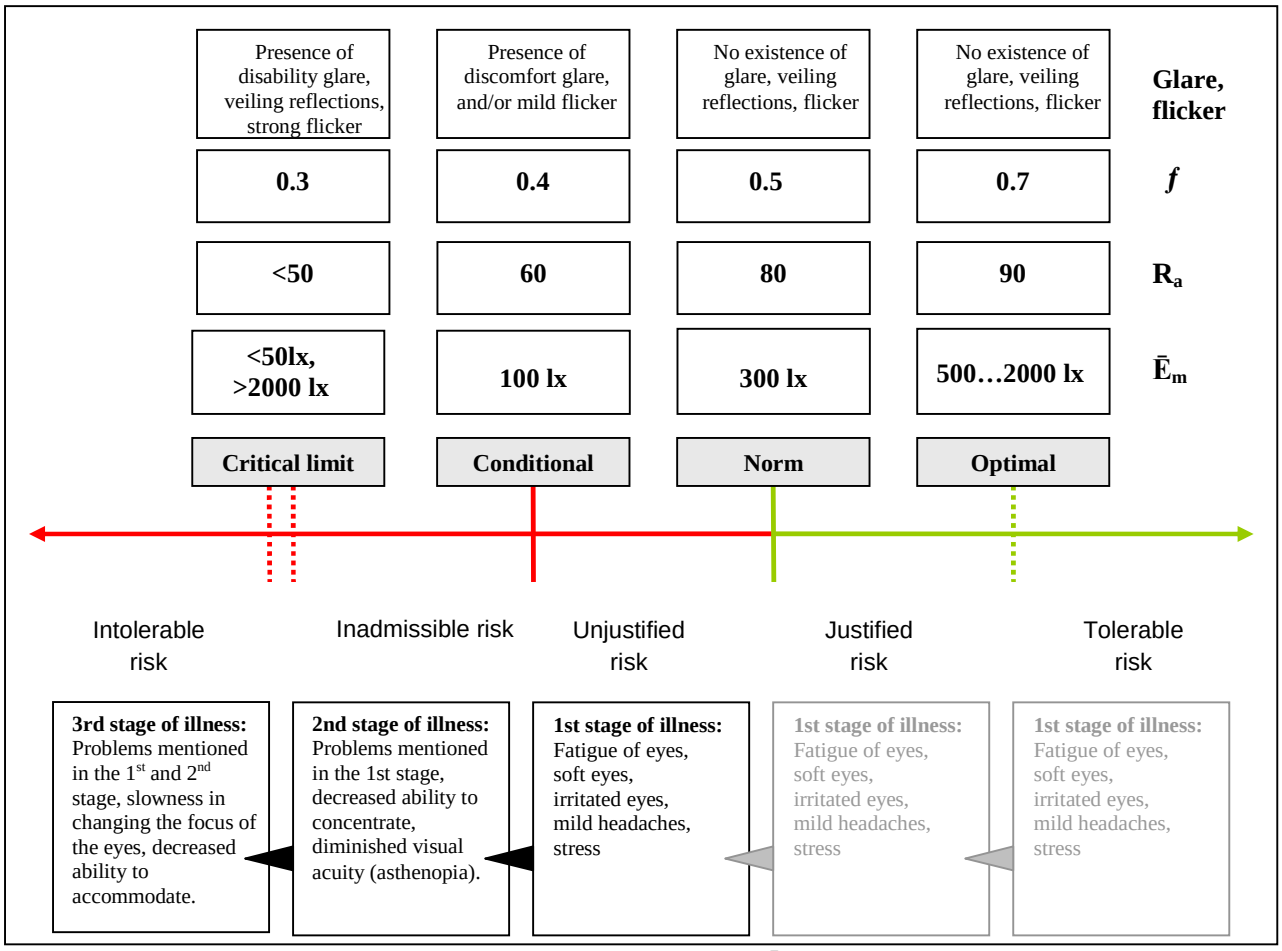

Fig. 2. Lighting and risk criteria (for office workers and for occupations where $\bar{E}_m$=300...500 lx is recommended)

Results of measurements of lighting (illuminance)

The data on investigated companies are given in Table 1. All investigated companies were assessed as small and medium-sized enterprises. In each company, the management attitude towards health and safety was assessed on the basis of the interest in the results of the research, the supportive actions to provide adequate information and details about the company and its investments into health and safety and the appreciation of workers' health through available protection, benefits, technical and administrative solutions present in the company and further efforts to enhance workplace safety. The awareness and supportive actions of the company management concerning occupational health and safety were assessed either as stimulating/supportive, neutral or impeding/negative.

Table 1. The data on companies and results of measurements of illuminance

Industry	Com-panies	Number of workers	Awareness of company manage-ment	Illumi-nance, lx, U* = 10.4%
Clot-hing	5	120…225	+ (2 cases) ± (2 cases) – (1 case)	525… 2040
Prin-ting	3	24…140	+ (4 cases) ± (1 case)	264… 1625
Wood	5	25…200	+ (2 cases) ± (2 cases) – (1 case)	320… 1050
Mecha-nical	2	90…175	± (2 cases)	88….. 1256
Plastic	3	25…180	+ (1 case) ± (2 cases)	138… 742
Offices	18	15…100	+ (9 cases) ± (7 cases) – (2 cases)	644… 2640

"+"stimulating, supportive; "–"impeding; "±" – neutral

Illuminance was measured at the local workplaces (normally at a height of 0.85 m above floor level), where a suitable measuring grid was applied. The arithmetic mean, $\bar{E}$, was presented. In addition, the uniformity f was calculated (ratio of minimum illuminance at one of the measuring points in the measuring great to the mean illuminance), possible glare sources were identified and the colour rendering index R_a was estimated. A digital luxmeter TES 1332 was used. To exclude the stray light, the measurements were carried out either in the dark or where possible, the windows were covered with blinds.

According to the measurements of lighting, it is no concern in the clothing industry, wood industry and in workplaces at offices of the companies. Improper lighting conditions were detected in two companies of the mechanical industry, in the plastic industry and one company of the printing industry. The problems are various, but mostly the luminosity is low due to expired, untended or work of general lighting systems and lack of local lighting devices. In some companies, observations of the workplaces revealed that some workers did not use the existing local task luminaries. Minor problems were connected with glare (constant and bright illumination from surrounding sources of light) and uniformity of illuminance. It is important to avoid dangerously deceptive shadows, which can be inadvertently produced in the vicinity of machinery.

Some complaints arouse among VDT users, mainly because of the reflection produced by large windows or local lighting sources (desk lamps), which appeared to wash out screen character images, and cause annoyance as well as possible visual fatigue.

The example of assessing the risk with simple/flexible risk assessment method is based on selected workplaces in a company of the mechanical industry where the most serious problems were detected (Table 2). Old, fluorescent lamps were used in the preparation department which CRI value was about 50…60. Those lamps were recommended to change to lamps with better colour rendering properties. According to the standard EN 12464-1:200, the recommended illuminance level for the work performed in the preparation department (sheet metal work, drop forging, medium assembly work) is 300 lx. Only one of the presented workplaces met the requirements, the results ranged from 123 to 325 lx. The uniformity values differed from 0.5 to 0.92. Glare was not observed in most workplaces, but flicker was detected in the workplaces which were lighted by mercury fluorescent lamps.

The risk of health impairment in workplace 3 was assessed justified since all the criteria presented in Fig. 2 were satisfied. The risk of health impairment in workplace 1 was assessed as unjustified risk (due to its low illuminance value) and in workplaces 2, 4 and 5 as inadmissible risk (due to their low illuminance and colour rendering index values and occurrence of mild flicker).

Table 2. Detailed results of lighting conditions in a mechanical company, selected workplaces

No	Work station	Lamp	Illuminance $\bar{E}$, lx; U = 10.4%	Uniformity, f	CRI R_a	Glare, flicker
1	Die machine Vipros S368	Incandescent	226	0.65	90	Not observed
2	Guillotine HACO TS3006	Mercury flourescent	133	0.5	60	Mild flicker observed
3	Press K 213DC	Incandescent	325	0.92	90	Not observed
4	Blending machine Amada HFF 130-3	Mercury fluorescent	123	0.75	60	Mild flicker observed
5	Blending machine Amada HT 50-12T	Mercury fluorescent	262	0.59	60	Mild flicker observed

Conclusion

In the investigated Estonian enterprises, insufficient or badly organized lighting as hazard was mainly under control. Glare and flickering were investigated in a mechanical company. The risk of health impairment in workplaces was assessed: 1) justified if all the criteria (illuminance, uniformity, no glare observed) presented in the model were satisfied; 2) unjustified (due to workplace's low illuminance value) and 3) inadmissible (due to workplace's low illuminance and colour rendering index values and occurrence of mild flicker). The illuminance at workplaces ranged from 88 lx in mechanical departments to 2640 lx in office-rooms.

References

1. **Harms-Ringdahl L.** Safety Analysis: Principles and Practice in Occupational Safety. Second Edition. – London: Taylor & Francis. – 2001.
2. **Reinhold K., Tint P., Kiivet G.** Risk assessment in textile and wood processing industry // International Journal of Reliability, Quality and Safety Engineering. – 2006. – Vol.13, No. 2. – P. 115–125.
3. **Eklund N., Boyce P. R., Simpson S. N.** Lighting and sustained performance: modelling data-entry task performance // Journal of the Illuminating Engineering Society. – 2001. – Vol.30, No. 2. – P. 126–141.
4. **Fontoynont M.** Perceived performance of daylighting systems: lighting efficacy and agreeableness // Solar Energy. – 2002. – Vol. 73, No. 2. – P. 83–94.
5. **Helland M., Horgen G., Kvikstad T. M., Garthus T., Bruenech J. R., Aarås A.** Musculoskeletal, visual and psychosocial stress in VDU operators after moving to an ergonomically designed office landscape // Applied Ergonomics. – 2008. – Vol.39. – P. 284–295.
6. **Roche L., Dewey E., Littlefair P. J.** Occupant reactions to daylight in offices // Lighting Research and Technology 2000. – Vol. 32. – P. 119–126.
7. **Smith N. A.** Lighting for Health and Safety. – London: Elsevier. – 2000.
8. **EN 12464-1:2002.** Light and lighting – Lighting of work places – Part 1: Indoor work places. – Brussels: European Committee for Standardization. – 2002.
9. **Freewan A. A., Shao L., Riffat S.** Interactions between louvers and ceiling geometry for maximum daylighting performance // Renewable Energy. – 2009. – Vol. 34. – P. 223–232.
10. **Froehner K.-D., Reuter M.** Visual comfort office workers using daylight and artificial light // Environmental Engineering. Selected papers of the 6th International Conference. – 2005. – P. 75–79.
11. **Bridger R. S.** Introduction to ergonomics. 2nd Edition. – London: Taylor&Francis. – 2003.
12. **Wilkins A. J., Nimmo-Smith I., Slater A. I., Bedocs L.** Fluorescent lighting, headaches and eyestrain // Lighting Research and Technology. – 1998. – Vol. 21. – No. 1. – P. 11–18.
13. **Blehm C., Vishnu S., Khattak A., Mitra S., Yee R. W.** Computer vision syndrome: a review // Survey of Ophthamology. – 2005. – Vol. 50, No. 3. – P. 253–262.
14. **Woodside G., Kocurek K.** Environmental safety and health engineering. – New York: John Wiley & Sons Inc. – 1997.
15. **Rea M. S., Quellette M. J.** Relative visual performance: A basis for application // Lighting Research and Technology. – 1991. – No. 23. – P. 139–153.

Received 2009 01 13

K. Reinhold, P. Tint. Lighting of Workplaces and Health Risks // Electronics and Electrical Engineering. – Kaunas: Technologija, 2009. – No. 2(90). – P. 11–14.

Lighting at workplaces might be insufficient or the workplaces might be over-lighted. If the lighting is not proper the accidents and occupational diseases can occur. The aim is to connect the level of hazards in the work environment and health risks. The aim will be gained through risk assessment at workplace that contains the measurements, listening to the workers' opinion and scientific medical investigations in the field of influence of lighting to human health (eye-sight worsening, fatigue, headache, errors in work methods causing accidents etc.). Glare and flickering are investigated in a mechanical company. The risk of health impairment in workplaces was assessed: 1) justified if all the criteria (illuminance, uniformity, no glare observed) presented in the model were satisfied; 2) unjustified (due to its low illuminance value) and 3) inadmissible (due to workplaces' low illuminance and colour rendering index values and occurrence of mild flicker). Ill. 2, bibl. 15 (In English; summaries in English, Russian and Lithuanian).

К. Рейнхольд, П. Тинт. Освещение рабочих мест и влияние на здоровье // Электроника и электротехника. – Каунас: Технология, 2009. – № 2(90). – P. 11–14.

Освещение на рабочем месте может быть недостаточным или рабочее место может быть слишком сильно освещено. Если освещение нерациональное, то возможны несчастные случаи и профзаболевания. Цель работы: найти взаимосвязь уровней риска и повреждений здоровья рабочих в результате влияния опасных факторов. Цель достигается с помощью определения оценки риска на рабочем месте, которая содержит измерения, опрос рабочих и медицинское наблюдение рабочих в области влияния освещения на здоровье человека. Недостаточное освещение на рабочем месте может привести к ухудшению зрения, усталости, головной боли, к ошибкам в работе, которые могут привести к несчастным случаям и т.д. Риск на здоровье от освещенности был определен следующим образом: 1) приемлемый, если все критерии (освещенность, однородность, нет ослепительного блеска) выполнены; 2) неприемлемый, если освещенность слишком низкая; 3) недопустимый, если освещенность очень малая (плохая различимость цветов и мерцание). Ил. 2, библ. 15 (на английском языке; рефераты на английском, русском и литовском яз.).

K. Reinhold, P. Tint. Darbo vietų apšvietimas ir jo sukeliama rizika sveikatai // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 2(90). – P. 11–14.

Darbo vietos gali būti apšviečiamos nepakankamai arba pernelyg gerai. Jei apšvietimas netinkamas, gali padaugėti nelaimingų atsitikimų bei profesinių ligų. Tyrimo tikslas – susieti darbo aplinkos pavojingumo lygį su rizika sveikatai. Jis pasiekiamas įvertinant darbo vietos riziką. Todėl išklausoma darbuotojų nuomonė, atliekami matavimai, medicininiai šviesos poveikio žmogaus sveikatai (regos pablogėjimui, nuovargui, galvos skausmui, sužalojimus sukeliančioms darbo klaidoms ir t.t.) tyrimai. Atspindžiai ir mirgėjimas tirti mechaninio profilio įmonėje. Darbo vietų keliamo pavojaus sveikatai rizika suskirstyta į: 1) pateisinamą, jei visi sudaryto modelio kriterijai tenkinami; 2) nepateisinamą dėl per mažo apšvietimo; 3) neleistiną dėl per mažo apšvietimo, prasto spalvų skiriamumo ir pasitaikančio mirgėjimo. Il. 2, bibl. 15 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).