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The comparison study of office workers' workplace health hazards in different type of buildings

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Abstract. The aim of the study is to investigate the office-workers' working conditions in the ordinary and atrium-type buildings. The indoor climate conditions in the cold season in two type of university buildings are presented. The air temperature is on the good level in the both of the buildings. The rooms in the atrium-side of the building **A** are too tight and the ergonomics is not considered designing the workplaces in the office-rooms. In the auditoriums of the building **B** it is too noisy (over 70 dB(A)) during the breaks that prevents the rest and the communication between the workers and students. The air humidity is too low in both type of the buildings (< 30% in the cold season, when the rooms are central-heated). It is recommended to moisten the air in the rooms artificially. For the health risk assessment in the workrooms a flexible risk assessment model is used. The risk levels for the indoor climate factors are different in the two type of buildings.

Key words: office-rooms, auditoriums, high schools, indoor climate.

INTRODUCTION

The main environmental issues today (Sundell, 2004) are outdoor air quality, energy use, and sustainable buildings, but not indoor air quality (IAQ). But, there is mounting evidence that exposure to IAQ is the cause of excessive morbidity and mortality. The main problem in developing countries with the indoor burning biomass for cooking and heating. The solution is a stove with the chimney. In developed regions, good ventilation, getting rid of 'Dampness' problems, an adequate testing of new materials would reduce morbidity and mortality.

The financial problems are usually the determining factor for the educational institutions in the construction of new buildings or updating of the existing ones (Valancius et al., 2013; Pikas et al., 2014). The ergonomics in the work-rooms in the buildings is usually possible to assess after the building or building-update is completed (Tint et al., 2012; Stradina et al., 2014).

The association between ventilation and health is rarely studied (Wargocki et al., 2002). The scientific evidence indicates that ventilation rates (outdoor air) below 25 l s^{-1} per person in commercial and institutional buildings are associated with an increased risk of Sick Building Syndrome (SBS), increased short-term sick leave, and reduced productivity (Wargocki et al., 2002). The conclusion from the European study (2002) was that the ventilation requirements in many existing guidelines and standards may be too low to protect occupants of offices, schools, from health and comfort problems and may not be optimal for human productivity. Higher ventilation rates can increase energy costs in relation to building operation, but it is also possible recover energy. The new energy recovery systems have been developed today (Valancius et al., 2013; Pikas et al., 2014) and the new standards are also available in the European area (CSN-EN 15251; EN 12464-1 etc.).

Winter indoor comfort and relative humidity: the colder the outdoor temperature is, the more heat must be added indoors for body comfort. However, the heat that is added, will cause a drying effect and lower the indoor relative humidity, unless an indoor moisture source is present. Degrees of comfort vary with age, activity, clothing, and body characteristics (Daisey et al., 2003).

The health problems inside the modernized buildings (with tight windows, central heating) are dry and stuffy air in winter (Urbane, 2004a); if the mechanical ventilation is not installed or not-rightly installed, (it is blowing on the worker and therefore switched off by the workers).

The arrangement of the lighting sources is always not correct from the standpoint of ergonomics (Urbane & Velicko, 2010). The lighting levels can be too low or too high for the task, so appropriate light levels depend on the visual task to be performed (Urbane & Velicko, 2010). Initial lighting power from all lamps decrease with age and with the effects of several factors. Recoverable light loss factors: area atmosphere (how dirty the space is); lamp burnout factor, lamp lumen depreciation, total light loss factor. Unrecoverable light loss factors are luminaire ambient temperature, voltage to luminaire etc.

The aim of the study: to investigate the shortages of design of buildings from the side of workers' safety, health and ergonomics and give the recommendations for the better solutions for arrangements of work- and study-places for people in the educational buildings.

MATERIAL AND METHODS

The study has been carried out during the cold season (outdoor air +5 to -10 °C) during the period Sept. 2014 – Jan. 2015. The workers and students work and study in different conditions (air temperature, humidity, velocity; the lighting or the workplaces, content of CO_2 in small office-rooms, noise in the workrooms and auditoriums etc.) that have to be measured using the accredited determination methods and the risk analysis has to be carried out by the occupational hygienist or other specialist in the field of occupational health and safety.

The existing risk assessment models (on the basis of BS 8800) contain the need to determine the probability of the occurrence and the severity of consequences of the influence of hazardous factors on workers. A flexible risk assessment method was worked out at Tallinn University of Technology, Chair of Work Environment and Safety (Reinhold et al., 2006). The four-step risk assessment model as the most suitable for office-rooms' risks assessment is presented in Fig. 1. The model is originally worked out from two-step to six-step for industrial rooms (Reinhold & Tint, 2009).

The investigated rooms in the building **A** (Fig. 2) were the office-rooms (Fig. 3), auditoriums and corridors (Fig. 6) and in the building **B** (Fig. 4) the office-rooms (Fig. 5), auditoriums and hallways (Fig. 7).

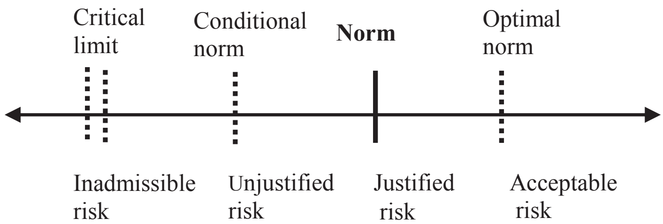

Figure 1. Four-step flexible risk assessment method.

Figure 2. The atrium of university building **A**.

Figure 3. The workroom in the building **A**.

Figure 4. The university building **B**.

Figure 5. The workroom in the building **B**.

The measuring devices used in the investigation, were: multi-function instrument TESTO 435-2 for indoor air quality (temperature, humidity, velocity and CO_2 content) measurements; light level metre TES 1332 for the measurement of lighting of workplaces; sound level metre TES 1358 for the noise measurements and the digital electrosmog analyser ME3030B for the measurements of non-ionizing electromagnetic fields.

Figure 6. The corridor in the building **A**.

Figure 7. The hallway in the building **B**.

The methods for the measurement and the exposure limits in the European Union area used in the current study are given in the following documents:

- BS EN ISO 7726:2001. Ergonomics of the thermal environment. Instruments for measuring physical quantities.
- CSN- EN 15251:2007. Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustics.
- EN 12464-1:2011. Light and lighting – Lighting of work places – Part 1: Indoor work places.
- ISO 2631-1:1997. Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1- General requirements.
- Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC).
- ISO 9612:2009. Acoustics – Guidelines for the measurement and assessment of exposure to noise in a working environment.
- ISO 1999:2013. Acoustics – Determination of occupational noise exposure and estimation of noise- induced hearing impairment.

RESULTS

The results of the measurements are given in the Table 1 and Table 2.

The air temperature in the workrooms and in the auditoriums is on the good level (>20 °C) in both of the educational buildings (**A** & **B**).

The ambient air in the rooms towards the atrium (building **A**) is not fresh even if the mechanical ventilation is working. It is not possible to switch on the mechanical ventilation as it blows on the worker. The original buildings (**B**) have advantages before the atrium-type (**A**), as the natural ventilation is possible as more suitable for the human being's biological systems.

The air is too dry in the winter season (**B**), the system of artificial lighting usually not designed considering the ergonomic principles (**B**), the shortage of natural lighting in the rooms towards the atrium is very significant (**A**), the workrooms are too small and the demands of CSN-EN 15251 are not followed before the distribution of the rooms to the workers in the new buildings (**A**). The recommendations are given for prevention of similar shortages in the future and to improve the present situation in the workrooms in the part of discussion.

The noise levels in the building **B** are over the norms determined for the office and educational rooms in CSN-EN 15251 (40-45 dB(A)) caused mainly by the organizational problems in the university **B**, not from the transport outside the building **B**.

Table 1. The microclimate and lighting characteristics in the atrium-type building **A**

Room type	Indoor air temperature, °C; U^1 = 0.6 °C	Humidity, % U = 2.0%	Air velocity, m s^{-2} U = 0.01 m s^{-1}	CO_2 content, ppm U = 10 ppm	Noise, dB(A) U = ±1 dB	Lighting, lx U = 5 lx
Auditorium	20–23	25–27	0.01–0.39	550–810	55–60	350–510
Office-room towards the atrium	23–24	23–24	0.00–0.01	550–800	45–50	500–800
Office-room with windows to the outside	23–24	27–29	0.01–0.03	550–600	50–55	500–800
Corridors	21–22	25–29	0.01–0.10	450–800	55–60	150–200

U1 – uncertainty of the measurements

Table 2. The microclimate and lighting characteristics in the educational building **B** (cold season)

Room type	Indoor air temperature, °C U^1 = 0.6 °C	Humidity, % U = 2.0%	Electro-magnetic fields, nT U = 2%	Air velocity, workplace, m s^{-1} U = 0.01 m s^{-1}	Noise, dB(A) U = ±1 dB	Lighting, lx U = 5 lx
Auditorium	21–24	28–30	–	0.1	49–87	340–590
Office-rooms	24–25		21–420	0.01–1.52	42–72	286–590
Cashier/seller	20–23	27.1	850	0.01	55	350
Hallway, learning space	21–23	22–25	–	0.06–0.01	74–78	171–245
Hallway	20–21	27–29	–	0.05–0.2	66–68	7–230

U1 – uncertainty of the measurements

The risk levels for the building **A** are determined by the model (Fig. 1) and taking into account the European Standards, the national legislation (National …, 2015) and the measurement results are presented in Fig. 8.

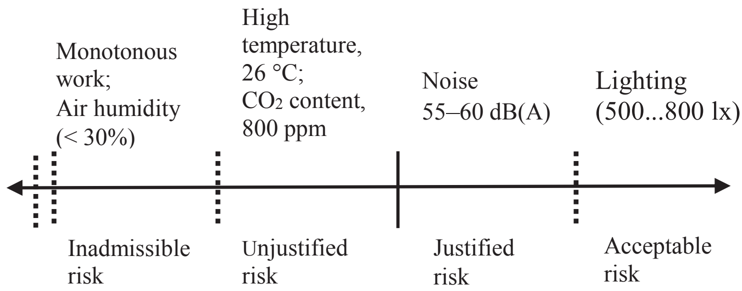

Figure 8. Assessment of work conditions using 4-step risk assessment model in building **A**.

The risk levels are determined by the model (Fig.1) and taking into account the European Standards and the national legislation (Urbane, 2004b) and the measurement results in the building B are presented in Fig. 9.

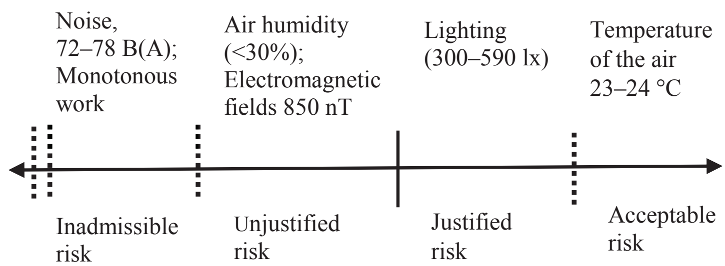

Figure 9. Assessment of work conditions using 4-step risk assessment model in building **B**.

The measurements show the differences in the health hazards level as the buildings are structurally different (ordinary (**B**) and atrium-type (**A**)). The measurement of CO_2 level in the building **A** and the measurement of non-ionizing electromagnetic fields in the building **B** were carried out at the request of the workers. The high content of CO_2 in the building **A** is caused by too small space (under 10m^2 per worker) (Table 1). The need for measuring the non-ionizing magnetic fields in the building **B** proceeds from the equipment (cashier machines, copy-machines) as the workers near-by had some health complaints (headache, dry skin) (Table 2).

DISCUSSION

In the current work the comparison of the advantages and disadvantages of the working conditions in the ordinary and atrium-type office-buildings in Latvia (building **B**) and in Estonia (atrium-type building **A**) is presented. The new atrium-type building **A** gives heat savings in winter, but causes health problems for workers as the shortage of natural lighting (inside the atrium), non-sufficient ventilation (if the windows are closed type) etc. Installation of mechanical ventilation systems in the ordinary type of buildings (**B**) has also to be very well thought-through, besides the problems in this area (ventilation) cannot always be foreseen in the stadium of repair-work design.

The novelty of the study lies in the application of the flexible risk assessment method (worked out in Tallinn University of Technology, Department of Work Environment and Safety and which differs from the standard method based on BS8800) for determination of health risk levels in ordinary and atrium-type buildings. The building type determines a lot of unforeseen health disturbances for workers which come to light when the buildings are already in use. The demands on safety, health and ergonomics management in the workplaces are needed in the stadium of the building design.

The flexible risk assessment method (in the graphic mode, Fig. 8) gives the possibility to look at a glance were the hazardous factors in the two investigated buildings in the assessment line are situated. In the building **A**, the noise and lighting level of buildings is accepted or justified, but not the air temperature nor CO_2 content and air humidity. The workers also complained about monotonous work and caused by this hazards musculoskeletal disorders (MSDs). The rehabilitation and prevention possibilities (massage) on the employers' expense are available in this building for the employees.

Air temperature and lighting of workplaces is good in the building **B** (Fig. 9), the unjustified risks are low air humidity and the level of electromagnetic fields (< 850 nT). The last is not over the norms, but is better to decrease, as the workers do not feel good. Some rearrangements of the equipment and devices or partitions could help. The inadmissible risk for educational buildings is noise level (Fig. 9): 72–78 dB(A). The warning signs: 'Keep silence, the others are learning' etc. could help.

The measurement results from the Table 1 and 2 can be placed into the model considering the exposure limits for occupational hazards in the office-rooms presented in the national resolutions and international standards.

The buildings are constructed by the building regulations (Ehitusseadus, 2002; *Buvniecibas likums*, 2014). The ergonomics has to be taken into account already in the design stage of the building. The architects are not sufficiently educated in safety and health during their studies. Therefore, the health inconveniences occur only if the building is ready. Some of the shortages are possible to correct afterwords, but those connected with the construction type of the building (ordinary or atrium-type) have sometimes peculiarities what cannot be improved.

The investigation of the work conditions and the design of workplaces in the modern buildings are very important in different countries (in cold and hot regions). The maintaining of good health of people, spending 60% of their life working inside needs scientific approaches. It is nowadays the problem for investigations in many countries (Finland, Malaysia, Czech, The Baltic States etc.).

Current study is the attempt to improve the ergonomics of teaching staff and students' workplaces in the educational buildings. Studies have shown that dry air has four main effects on the body: breathing of the dry air can cause respiratory disorders as asthma, bronchitis, sinusitis and nosebleeds; skin moisture evaporation can cause skin imitations and eye itching; irritating effects, such as static electricity which causes mild shocks when metal is touched; the 'apparent temperature' of the air is lower than what the thermometer indicates, and the body 'feels' colder. These problems can be reduced by simply increasing the indoor relative humidity. This can be done through use of humidifiers, vaporizers, steam generators, sources such as large pans, or water containers made of porous ceramics (Waterborne, 2013). The lower the room temperature is, the easier the relative humidity can be brought to its desired level.

Old times (Myhrvold et al., 1996) the CO_2 concentrations were very high and there is a correlation between the disturbing health symptoms and ventilation rate or CO_2 concentration in schools. These investigations found a statistically significant partial correlation (one-way ANOVA, $p < 0.001$) between symptoms of headaches, dizziness, heavy headed, tiredness, difficulties concentrating, unpleasant odour, and high CO_2 concentrations (1,500–4,000 ppm). Health symptoms characterized as 'irritations of the upper airways' were also higher at higher CO_2 concentrations ($p=0.024$). Organizational changes in the most companies are continuous and require flexible changes in work methods and workspaces (Kosonen & Tan, 2005). Nowadays, the carbon dioxide concentrations are high in the office-rooms if the windows cannot be opened or if there are more workplaces than allowed by the norms (< 10 m^2 per person, CSN-EN 15252). The concentration of the carbon dioxide outdoors in towns is increased particularly in summer time if the frequency of car transportation is high. It also influences on the concentration of CO_2 indoors and workers feel the air in the room not clean and fresh. Therefore and also due to the environmental issues, the worldwide demand is settled to decrease the CO_2 pollution in the environmental air.

If the noise level in the educational rooms is over the norm (40-45 dB(A)) due to the organizational problems in the university **B**, the means have to be taken to minimize the noise level to such values that the students and the professors could rest and communicate during the breaks (Resolution, 2000; Resolution, 2002).

The study-rooms and offices have to be naturally lighted during the light time (Resolution, 2000). Daylight in the offices improves sleep, physical activity and quality of life (Paul, 2014). The artificial lighting sources only help to gain the lighting level needed by the norms (EN- 12464-1:2011). Too strong lighting is also not permitted as it poses too great contrasts and tires eyes.

The atrium-type buildings are low cost establishments, therefore they are rather popular in modern construction (Pikas et al., 2014).

CONCLUSIONS

The indoor air quality in two differently designed school-buildings (**A**-atrium-type building; **B**- common-used, ordinary building) is investigated.

The results of the study show that the working and learning conditions depend on the building type, but also where this building is located. If it is located in a big town (**A**) and the ventilation is not properly designed (the ratio of the 'clean', coming from the outside and used air is not followed), the workers and the students health is in danger, the persons feel themselves drowsy and tired.

The ventilation was not adequate in both of the buildings (**A, B**). The buildings without windows which can be opened, are not allowed for the office-work.

It is suitable to use four-step risk assessment method for the risk assessment of the health hazards in the office-rooms. In the building **A** the inadmissible risk is too low air humidity (under 30%), not enough of natural lighting in the office-rooms, non-sufficient ventilation and fresh air shortage; in the university building **B** the inadmissible risk was too high noise level (until 70 dB(A)) that resists the communication between the office workers and the shortages in the ventilation of the rooms.

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