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THE IMPROVEMENT OF INDOOR ENVIRONMENT IN COMPUTER-CLASSES

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Abstract. The indoor environment in classrooms of Tallinn University of Technology was investigated. The classrooms are located in the new building (FEBA) and in the 25 years old building (FI). The main disadvantage in these rooms is the improper design of workplaces as the light is coming from the behind the student using the computer, even in the new building. This shows the inconsideration of ergonomic principles during the design of computer workplaces. The windows are equipped with blinds, but they transmit the light through the space between the adjacent blind. In the building of FEBA the windows are mostly directed North and West, so the sunlight is falling on the screen of the computer only afternoons (in April, May, September the sunlight is the strongest). In autumn-winter it is very dark in Estonia, so the work conditions with computers are better from October to March. The temperature of the air (21-22^{0}C) and the lighting of keyboards (360lx) and the screens (200-300lx) were within the norms, but the humidity of the rooms (15%) was below the norm (measurements in February, during the period of central heating of the rooms). The rooms were not over-equipped with computers in the new building (5 m^2 per one computer), but the classrooms in the building of FI were over-crowded with computers. The content of CO_2 in the air (until 1200 ppm) was over the limits (800 ppm). The health complaints and diseases connected with the continuous work with computers in the Estonian office-rooms were analysed in the paper using the data of the National Labour Inspectorate. The conclusion: in the ventilation system, the sensors for air temperature and CO_2 both have to be used to gain normal indoor environment conditions in computer-equipped classrooms. Interior architect has to consider the ergonomics of workplaces.

Keywords: info technology, education, work conditions, health complaints.

1. Introduction

Indoor environment affects health, productivity and comfort of the occupants. By thermal comfort, the rooms are divided into three categories from I to III (EVS-EN 15251:2007). Recent studies (Rashid *et al.* 2008; Jalas *et al.* 2000; Fisk *et al.* 2000; Tint *et al.* 2006) have shown that costs of poor indoor environment for the employer, the building owner and for society, as a whole are often considerable higher than the cost of the energy used in the same building. Unfortunately, indoor air can be far more polluted than outdoor air. Asthma affects some 23 million people (Fisk 2009), including over six million children. Many other serious health problems are directly attributed to indoor air quality. Indoor air pollutants come from dozens of sources. Carbon monoxide, for example, is usually the result of over-occupied classrooms. New buildings aren't safe from indoor air pollution - in fact, many newer buildings contain hundreds of products that off-gas high amounts of volatile chemicals. New carpet and carpet adhesives, fresh paints and varnishes, new furniture and panelling systems made with particleboard, and fabric used in upholstery and drapery can all contribute to what's often called "sick building syndrome," (Apte *et al.* 2000; Fisk *et al.* 2009) where occupants' illnesses can be blamed on the building itself. In some cases, building occupants complain of sick building syndrome symptoms that can include headache, nausea, fever, dizziness, eye or skin irritation, dry cough or fatigue (Caterina *et al.* 2003; Palmer 2003; Aaras *et al.* 2000). These symptoms may lessen or disappear when occupants are outside the building. Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the room (Reinhold *et al.* 2009a). High temperature and humidity levels can also increase concentrations of some pollutants. In the same time the ventilation systems' choose has to be done by very qualified engineer as different factors (in classrooms mainly concentration of CO_2 and temperature of the air) have to be considered; the adjusting system has to be multifunctional (Reinhold *et al.* 2009b, c; Katzev 1992). The current work focuses on computer-equipped classrooms indoor climate and lighting in a high-school. The importance of the problem is growing as more and more young persons began to use computers and the health problems could be rather serious in the future life if the health protection norms are not followed during their education (Resolution… 2000; 2001).

At the first half of 2008, a target inspection on work with display screens was carried out by the National Labour Inspectorate of Estonia in the office-rooms of Tallinn and Harju County (Estonia), in course of which 1323 workplaces with display screens were investigated (National.. 2009). This investigation gives the overall picture of health hazards in work with computers in office rooms in Estonia.

The general situation regarding work with display screens can be assessed as satisfactory:

- Health examinations of those employees who were supposed to pass eyesight tests, had been carried out with more than 50 % of the employees;
- In the course of inspection the workplaces' ergonomical arrangement was assessed, including suitability of workplaces to the workers' anthropological measures; the direction of the light falling on the screen, the height of chairs and tables in correspondence to employee's height;
- Assessment of the internal climate: air temperature, humidity and velocity: these factors were assessed as good at 83 % of workplaces;
- About 50 % of the enterprises had considered risks related to work with display units in their workplace risk assessment.
- Introduction of workers to safety issues was performed by 50 % of employers.

Target inspection on work with display screen was performed in Ida and Lääne-Viru County (Estonia) together with inspection of compliance of the procedure for health examinations and welfare facilities. As a result of the inspections 127 infringements were identified. In the course of inspection visits 32 notices were formulated and in 12 cases violations were reflected in the inspection reports. The most frequent shortcoming was that eyesight tests and health examinations had not been organised for employees working with display screens, there was not enough space on the work-table, unsuitable work-chairs and bad ventilation of work rooms. Quite often work with display screens had not been reflected in the risk assessment. The indoor air quality for workers can be defined as an optimal indoor environmental condition containing the lowest possible levels of hazards to satisfy the health, comfort, and wellbeing of the vast majority of workers in any type of buildings at any given time. In office-rooms, it mainly depends on the air temperature, relative humidity, and air velocity at workplace; the design and availability of the appropriate furniture at the workplace.

2. The method and measuring equipment

This study focuses on computer workplaces in school buildings, where the main hazards at the workplace are high air temperatures in the warm season, possible low temperature in the winter, low relative humidity in centrally-heated rooms in the cold season, high concentration of CO_2; improperly installed display-units (the (sun)light is falling from behind the student). The workplace risk assessment has to be carried out to determine the hazards' character, risk level, and their possible negative influence to the workers' health. The imperative to identify approaches to risk assessment has led to the development of various schemes for evaluating and controlling the risks of working with computers (Horgen *et al.* 2005; Aaras *et al.* 1998; Hedge *et al.* 1999).

The criteria for risk assessment at computer workplace were derived from regulative norms, standards, directives and scientific literature:

1. To perform the measurements of occupational hazards, the following standard methods were used: ISO 7726:1998 "Thermal environments – Instruments and methods for measuring physical quantities"; and 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".
2. The parameters of indoor climate were measured with TESTO 435 (air temperature, relative humidity, air velocity, concentration of CO_2) in 4 points of the classroom (8 if the surface area was over 100 m^2), at a level of 1.0 metres. Triplicate readings were recorded for each measurement and the average was presented. The measurement of CO_2 was carried out according to EVS-EN 1231:1999.
3. Measurements of lighting the workplaces and screen were performed using the light-metre TES 1332 (ranges from 1-1500 lx). Standards EVS-EN 12464-1:2002 and EVS 891:2008 were used. The lighting was measured on the worktable, on the screen and on the keyboard.

3. Design of the workplaces

The display device in modern monitors is typically a thin film transistor liquid crystal display (TFT-LCD), while older monitors use a cathode ray tube (CRT) (Meriaudeau *et al.* 2010). LCD has little or no flicker depending on the backlight technology. Glare is a problem caused by the relationship between lighting and screen, or by using monitors in bright sunlight. If the problem persists despite moving the monitor or adjusting lighting, a filter using a mesh of very fine black wires may be placed on the screen to reduce glare and improve contrast. These filters were popular in the late 1980s. They also reduce light output. A filter above will only work against reflective glare; direct glare (such as sunlight) will completely wash out most monitors' internal lighting, and can only be dealt with by the use of a hood or a transreflective LCD. For mixed paper and computer-based tasks, the minimum recommended desk length is 1500 mm. The desk should be deep enough to enable the employee to position the screen at a comfortable viewing distance, usually between 400 - 550 mm from the desk's front edge. If a Cathode Ray Tube (CRT) computer screen is used, this requires a desk depth of at least 900 mm. If a Liquid Crystal Display (LCD) screen is used, a shallower desk is acceptable (Horgen 2005; Aaras 1998). Research has shown that glare and reflections from VDUs may be linked to eyestrain and headaches (Caterina *et al.* 2003), however there are other contributing factors such as indoor air quality, room temperature, improper illumination and ergonomically improper workstations (Wolska *et al*. 1999; Palmer 2003). Cataracts and other eye diseases which have not been found to have any link are usually gradual and should be assessed through regular eyesight testing by an eye care professional. With VDU work, however a person's visual capacity can change over time due to natural causes. These changes such as eyestrain and other muscular strain from using a VDU are largely preventable by maintaining a suitable work environment and implementing appropriate ergonomic measures (Taal 1999; 2004; 2008), such as ensuring screens are at the correct height for and distance from the user, providing adequate lighting and diminishing glare. In the new building the most concern is that during the modelling of the room, the direction of the light is not considered.

For example, the room in Figure 1 has two glass-walls. One of them to the direction – North and the other to the direction –West. There is no blinds yet in these classrooms but it is obvious that blinds have to be bought as we move into spring (April, May) and working with computers without blinds in a sunny day would be impossible. The situation is better in the room shown in Figure 2 as the light is coming only from the direction of North. The concentration of CO_2 was measured 500-600 ppm (limit 800 ppm according to EVS-EN 15251). The rooms are high, not overcrowded with computer-places.

Figure 3: the classrooms in the old building. The windows are situated in the upper height of the outer wall of the room by the two sides. The one big room is divided with the plastic walls so, that 9 smaller classrooms and entrance hall are formed. In room 8 in the centre, the lighting on the computers keyboard was 113 lx (needed 400 lx). The artificial light sources were in the ceiling in two rows, general lighting, no workplace-lighting was available. The rooms were installed with local ventilation sources (in every room one ventilator in the ceiling) after the measurements of CO_2 (the concentration was 2000 ppm) 5 years ago. The concentration of CO_2 measured in 2010 was yet up to 1200 ppm.

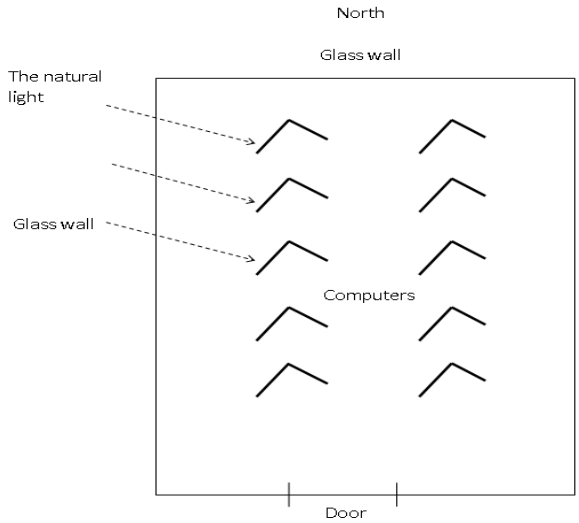

Fig 1. A classroom with two glass-walls (FEBA-1)

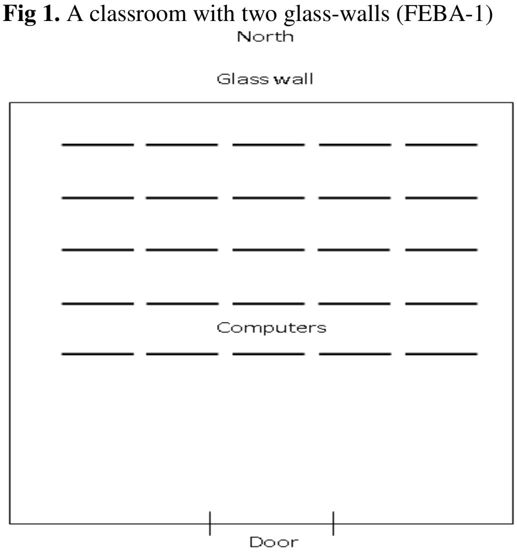

Fig 2. A classroom with one glass-wall (FEBA-2)

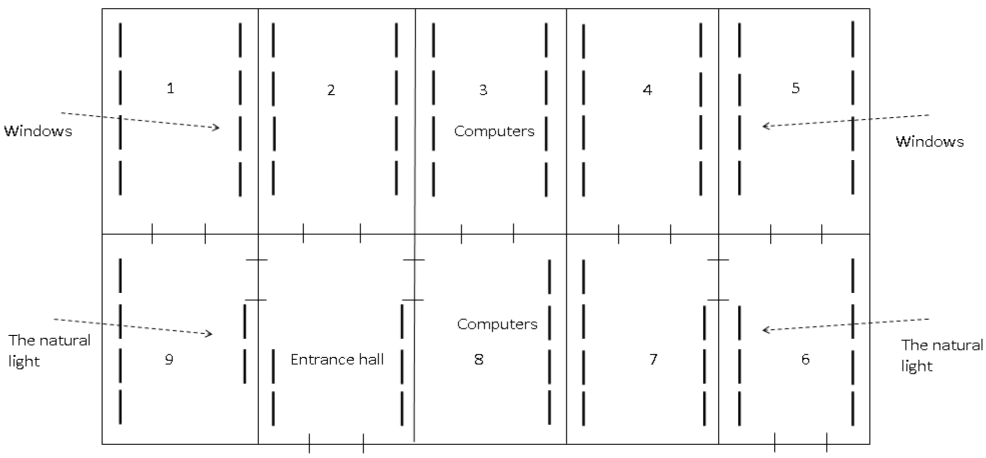

Fig 3. Computer classrooms built in 1984 (FI), one room, divided into separated with plastic walls

Table 1. The results of measurements of indoor climate, lighting and CO_2 concentration

Class-rooms	Indoor air temperature, ^{0}C, U = 0.6 ^{0}C		Indoor air humidity, %, U= 2.0%		Air velocity, work-place, m/s, U= 0.01 m/s	The CO_2 content,	Lighting of keyboard/ screen
	Cold season, 02.2010	Warm season 05.2006	Cold season 02.2010	Warm season 05.2006		ppm; U=50%	lx; U=5 lx Time of measure-ments02.2010
FEBA-2	22.0	-	15.6	-	0.05	528	225-1200
FEBA-1	21.7	-	15.0	-	0.03	438	225/295 329/272
FI-1	22.0	27.7	30.0	47.0	0.01	890	275/300
FI-2	21.5	28.6	32.1	46.8	0.02	1100	300/295
FI-3	21.7	28.6	33.0	47.1	0.39	1205	294/275
FI-4	21.8	29.4	32.8	47.2	0.35	980	300/275
FI-5	22.0	28.7	32.8	47.2	0.19	600	350/325
FI-6	22.0	29.5	32.6	47.0	0.02	689	302/356
FI-7	21.5	29.1	32.2	46.9	0.01	670	275/300
FI-8	21.4	29.2	32.2	46.9	0.29	800	113/275
FI-9	22.2	29.1	32.3	47.1	0.15	902	350/380
Entrance hall	21.0	28.6	32.1	47.0	0.05	500	101

U- uncertainty of the measurements

4. Results of measurements

The summary of the results of measurements is presented in Table 1. Standard EVS-EN 15251 gives the limits for air temperature in classrooms 20-24 ^{0}C (cold season: the mean temperature of ambient air is below 10 ^{0}C) and 23-26 ^{0}C (warm season: the mean temperature of ambient air exceeds 10 ^{0}C). The optimal relative humidity is 30-60 %, while permitted humidity is up to 70 %. The permitted concentration of CO_2 is <800ppm; the air velocity in the computer-workplace is until 0.1 m/s in winter until 0.3 m/s in summer.

In the new building (FEBA) the air temperature in the classrooms was at an acceptable level. Problems with air temperature inside the rooms were encountered in the warm season in the old building (FI) where it was higher than 29 ^{0}C due to deficiencies in ventilation systems or lack of them; however, it normalised after the reconstruction (installation of ventilation) and is now between the limits at least in the cold season.

Relative humidity (15-16 %) posed a problem during the cold season in the new building (FEBA), the air dried due to the heating system and the ventilation system is not able to balance the relative humidity of the air. Some of the students complained dryness of mucous membranes, which may be caused by the low value of relative humidity during the cold season. The relative humidity has to be raised with suitable air conditioning systems at least until 30 %.

The values of the air velocity were acceptable in FEBA building, except shortage of air during the warm weather in rooms where the ventilation system was not regulated to produce the air velocity up to 0.3 m/s in all computer workplaces (FI-1 to FI-9).

5. Discussion

In the computer-classes the ventilation rate is monitored only by CO_2 concentration. In the same time the air temperature has to be followed. The experience of the Laboratory of Ergonomics of Tallinn University of Technology (TTU) has shown that if only the CO_2 sensors are used, then the increased concentration of CO_2 has led to the increased inflow of the cold air into the rooms (the air temperature has not been followed). The recommendation to the authorities of TTU was given to follow the hazards (particularly the content of CO_2 in the classroom air and the air temperature) multifunctionally. In winter, when the outdoor air is cold, the increase of the air inflow (caused by the increased CO_2 concentration in the rooms during the lessons) will decrease the air temperature in the classroom if it is not simultaneously followed with the CO_2 concentration.

In two example calculations, Fisk (1997; 2000) compared the cost of increasing ventilation rates and increasing filter system efficiency in a large office building with the productivity gains expected from reductions in health effects. The estimated benefit-to-cost ratio is 14 and 8 for increased ventilation and better filtration, respectively (Fisk 2009). Several energy efficiency measures in buildings are not sufficiently profitable from the energy point of view. When these measures are considered together with the renovation needs of buildings, some of them may occur quite useful.

Using Itho's CO_2 sensors (Itho 2011) it is possible to closely monitor the carbon dioxide concentration within a building. Once levels reach an undesirable level, the sensor sends a signal to the existing ventilation unit which automatically adjusts the airflow to the appropriate room(s) to bring the air quality level back to normal, consequently heightening concentration levels.

6. Conclusions

To guarantee the good indoor air quality in computer-classes, the following has to be improved:

1. The buildings have to be equipped with mechanical supply and exhaust ventilation which also includes heat recovery from the exhaust air.

2. The ergonomic design of computer workplaces is very important. The interior architect has to follow the ergonomic principles of computer-equipped workplaces. It influences on the health of young studying generation. The ergonomic furniture should be chosen into computer classes. The table has to be at least 70 cm broad (there should be the place to put the papers and books if needed) and there has to be the possibility to regulate the height of the chair. There are demands for keyboards and mice and the expectation of having to remain in sitting position when working with computers should be diminished. The students are too young to complain about the pain in the wrist or neck.
3. The most demanding issue in the work with computers is the direction of the light related to the computers (not straight from the back).
4. The air quality has a direct effect upon an individuals' ability to concentrate on their job. The re-design and surveillance of the ventilation system is cost-effective considering the health of the young generations.

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