IMPACT OF MICROCLIMATE CONDITIONS ON THE CONTROL ROOM PERSONNEL - CASE STUDY

LUBOS KOTEK[1], PETR TRAVNICEK[2], FRANTISEK BABINEC[3], PETR JUNGA[2], LEISAN MUKHAMETZIANOVA[1]

[1]Brno University of Technology, Faculty of Mechanical Engineering, Institute of Production Machines, Systems and Robotics, Brno, Czech Republic

[2]Department of Agricultural, Food and Environmental Engineering, Faculty of Agronomy

Mendel University in Brno, Brno, Czech Republic

[3]RISCO – Risk Consulting Brno, Brno, Czech Republic

DOI: 10.17973/MMSJ.2015_10_201535

e-mail: kotek.l@fme.vutbr.cz

The present contribution deals with the influence of work environment factors on the control room personnel, in particular the temperature and humidity parameters, and concentration of CO_2. This contribution summarizes selected practical experience of implementing ergonomic analysis and evaluation of the impact of these parameters on the reliability of human factor in the chemical industry, power engineering and gas industry.

KEYWORDS

ergonomics, reliability of human factor, control room, work environment, temperature, humidity, carbon dioxide

1 INTRODUCTION

A control room is defined as a basic functional unit and its physical structure, where the personnel carries out a centralized control, monitoring and administrative tasks. It is usually a structurally separated space accommodating the control and display unit. Control rooms in the chemical industry, power engineering and gas industry are key centres from where the large technological units are controlled. Failure of their personnel is often the cause of incident or accident; therefore the reliability of personnel is very important.

The key parameter, which affects the personnel reliability, is working environment, especially temperature and humidity parameters and CO_2 concentration.

2 REQUIREMENTS FOR THE ANALYSIS OF THE IMPACT OF MICROCLIMATE FACTORS ON THE RELIABILITY OF HUMAN FACTOR

The EN 31010 standard "Risk management - Risk assessment techniques" underlines the importance of HRA methods: "The importance of HRA method is illustrated using various accidents where critical human errors contributed to a catastrophic chain of events. Such accidents are a warning for the risk assessment, which focuses only on hardware and software in the system.

The EN 62508 standard specifies that external factors shaping the performance are the result of organizational and technical preconditions. Organizational requirements can often be described only qualitatively. In contrast, a special attention should be paid to technical preconditions (including environmental factors) and these factors should be more likely described quantitatively.

3 FACTORS AFFECTING THE PERFORMANCE AND RELIABILITY OF PERSONNEL IN THE CONTROL ROOM

The term factor affecting the performance denominates the phenomena, which decrease or increase the personnel performance and likelihood of their errors. However the influence of a particular factor in a particular situation is always different and related to a great number of other factors. Experimental work has not yet provided such data that could be implicitly accepted to quantify the human errors. Therefore, the evaluation of individual factors consists primarily in minimizing their adverse effects.

In terms of microclimatic factors of working environment in control rooms, it is important to monitor in particular the temperature and humidity parameters and the level of CO_2 concentration.

Basic requirements for the workplace environment are defined in the EN ISO 15265 standard. It sets out the requirements for both heat and coldness burden. These requirements protect the operator from stress and discomfort; however they are not directly related to his/her reliability and performance.

4 TEMPERATURE AND HUMIDITY PARAMETERS

In terms of health prevention of employees, the workplace must ensure a sufficient air exchange via natural, forced or combined ventilation. Forced or combined ventilation must be always installed provided that the natural ventilation proves to be insufficient to ensure a year-round health prevention of employees. Nevertheless, ventilation devices must not interfere with microbial purity of the air and must be adjusted so that the employees are not exposed to drafts.

The workplace should be operated under specified microclimatic conditions, particularly in terms of the volume of air, ventilation, humidity and temperature [Chundela 2013]. As these parameters interact with each other, it is preferable to use a multi-criteria evaluation method [Kalibatas 2012]. A good tool for evaluation of comfort zones is Fig. 1, which divides the working environment in terms of temperature and humidity into four zones. For activities, which also include the work in the control room, the environment in the comfort zone A should be ensured. Zone B means satisfactory environmental conditions (decreasing of human reliability), zone C means dissatisfactory conditions (causes a number of errors) and zone D means harmful climate.

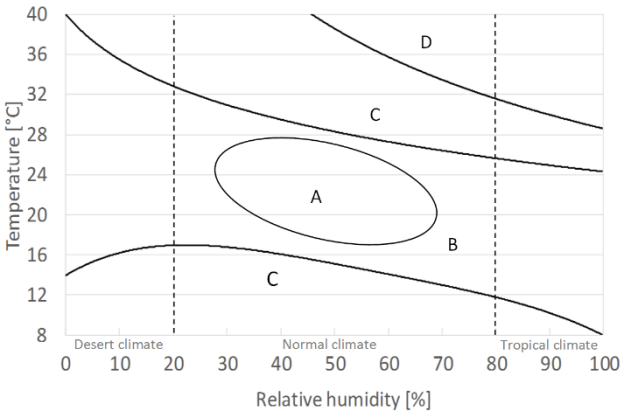

Figure 1. Zones of temperature and humidity parameters [Chundela 2013]

During heating season, the absolute external humidity is about 1 to 5 g/kg whereas the indoor absolute humidity is around 7 to 9 g/kg. Each cubic meter of air change indoor by outdoor air takes some 2 to 8 g of water vapour out of the building. [Pfluger 2013]

When considering the environmental effects on the operational personnel, we can refer to the following findings:

- High temperatures cause excessive weariness and lack of concentration leading to serious accidents.
- Working in cold environment leads to a reduction of skin blood flow, increase in blood pressure and increased heart rate. A decreased activity of the central nervous system causes drowsiness.
- Low air humidity brings about, even in healthy individuals, intensive drying of mucous membranes of the upper airways, decrease in their protective functions and increase of potential penetration of certain harmful substances to the lower airways. Low humidity also reduces the ability to concentrate and the increased aggression [Chundela 2013]. In such cases, in winter, it is suitable to artificially increase the humidity using humidifiers, but only up to a maximum value of around 40%. At higher temperatures and high relative humidity of air, the evaporation via perspiration decreases while weariness increases.

Humidity also influences some other factors that may affect the health and performance of employees. This is summarized in Figure 2.

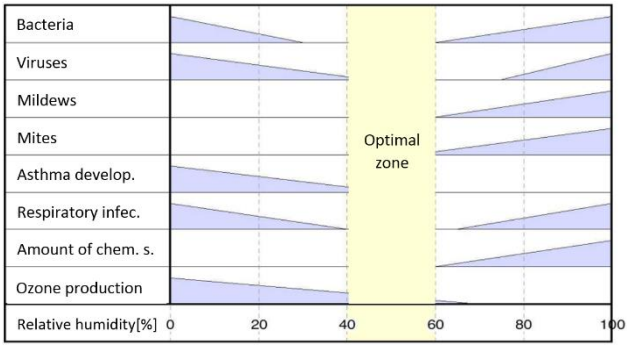

Figure 2. Factors affected by air humidity [Diwakar 2014]

However, the use of air conditioning needs to be properly solved; otherwise the so-called (sick-building syndrome - SBS) may occur among the workers. It is irritation of the eyes and throat, a strong feeling of dryness of mucous membranes, headache, mental symptoms such as restlessness, reduced working capacity, lack of concentration, memory problems, irritability, nervousness, daytime sleepiness or, on the other hand, nightly insomnia.

5 CONCENTRATION OF CO_2

Due to the increase in energy efficiency of buildings, accumulation of CO_2, which is formed in the body, is present; air expired by an adult contains an average of 40,000 ppm of carbon dioxide. A normal concentration of CO_2 in the external environment is from 350-400 ppm (depending on the type of agglomeration and season of the year - in winter, the concentration of CO_2 in the northern hemisphere is, due to low activity of plants, higher than in summer [Robertson 2001].

The DIN EN ISO 11064-6 standard, which is focused on the evaluation of the environment inside the control rooms, sets the recommended maximum value of CO_2 for 910 ppm. The work in the control room also requires a minimum amount of air supplied to the workplace; it must be 29 m^3/h. [Guais 2011]

At concentrations exceeding 1,000 ppm in the working environment, a feeling of drowsiness may occur, while concentrations of more than 2,000 ppm reduce the capability of concentration, or may cause headache [Tillett 2012].

Concentrations exceeding 5,000 ppm cause changes in heart rate and other physiological responses and therefore they represent a health risk [Norback 2012].

Studies show a significant impact on the performance and quality of decision making at higher CO_2 concentrations [Satish 2011].

Information on the effects of very high CO_2 concentrations on humans was also obtained from several eruptions of CO_2. The probably most significant release in a residential area in the modern history occurred in the vicinity of Lake Nyos in Cameroon in 1986; nearly 2,000 people died [Bang 2012]. The accidents associated with CO_2 release also occurred in the course of industrial processes [Kotek 2014].

6 CASE STUDY

Measurements were carried out in the control rooms in enterprises of chemical and gas industry, and power engineering sector. From among a series of performed measurements, typical examples were chosen to show the errors in the construction of the control room.

6.1 Example 1

Measurements were carried out in the control room of about 90 m^3, with permanent staff of two persons. The control room is equipped with functional air conditioning; however it switches in cycles. Therefore, a problem was identified with rapid temperature fluctuations.

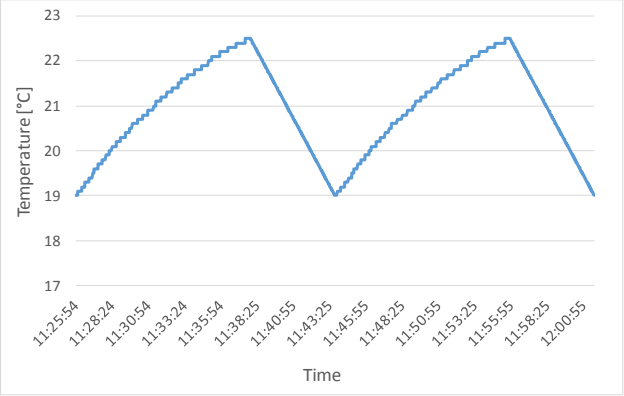

Figure 3. Temperature measurements in the control room of chemical plant

6.2 Example 2

Measurements were carried out in a large control room of ca. 300 m^3 with permanent staff of three employees. The control room is provided with an air exchange device but it is not fitted with a humidifier. The outdoor temperature during the measurement was 4.4 ° C, outdoor humidity being 89%. As shown in the following figure, there is a long term (in winter) problem with low humidity of air (minimum measured relative humidity was 25%).

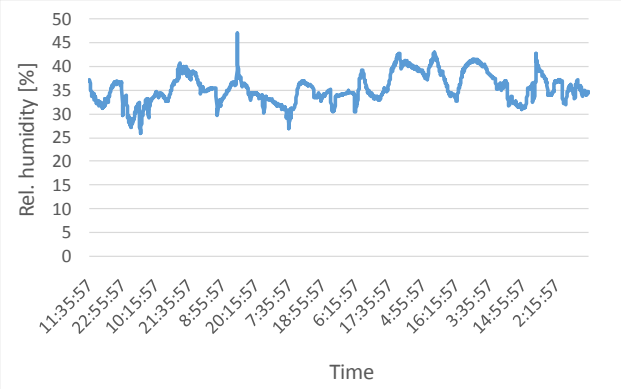

Figure 4. Measurement of relative humidity in the control room

6.3 Example 3

Measurements were carried out in the control room of a biogas plant. The volume of the control room is 11.4 m^3; it is a container room without windows (very narrow) in the vicinity of cogeneration unit. The control room is unmanned, i.e. it is checked at regular cycles. As seen from Figure 5, upon arrival of the operators (two persons) in the control room, there is a rapid increase in the CO_2 concentration with a trend of 42 ppm / min. In the control room there is not a sufficient air exchange for the two employees.

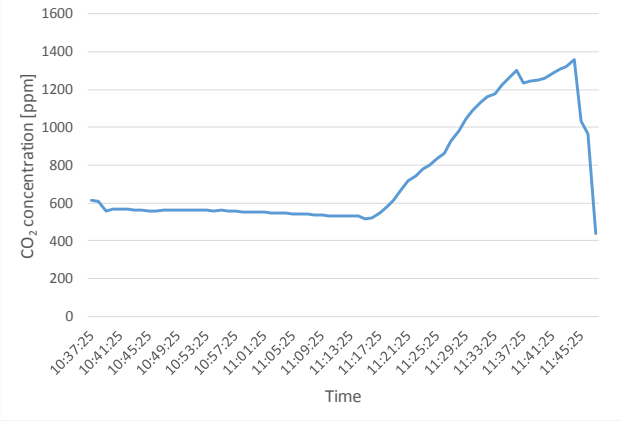

Figure 5. CO_2 measurements in the control room of unmanned biogas plant

7 DISCUSION OF RESULTS

A detail discussion of the all environmental factors goes beyond the scope of this paper. General conclusions of this paper show the most significant error of microclimate control systems and describes the references for designers and engineers.

- Microclimate control system should be properly chosen in terms of performance; inappropriately chosen system leads to fluctuations in internal temperature, which is unfavorable to employees.
- Ventilation for the working area should be adjusted to the moisture sources in space and occasionally reduced, especially in case of very low outside air humidity.
- Using of a CO_2 demand-controlled ventilation system may improve the indoor air quality.
- Continuous monitoring of microclimate factors using a data-logging device can be useful in investigations of building ventilation and indoor air quality.

8 CONCLUSION

Microclimatic conditions in the workplace have a major impact on the reliability and performance of employees [Hricova 2014]. This article discusses the influence of temperature, humidity and increased CO_2 concentration on the employees concerned. Increasing pressure on energy savings (better insulation of buildings, higher quality sealing of window joints) leads to an increase in humidity and, in particular, the CO_2 concentration in the interior. The installed system and control of air conditioning have also a major influence on microclimatic parameters.

Measurements in selected plants demonstrated a non-compliance with requirements for environmental parameters (CO_2, temperature and humidity). The solution is a design of air-conditioning control systems, which will follow the recommended values.

Provided that the analysis of occupational hazards makes it possible (plant operators do not represent a serious risk), it is necessary to equip the workplace with at least a measurement of microclimate parameters [Blecha 2011]. This would at least ensure that the personnel are informed about the working conditions.

ACKNOWLEDGEMENT

This work is an output of cooperation between internal BUT research project Reg. No. FSI-S-14-2401.

REFERENCE

[Bang 2012] Bang, H.N. Disaster management in Cameroon: The Lake Nyos disaster experience. Disaster Prevention and Management, 2012, Vol.21, No. 4., pp. 489-506.

[Blecha 2011] Blecha, P., et al. Integration of risk management into the machinery design process. In: Proceedings of 9th International Conference on Mechatronics 2011, Warsaw, 21-24 September, 2011. Berlin: Springer-Verlag Berlin Heidelberg, pp. 473-482.

[Chundela 2013] Chundela, L. Ergonomie. Praha: CVUT, 2013. ISBN 978-80-01-05173-3

[Diwakar 2014] Diwakar, L. B., et al. Effect of Indoor Air Humidity on Human Health. International Journal of Engineering Science Invention, 2014, Vol. 3, No. 1., pp. 44-50.

[Guais 2011] Guais, A., et al. Toxicity of carbon dioxide: A review. Chemical research in toxicology, 2011, Vol. 24, No. 12., pp. 2061-2070.

[Hricova 2014] Hricova, J., et al. Monitoring the air quality in conventional wet machining. Manufacturing Technology, 2014, Vol. 14, No.2., pp. 166-172.

[Kalibatas 2012] Kalibatas, D., et al. A method of multi-attribute assessment using ideal alternative: Choosing an apartment with optimal indoor environment. International Journal of Strategic Property Management, 2012, Vol. 16, No. 3., pp. 338-353.

[Kotek 2014] Kotek, L., et al. Low concentration of oxygen in external environment - Modeling the consequences of accident. Chemical Engineering Transactions, 2014, Vol. 36, pp. 553-558.

[Norback 2012] Norback, D., et al. Carbon dioxide (CO2) demand-controlled ventilation in university computer classrooms and possible effects on headache, fatigue and perceived indoor environment: an intervention study. International Archives of Occupational and Environmental Health, 2012, Vol. 86, No. 2., pp. 1-19.

[Pfluger 2013] Pfluger, R., et al. Physiological impairments at low indoor air humidity. Air Quality Control, 2013, Vol. 2013, No. 3, pp. 199-209.

[Robertson 2001] Robertson, D. S. The rise in the atmospheric concentration of carbon dioxide and the effects on human health. Medical Hypotheses, 2001, Vol. 56, No. 4., pp. 513–518.

[Satish 2011] Satish, U., et al. Impact of CO2 on human decision making and productivity. In: Proceedings of the 12th International Conference on Indoor Air Quality and Climate, Austin, 5-10 June, 2011. Texas: International Society of Indoor Air Quality and Climate (ISIAQ), pp. 1572-1573.
[Tillett 2012] Tillett, T. Don't hold your breath: Indoor CO2 exposure and impaired decision making. Environmental health perspectives, 2012, Vol. 120, No. 12., pp. A475.

CONTACTS

Ing. Lubos Kotek, Ph.D.
Institute of Production Machines, Systems and Robotics
Brno University of Technology, Faculty of Mechanical Engineering
Technicka 2896/2, 616 69 Brno, Czech Republic
tel.: +420 541 142 391 e-mail: kotek.l@fme.vutbr.cz
http://www.fme.vutbr.cz/