APPROACHES TO THE EVALUATION OF WORKSHOP MICROCLIMATE CONDITIONS

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The article deals with the evaluation of microclimate conditions at the workplaces of the engineering workshops. By measuring the conditions of the thermo-humidity parameters, these were objectified and compared with the results of the subjective evaluation, obtained by the questionnaire survey. Based on investigators' research up to the present day, these outputs are not always consistent, and therefore the research objective was to look for narrow spots of this "disagreement". Appropriate workplace conditions "well-being" are indispensable for a manufacture production, as workers are the most valuable resource of the company, which is still true, at of today's high automation, and at the onset of the so-called "4th industrial revolution", the employees health protection must be ensured above all, because workplace comfort is affecting not only a health, but also a productivity of employees.

KEYWORDS

Thermal comfort, microclimate, environment, measurement, questionary survey

1 INTRODUCTION

Today's competitive environment requires not only competitive technological equipment and efficient, cheaper and more stable processes, but also an emphasis on the third pillar of the production process, i.e the manufacturing workers themselves. Experienced and highly satisfied worker (the knowledge worker) once again plays an important role in business process management, and businesses must try to ensure that "well-trained and trained workers" do not. In addition to financial benefits, they come to the non-financial word, such as "well-being". Notwithstanding the fact that health protection at work is set by law. Its role is played by the above-mentioned employee satisfaction and their impact on labor productivity [Trebuna 2017].

This is why not only in many companies they are increasingly focusing on improving working conditions. Suitable conditions at the workplace are essential for production. As the most important source of entrepreneurship, today still in high automation, at the threshold of the so-called 4th Industrial Revolution. The health protection of employees must be safeguarded in the future, not only because it is laid down by law in the developed countries of Europe, for example in Slovakia the protection of health from adverse microclimate influences is outlined by national legislation based on international standards as [ISO 45001: 2016] (formerly OHSAS 18001).

In Slovakia, especially according to Act [355/2007] are employers obliged to provide technical and organizational measures which eliminate or reduce the adverse effects of the factors of the thermal microclimate ("microclimatic conditions") on the health of employees at the lowest possible and attainable rate. In addition, the Act [355/2007] further stipulates that employers are required to provide a drinking regime and appropriate protective clothing and personal protective equipment for increased heat or cold loads.

In the implementing decree [99/2016] there are determine:

- optimal and acceptable microclimate conditions,
- acceptable microclimate conditions due to heat load,
-admissible surface and liquid temperatures; and
-for heat and cold load including drinking regime.

These conditions must be respected and appropriate precautions should be taken to avoid adverse effects. However, current values (the current state in which the workplace is located) must be known. This study has been realized by analyzing recent international literature. [Jendritzky 2012], [Karvatte, 2016], [Mishra 2016], [Song 2015]

2 RESEARCH METHODOLOGY

Evaluation and assessing the microclimate of the working environment requires a comparison of the identified facts with the requirements of the standards and the applicable regulations. There are two basic approaches to assessing the work environment:

- an objective assessment of measurable factors, using current measurement methods and techniques [ISO 7730: 2005],

- a subjective assessment under which measures are taken to improve the current situation. Frequently, a questionnaire survey or a structured interview technique is used.

The aim of the research was to compare the results objectivized by the measurement with the results of the subjective evaluation obtained by the questionnaire survey. In this research we analysed of the variance of monitored parameters further. We examined if microclimate conditions of particular points of measurements are identical and if the differences between monitored parameters are statistically significant.

Based on investigators' research so far, these outputs are not always consistent, so research has also sought to look for bottlenecks in this "disagreement."

Both approaches were used in the present research on the impact of microclimatic conditions on employees. Both will be briefly introduced. Objective approach, the measurement determining physical quantity (e.g. temperature, air speed, and relative humidity) may be used for detecting the actual state of the work, a subjective assessment of the feeling in comparison to the standards. This approach is very important because, based on their subjective feelings, workers are decided.

Objective evaluation methods microclimate conditions consist in comparing the measured values with the limit values laid down under the heat balance equation.

A prerequisite of a person's thermal balance is the need to guide the temperature of man's production and the transmission properties of his garment. Heat production of man depends on the mechanical work performed, the transmission properties of the garment are characterized by the thermal resistance of the garment.

The standard values are given taking into account the annual period and the individual working categories in the Annex to degree no. 99/2016 Coll. [Decree No. 99/2016]

Subjective evaluation was conducted in the form of a structured questionnaire.

3 OBJECT OF RESEARCH AND MEASUREMENT RESULTS

The measurement was carried out in the workshop of the engineering factory located in a one-storey hall building during a warm day. Warm period of the year is stated as period during which average daily outdoor air temperature is 13 °C or higher. Daily temperatures ranged from +30° C up to +35° C, with relative humidity ranged from 45% to 56% and air velocity va from 2.27 to 6.25 (ms^{-1}). Parameters characterizing the work activities performed at the workshop workplace are given in Table 1.

Characteristics of wokrshop	Machine processing and assembly of small light parts, piecework of tool makers and mechanics
Specific Job Class: 1b	The stand-up work , slow walk on a flat floor with the carrying of light loads or overcoming a small resistance
Metabolic rate	81-105 W.m-2, M = 146 – 190 W
Heat resistance of clothing	Rcl = 0,64 clo
Exposure of workers	8 hours per shift

Table 1. Parameters characterizing the work activities

There were eight samples during 6 hours in interval of 50 minutes taken at each measuring place (M1, M2, M3, M4). Measurements were realized with specialized calibrationed instruments (multifunction meter TESTO 435.2 with 3 function probe: measurement of flow, temperature and humidity and Vernon-Jokl globe thetmomether) capable of monitoring, analyzing and diagnosing indoor air quality.

Measured data were sent to a personal computer for further processing. The measurements of values of ambient dry temperature t_a, relative humidity r_h, air velocity v_a and operative temperature t_o was calculated from globe themperatures t_g measured at three various heights (ankle: 0,1m, waist: 1,1m, head: 1,7m). The resulting of mean values of the parameters (arithmetical mean and measurement uncertainty) are given in Table2.

Loc	t_o [°C]	v_a [ms^{-1}]	r_h [%]
M1	32,00 ± 0.5 **Not acceptable**	0,15± (0,05 + 0,05v_a) **Acceptable**	43,85 ± 3 **acceptable**
M2	31,60 ± 0.5 **Not acceptable**	0,14 ± (0,05 + 0,05v_a) **Acceptable**	44,11 ± 3 **Acceptable**
M3	32,46 ± 0.5 **Not acceptable**	0,14 ± (0,05 + 0,05v_a) **Acceptable**	41,88 ± 3 **Acceptable**
M4	34,50 ± 0.5 **Not acceptable**	0,16 ± (0,05 + 0,05v_a) **Acceptable**	41,10 ± 3 **Acceptable**
Limit	22-25 (19-27)	≤ 0,3	30 – 70

Table 2. Comparison of resulting measured values with limits

From the results in Table 2 (see „Limits“) we can determine that operative temperature values were not in accordance with operative temperature permissible values for given job class and given season of the year, the air velocity and relative humidity values correspond with specified conditions pursuant to Decree No. 99/2016 Coll, see Table 3. [Decree No. 99/2016] Overall progress of relative humidity, air velicity and globe temperature you can see on Figure 1-3.

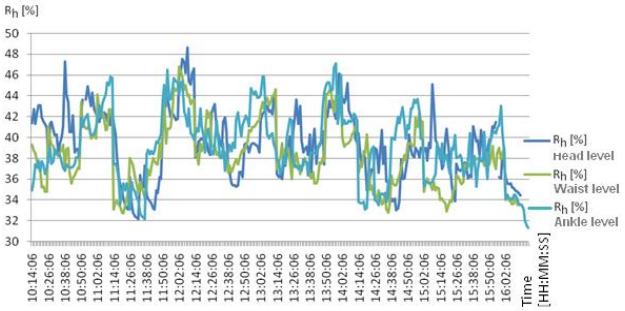

Figure 1. Overall progress of relative humidity

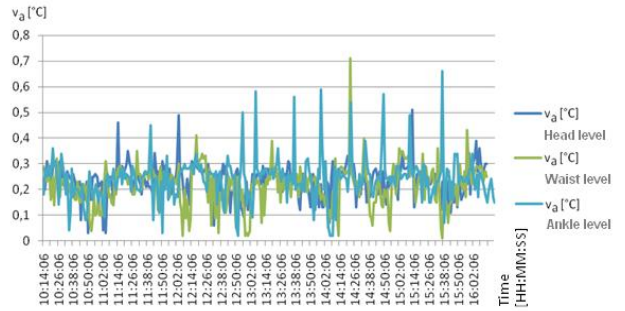

Figure 2. Overall progress of air velocity

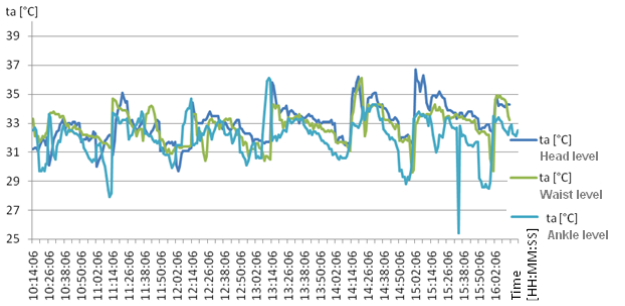

Figure 3. Overall progress of air temperature

3.1 Analysis of the variance of monitored parameters

In the next step, we were interested, if microclimate conditions of particular points of measurements are identical and if the differences between monitored parameters are statistically significant. We will use ANOVA method. A condition for its use is an independence of files, homogeneity of variances and normality of basic files [5 Andel, J, 1998]. We ascertained a variance of homogeneity by Bartlett Test of Homogeneity. It ensues from the test results that we do not deny a zero hypothesis for any monitored parameter.

So as to consider normality, we used Shapiro-Wilk Test of Normality. It ensues from the given results that files of all indicators correspond with a condition of normality. In the case of globe thermometer temperature in height of 0.1m, it ensures that we reject the null hypothesis on equality of mean values of basic files. A variability ration (factor effect) explained by point of measurement is 0.744 what means that globe thermometer temperature value in depends approximately to 74.4 % on what point of measurement in manufacturing premises is this value measured in and only 25.6% from other factors. Similarly, we will carry out the analysis of variance also for other remaining indicators. Resulting p-values and factor effects are given in Table 3.

Index	p-value	Equality of Mean Values	Factor Effect
$t_{g0.1}$	$1{,}9 \cdot 10^{-8}$	Ho reject	74,40%
$t_{g1.1}$	$1.5 \cdot 10^{-8}$	Ho reject	74,86%
$t_{g1.7}$	$5{,}9 \cdot 10^{-8}$	Ho reject	72,28%
t_a	$2{,}6 \cdot 10^{-8}$	Ho reject	73,88%
v_a	0,913	Ho do not reject	1,84%
r_h	0,094	Ho do not reject	20,13%

Table 3. Analysis of variance of monitored parameters

We reject the null hypothesis about equality of mean values by the analysis of variance for first four parameters.

In next step, we examined which pairs of points of measurement differs significantly by post hoc tests, Table 4.

Post Hoc Tests	
$t_{g0.1}$	M1-M4, M2-M4, M3-M4
$t_{g1.1}$	M1-M4, M2-M4, M3-M4
$t_{g1.7}$	M1-M4, M2-M4, M3-M4, M2-M3
t_a	M1-M4, M2-M4, M3-M4, M2-M3

Table 4. Results of Post Hoc Tests for Particular Parameters

It results from final evaluations that the values of monitored parameters significantly differ between point of measurement M4 and other three points of measurement (M1, M2 and M3) in almost all monitored parameters. From the calculations and the evaluation of the measured values it follows that the temperatures most exceeded the limit values at the place M4 (near the window). This was caused by high outdoor temperatures during the day the measurement was made. During a very hot days, the employer provides a sufficient supply of fluids and adjusts the length of work by incorporating frequent breaks.

3.2 Questionary survey

In order to find out whether the microclimate conditions are suitable for their, a questionnaire survey was conducted in which we were concerned how manufacturing workers feel microclimate conditions usually, during the all year.

Questionnaire survey on difficulties at job, persisting after its completion and depending on microclimatic conditions at workplace was performed. There were 200 employees participated in the survey, including 129 men (64,5 %) and 71 women (35,5 %). The age category of the respondents is from 25 to 60 years, while the average age is 40 years. All employees have stated in the questionnaire that they are of good health condition and do not suffer from any serious disease. We were interested in following spheres of information:

A. Microclimatic conditions at a workplace
B. Health troubles in connection with microclimate parameters
C. Additional information (relation of employer, drinking regime and thermal comfort).

For questions of A. and B. group we used 4-grade rating scale: "never = 1", occasionally/rarely = 2", "often = 3", very often/almost always = 4".

Humidity in the workplace complies 85,5% of respondents (171). Almost the same number of respondents (174 respondents, 87%) indicated that the air velocity is not suitable.

The results from measurement and survay were diferent in parameter of air velocity. This parameter plays a role in the perception of thermal comfort. In hot space, as the body tries to cool itself, the flow of air across the body will assist evaporative cooling from sweating.

In this questionnaire survey 66 respondents (33,0%) answered that feeling the room temperature as slightly warm. Almost the same number of respondents (63 respondents, 31,5%) indicated the feeling of neutral warm (57 respondents, 28,5%) felt the heat and only 14 respondents (7,0%) indicated the feeling of slightly cool up to cool. Graphic representation of the evaluation of the thermal comfort to the age structure of the respondents is shown in Figure 4.

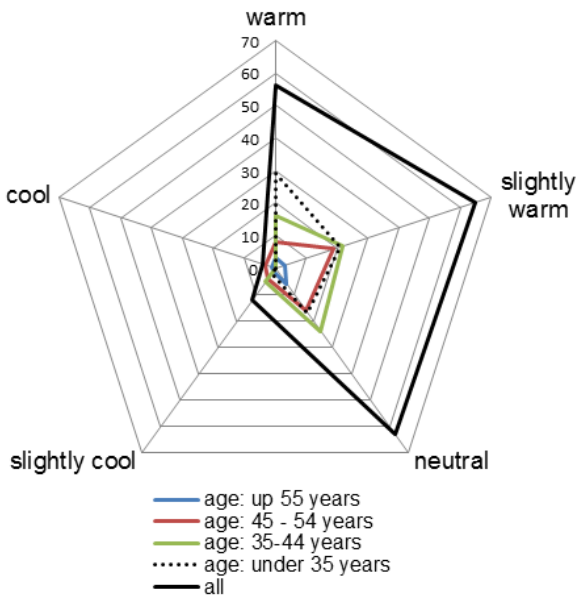

Figure 4. Graph of feeling of all respondents according to age

From pre Figure 4 we can see, that most people from respondents were feeling warm and and singly warm thermal microclimate.

In event of thermal discomfort is the risk and the employees are complaining and/or reporting illnesses that may be caused by the thermal environment, then organisation should review the situation and if necessary implement appropriate controls to manage the risks. In this case the thermal conditions may need to be monitored and where possible recorded as part of risk management programme, the health surveillance or medical screening may be required for staff who have special requirements due to pregnancy, certain illnesses, disabilities and/or maybe taking medication, this is particularly relevant when working in temperature extremes (medical advice should be sought if necessary) and working habits and current practices need to be reviewed periodically and where necessary changed and to control the risks.

4 DISCUSION

The aim of our paper was to monitor and evaluate parameters of thermal and humid microclimate under real conditions of an engineering factory and to determine satisfaction or dissatisfaction of employees relating to microclimatic conditions on their workplaces through a questionnaire survey.

The results of the survey can be instrumental for the factory management in elimination of potential drawbacks in the sense of a principle of continuous improvement also in the sphere of microclimatic conditions with the aim to ensure high level of hygiene, quality and safety of working environment.

Employer is to create a hospitable working environment on a long-term basis through taking care about its employees so as to motivate them to high working performance. A suitable or comfortable working environment is of its relevant significance and brings not only positive results in the form of high working performances, but also in the form of satisfied employees. Increasing labour productivity as well as quality of services provided reflects positive working climate. Similarly, a quality of working environment motivates and encourages activity, expecting creative improvement of performance. Thus, the expectations of an organization could be fulfilled only provided that the expectations of its staff are fulfilled.

In creating and maintaining a good market position, it is a very important factor for companies to provide employees with a working environment tailored to their capabilities and needs. Nowadays, when there is a strong competition among employers, the employer can gain competitive advantage even through the optimal working environment and the satisfied employees.

Appropriate workplace conditions "well-being" are indispensable for manufacturing production, as workers are the most valuable resource of the factory, which is still true, at today's high automation, and at the onset of the so-called "4th Industrial revolution ", the employees health protection must be ensured above all because workplace comfort affects not only health, but also productivity of employees.

5 CONCLUSION

The article should contribute to the thermo-humidity microclimate as a major part of the working environment. The aim of this article was to emphasize the importance of the people sources, to show the evaluation methods of microclimate conditions and contribute to the discussion of high actual, though still neglect areas, which could have a major impact on the competitive skills of the factory. With global climate change and looming reality, designing low energy buildings needs to consider capricious climate variations at play. In a warming world, heating energy demands should reduce while cooling energy demands rise. What is anticipated is that with economic growth, occupant expectations of indoor environments would rise, leading these climate changes to contribute most to rising cooling demands. The main challenge for the future is to find ways how to influence comfort criteria by designing and operating such buildings so that users can be satisfied while avoiding buildings becoming "cold domains" closed off from the natural environment.

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REFERENCES

[355/2007] Act of National Board of the Slovak Republic No. 355/2007 Coll. on Protection, Support and Development of Public Health and on Change and Amendment of Some Acts.

[99/2016] Decree of Ministry of Health No. 99/2016 Coll. on Details on Health Protection against Heat and Cold Loads at Work.

[ISO 7730: 2005] EN ISO 7730:2005, Ergonomics of thermal environment.

[ISO 45001: 2016] ISO 45001: 2016, Occupational health and safety

[Andel 1998] Andel, J., Statistical methods, Matfyzpress, Praha, 1998. 274 p.

[Jendritzky 2012] Jendritzky, G.,de Dear, R., Havenith, G.,UTCI-Why another thermal index?(2012) International Journal of Biometeorology, 56 (3), pp.421-428.

[Karvatte, 2016] Karvatte, N., Klosowski, E.S., de Almeida, R.G. et al. Shading effect on microclimate and thermal comfort indexes in integrated crop-livestock-forest systems in the Brazilian Midwest, (2016) International Journal Biometeorology, pp.1-9.

[Mishra 2016] Mishra, A.K., Loomans, M.G.L.C., Hensen, J.L.M., Thermal comfort of heterogeneous and dynamic indoor conditions — An overview. (2016) Building and Environment, 109, pp. 82-100.

[Song 2015] Song, X., Yang, L., Zheng, W., Ren, Y., Lin, Y., (2015) Analysis on Human Adaptive Levels in Different Kinds of Indoor Thermal Environment, Procedia Engineering, 121, pp. 151-157.

[Trebuna 2017] Trebuna P., Petrikova, A., Pekarcikova, M. Influence of physical factors of working environment of workers performance from ergonomic point of view. (2017) Acta Simulatio. 3(3), pp. 1-9.

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