ASSESSMENT OF THE MICROCLIMATE IN THE WORK ENVIRONMENT

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Abstract: *Microclimatic parameters are important factors in the physical environment which significantly affect the conditions of the working environment. These microclimatic parameters significantly affect the welfare of working people; define their subjective perception of well-being or discomfort. In case of extreme values, those can be perceived as harmful or adverse effects on human health. The paper is a contribution to assessment of thermo-humidity microclimate based on measurements with aim to give results about real conditions of the working environment.*

Key words: *working environment, microclimatic parameters, load environment, complex assessment of the load*

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1. Introduction

The work environment is an extensive summary of the factors that may affect its quality. In the area of the working environment it is necessary to draw attention not only to the most significant factors, but also to consider the impact of individual elements of a complex environment in which employees operate. Most common elements affecting the work environment are: noise, ventilation, temperature, humidity, light and stress.

Environmental well-being can be defined as state of the environment in which a person subjectively feels best and is capable of maximum performance, whether physical or mental. State of the environment in which human well-being is achieved, depends on several factors. Here belongs: air condition, wall temperature, temperature of surrounding objects, clothing, human subjective parameters, intensity of work and other effects (Hanker, 1978).

2. Microclimatic parameters

Microclimatic parameters (or conditions) of the work environment also known as thermal-moisture parameters are determined by temperature, relative humidity and airflow. These physical quantities define subjective well-being (comfort) or ill-being (discomfort). In extreme cases can be considered as pollutants with adverse effects on human health.

2.1 Temperature

Particular type of working class has got determined the optimal microclimate conditions, depending on body heat production affected by intensity of employee's activity. The total energy expenditure assigns the individual work activities to the working classes: 1a (sitting at work, administration), 1b (standing at work), 1c (such us mechanics work, work in the steel industry), 2 (such as operating machines, work in the building industry), 3 and 4 (intensive and very intensive work).

Working class	**Temperature [°C]**			
	Optimal temperature		**Permissible temperature**	
	Warm season	**Cold season**	**Warm season**	**Cold season**
1a	21-25	20-23	20-28	20-26
1b	20-24	18-21	18-26	17-24
1c	18-22	15-19	16-25	13-22
2	16-19	12-17	12–24	10-20
3	The value does not determine			
4				

Tab.1. The optimal and permissible temperature for some working class

Range of optimal values of microclimatic conditions in the working environment is set for a warm period (average daily outdoor temperature 13°C and more) and winter season (decrease of the average daily temperature for two consecutive days below 13°C). The optimal and permissible temperatures for warm and cold season of the year are in the Table 1 (Slovak Directive No. 544/2007).

In case of the workplace with long-term nature where it is impossible to provide optimal conditions, the employer is required to ensure compliance with permissible microclimatic conditions. Exceptions are in need of special workplaces where the burden of heat or cold is impossible to be removed due to various technological reasons.

2.2 Humidity

Humidity in the working environment is a specific factor. The specificity of factor is mainly in the fact that unlike the temperature, this can be subjectively very difficult to perceive and then evaluated. The human body can have an adverse effect on the decrease in humidity on the level of 20% mainly in winter (due to heating) and the humidity in excess of the 60% in other seasons. The scope of permissible values of relative humidity is in the Table 2 (Kubani, 1998).

Temperature	Humidity	Working performance
21°C	40%	Very good
	85%	Good at changing work and rest
	91%	Reduced, there is a fatigue and depression
26°C	30%	Very good
	65%	Reduced, rapid fatigue
	80%	Difficult, the need for frequent rest
32°C	25%	Very good
	50%	Strongly reduced performance
	65%	Work is almost impossible
	81%	Exhaustive, leads to an increase in body temperature
	90%	Work threatens health
	100%	Work is impossible

Tab. 2. Relationship of temperature, humidity and work performance

2.3 Airflow

In practice it is often not possible to keep the airflow and the intensity at a low level to ensure a comfortable working environment. Difficulties were encountered in most cases, particularly for space cooling. Increasing airflow increases the flow of cooling the body and decreases the amount of sweat produced (Slovak Directive No. 544/2007).

The velocity of airflow in the place is to create thermal comfort environment of considerable importance. People with sedentary work in confined spaces are more responsive to airflow than the movement in the nature. In case of temperature and as well as for airflow factor values exist. These should be respected in the work environment. Summary of values for each type of working class is shown in Table 3 (Franko, S. at al. , 2011).

Working class	Permissible velocity of airflow [ms^{-1}]		Permissible humidity [%]	
	Warm season	Cold season	Warm season	Cold season
1a	≤ 0,25	≤ 0,20	30 - 70	30 - 70
1b	≤ 0,30	≤ 0,25	30 - 70	30 - 70
1c	≤ 0,30	≤ 0,30	30 - 70	30 - 70
2	0,1-0,3	≤ 0,30	30 - 70	30 - 70
3	The value does not determine			
4				

Tab. 3. The value of permissible velocity of airflow and humidity

3. Method

The working environment is characterized by a set of negative factors at any time varying by intensity of effect on the human organism during work. Complex work load is the total of external conditions and requirements in the working system adversely affecting the health of humans.

To evaluate the work load is commonly used the value q that represents how many times the actual load factor of a given work environment is more than the permissible load (Kapustova, 2004). Relationship applies:

$$q = \frac{F^r}{F^p} \tag{1}$$

where F^r is real load and F^p is permissible load factors.

By using methods of mathematical statistics mathematical model was developed. This allows to express a summary effect of negative environmental factors and to evaluate the complex load of the human body during work. In any work environment more load factors affect on people during the workday. The total load of these factors F can be expressed as the result of all load factors:

$$F = F_1 + F_2 + F_3 + \cdots + F_n \tag{2}$$

where $F_j, j = 1,2, \ldots, n$ are load factors that affect the human body.

It is known that not all of the factors involved in the total load equal weights. For this reason, the load factor $F_j, j = 1,2, \ldots, n$ has the weight of the load α_j with the condition:

$$\alpha_1 + \alpha_2 + \alpha_3 + \cdots + \alpha_n = 1, \ \ \alpha_j \in (0; 1), j = 1,2, \ldots, n, \tag{3}$$

where α_j, $j = 1,2, \ldots, n$ are coefficients of severity impact factors of working environment (Kapustova, 2004).

The principle and method of determining the coefficients $\alpha_j,\ j = 1,2,\dots,n$ is described at the Table 4. The point value b_{ij} is the impact of load factor F_j on the health and some parts of the human body T_i (Kapustova, 2004).

Body parts	**Load factors**					**Sum**
	F_1	F_2	F_3	**...**	F_n	
T_1	b_{11}	b_{12}	b_{13}	...	b_{1n}	$\sum_{j=1}^{n} b_{1j}$
T_2	b_{21}	b_{22}	b_{23}	...	b_{2n}	$\sum_{j=1}^{n} b_{2j}$
...	...	...	...	...	...	...
T_k	b_{k1}	b_{k2}	b_{k3}	...	b_{kn}	$\sum_{j=1}^{n} b_{kj}$
Sum	$\sum_{i=1}^{k} b_{i1}$	$\sum_{i=1}^{k} b_{i2}$	$\sum_{i=1}^{k} b_{i3}$	...	$\sum_{i=1}^{k} b_{in}$	$\sum_{i=1}^{k}\sum_{j=1}^{n} b_{ij}$

Tab. 4. Principle of the method

The coefficient values $\alpha_j,\ j = 1,2,\dots,n$ are determined by a point method which is based on the allocation of points in the scale of 0 to 10 and its applications for each type of load $F_j$of the individual health and well-being human body parts T_i by work activity (Table 4). Relationship applies

$$\alpha_1 = \frac{\sum_{i=1}^{k} b_{i1}}{\sum_{i=1}^{k}\sum_{j=1}^{n} b_{ij}}, \alpha_2 = \frac{\sum_{i=1}^{k} b_{i2}}{\sum_{i=1}^{k}\sum_{j=1}^{n} b_{ij}}\ , \dots, \alpha_n = \frac{\sum_{i=1}^{k} b_{in}}{\sum_{i=1}^{k}\sum_{j=1}^{n} b_{ij}}. \tag{4}$$

These coefficients characterize the degree of load on the human body. The value close to 0 reflects the modest impact of load factor. The value close to 1 means a significant impact of factor.

For each working class are known values of the permissible load F_j^p; for the individual load factors F_j and we can always determine real load F_j^r. Immediate complex working load is given by

$$q_C = \alpha_1 \frac{F_1^r}{F_1^p} + \alpha_2 \frac{F_2^r}{F_2^p} + \dots + \alpha_n \frac{F_n^r}{F_n^p} = \sum_{j=1}^{n} \alpha_j \frac{F_j^r}{F_j^p} \tag{5}$$

where $\alpha_j \frac{F_j^r}{F_j^p}, j = 1,2,\dots,n$ defines the degree of real load human body with factor F_j (Kapustova, 2004; Hnilica, 2011).

4. Complex assessment of the work load

In assessing the impact of microclimatic parameters (temperature, humidity, airflow) for comfort of working environment, we chose one engineering company in Slovakia. Measurement of microclimatic parameters was held in the building of the production hall. The measurement points were chosen to represent the place of residence of employee performance during working hours.

Effect of load parameters were observed on sweating, breathing, psychological well-being at work, cervical and lumbar spine and the hearing organs. The average values of coefficients are obtained by a point method, which involved five employees (Table 5). The calculations show that $\alpha_1 = 0{,}4107$, $\alpha_2 = 0{,}2143$ and $\alpha_3 = 0{,}3750$.

Impact on	**Temperature**	**Humidity**	**Airflow**	**Sum**
	Points	*Points*	*Points*	
Sweating	9	4	2	**15**
Breathing	6	4	3	**13**
Psychological well-being at work	7	3	3	**13**
Cervical and lumbar spine	1	1	7	**9**
Hearing organs	0	0	6	**6**
Sum	**23**	**12**	**21**	**56**

Tab.5. Results of the method

Based on results, the temperature has a clear effect on excessive sweating at work, which also affected the psychological well-being and shortness of breath conditions. The evaluation of the humidity does not work very negatively on the human body. Possible increased humidity is reflected by excessive sweating, difficulty in breathing and also distress at work. The third factor airflow significantly affects the hearing organs and lumbar and cervical spine.

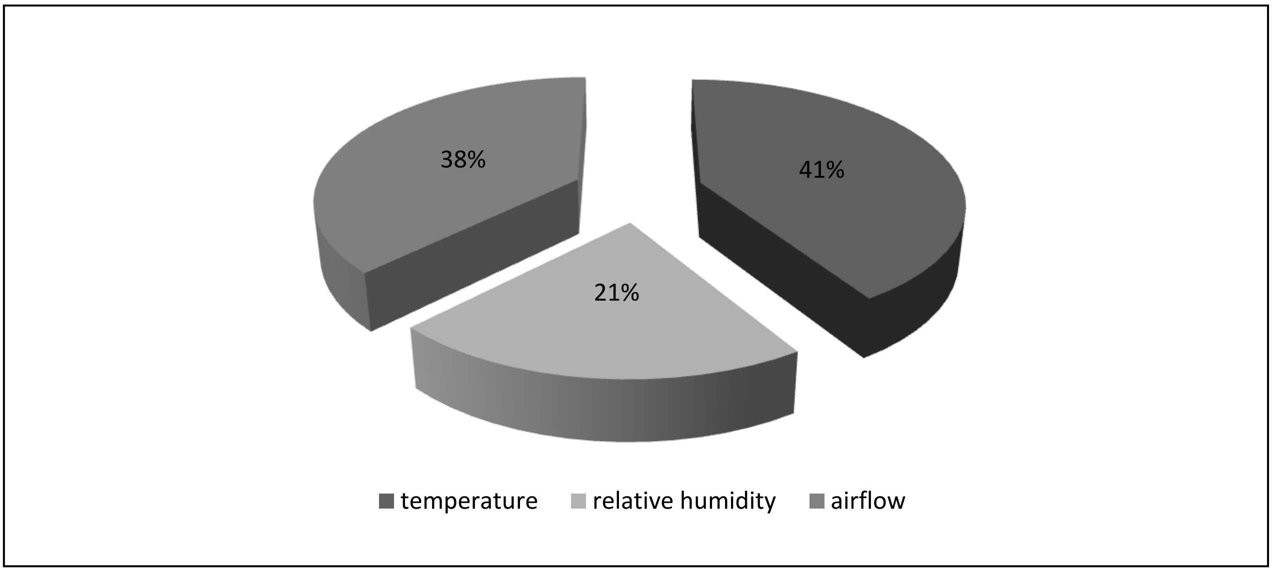

Fig. 1. The values of the coefficients

To create comfort in the work environment, temperature and airflow are main factors. According to research results is the temperature to 41% of the discomfort and dissatisfaction in the work environment (Fig.1). Approximately the same impact on the overall discomfort is also factor airflow (nearly 38%).

The complex working load of microclimatic conditions in the work environment was carried out during working hours from 8.00 to 13.00. The measured values of the real load factors F_j^r together with the complex working load are in the following Table 6. Permissible load F_j^p for the relevant working class is specified in the Slovak directive No. 544/2007. The benchmark is considered the value $q_C = 1$.

Measurement	**Temperature**	**Humidity**	**Airflow**	**Complex load**
8:00	21,8	55,3	0,11	0,883
9:00	24,9	50,3	0,12	0,934
10:00	25,7	48,2	0,11	0,911
11:00	26,5	44,0	0,18	1,079
12:00	27,0	45,6	0,22	1,195
13:00	24,5	44,6	0,13	0,925

Tab. 6. The measured values of load and complex working load

The results show that measuring with the value of a complex assessment of the load less than 1 can be considered satisfactory. If that was exceeded at least in one admissible value, the resulting value of a complex evaluation is larger than 1 (Fig. 2).

In this case, it is the zone with working discomfort and high-harmful effect on human body. Zone, in which the value is near to 1, can be considered permissible with slightly detrimental effects.

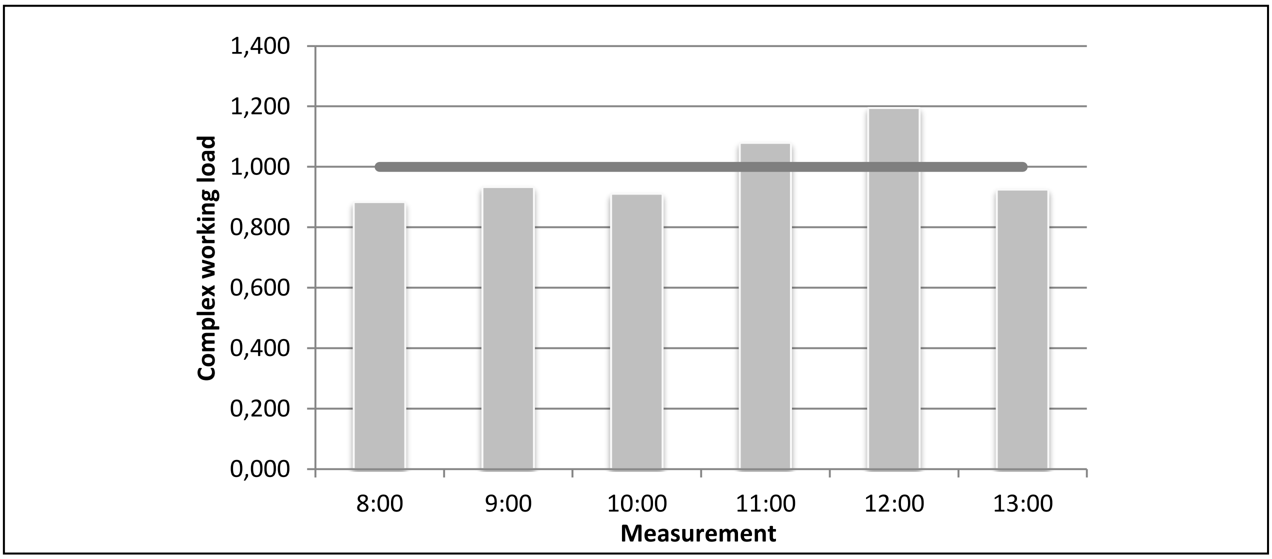

Fig. 2. The complex working load

5. Conclusion

Today we put great importance on all factors that affect the quality and safety working environment, but many of them are not in accordance with prescribed standards. Microclimatic parameters (conditions) have much greater impact on subjective well-being human, the quality of rest and real labour productivity than other specific pollutants, for example noise. Knowing the climate conditions of the environment, in which research on the working conditions in terms of the effect of temperature, humidity and airflow is being performed, is an important step towards optimizing the internal components to reduce the impact of these factors.

In order to prevent the effects arising from thermal stress due to failure of the thermoregulation mechanisms, microclimatic indices of stress have been devised in order to point out the existence of thermal stress risk as a result of metabolic situations or excessive physical strain.

To evaluate the comfort of working environment is very important, because only employee working in optimal conditions can provide the activity that leads to the growth of society and a stable market position. It is important to ensure the quality of the real situation because it can provide reliable, relevant and timely information that will be used when deciding on preventive or corrective measures.

As a result of the general improvement of microclimatic conditions in the working environment and the adoption, in many jobs, from air conditioning systems, further research will be focused on the determination of more complex indexes of evaluation, with aim to include the existence of the subjective conditions for thermal comfort.

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