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THERMAL COMFORT

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Résumé. On présente des notions théoriques sur le confort thermique et quelques indices bioclimatiques, utilisés en bioclimatologie en vue d'établir le caractère du confort ou stress du climat sur l'organisme humain et pour des régionalisations bioclimatiques. On a pris en considération quelques indices bioclimatiques calculés a l'aide des formules ou nomogrammes spécifiques, et on a effectué un étude pour un mois d'été, a midi, dans de conditions normales du point de vue météorologique. On estime ainsi quelques critères pour utiliser les indices bioclimatiques, en fonction de but et des conditions atmosphériques.

1. General notions

The climatic factors influence all organisms and condition their existence, in such a way that we may say that the climatic ambiance from the earth represents one of the conditions preserving life. The meteorological factors, separated, influence to a small extent the human body, in comparison with the whole complex of weather conditions that manifest themselves at certain moment or in a certain period of time.

The human body is in a continuous fight for adjusting to environmental conditions, but its efforts are to be felt as negative effects.

The quality of the living organisms to preserve, within the limits of the functional balance, various physico-bio-chemical parameters, constant from the physiological point of view, is called *homeostasy*.

Homoiothermy is the term through which is defined the quality of warm blooded animals to preserve constant the internal temperature of the body (~ 37.5°C at humans), even within the large limits of the external and personal conditions.

Starting from this quality of the human body, we may speak about *thermal comfort* that, establishes a connection between the external thermal stress and the human thermoregulation capacities (heat loss or storage). The stress of the

thermoregulation system when it surpasses its capacity may become harmful for individuals' life and health.

The *thermal comfort,* is a narrow area in which a human body, relatively healthy, relatively slightly dressed, reposing, does not loose nor receive heat. The basic parameters for determining the thermal comfort are: air temperature, steams' quantity, air dynamics and direct solar radiation. Beside these physical factors of atmosphere, the thermal comfort depends also on age (children, seniors), health status (affections – rheumatisms, respiratory, cardio-vascular, endocrine, etc.), cloth (texture, thickness, color etc.), activity (physical, psychical, moderate, intense, - repose, tiredness), adjustment – training.

In terms of these parameters, in conditions of external stress, intervenes the adjustment of the body to environment, its reaction being different from one individual to another. For adjusting, the body requests one of its most important functions, namely the function of thermoregulation, with implications on all the other functions, including on the basic function of life, the metabolism.

The state of comfort derives from a series of factors, namely:

- rest – necessary to any individual in terms of age and activity
- activity – physical and intellectual, moderate or intense
- tourism – practiced depending on age and physical capacities of each individual
- climato-therapy – air-therapy and heliotherapy, differentiated depending on age, affections, individual constitution, health state and season.

The state of comfort felt by the body may be caused by a climatic stress differentiated depending on its intensity. If the stress is reduced (e.g..: temperature oscillations close to comfort level), it does not influence to a large extent the body, being easily tolerated by most people, most of the time it is incentive, causing the reaction of the body for adjusting, acclimation and naturalization.

In case the stress is accentuated and it is long lasting (e.g.: important modifications of the temperatures with jumps of 15 – 20 ^{0}C in a few hours) intervenes the danger for health, by reducing the resistance of the body until exhaustion. These situations are to be encountered mostly during the transition seasons, favoring the increase of diseases caused by "cold".

Following the researches performed in various countries, it has been established comfort limits different from one are to another, depending on latitude and human race. Taking into consideration the equivalent temperature, that represents a value deriving from calculation and gives the temperature felt by the body, in certain conditions of temperature, moistness and wind, these comfort limits differ from one region to another, namely:

18-22 °TEE (American Society of Heating);

14.4-20.6 °TEE (Great Britain);

16.7-21.8 °TEE (Yakovenko – Russian region);

23.3-29.4 °TEE (tropical countries).

The connections between temperature, moistness and wind (bioclimatic indexes), are given by formulas or specific nomographs. Among the bioclimatic indexes used in appreciating the thermal comfort we mention:

- Equivalent effective temperature TEE (Yakovenko, 1927, Zaninovicz, 1992)
- Radiation, convection temperature (Vernon, 1930)
- Equivalent temperature (Dufton, 1932)
- Missenard indexes (1935, 1948)
- Cold wind indexes (Siple, Passel, 1945)
- Environment propitious temperature (Vogt, 1940)
- Effective temperature indexes ETI (Yaglou, 1947)
- Radiant average temperature (Bedfort, 1948)
- Resultant temperature indexes RTI (Missenard, 1948)
- Equivalent effective temperature depending on radiation TEER (Şeleihovski, 1948)
- Sweating probable rate index for 4 hours PaSRI (Mc Ardle 1947, Smith 1955)
- Heat stress index HSI (Belding, Hatch, 1955)
- Effective temperature (Seifert, 1958)
- Thom indexes (1958, 1959)
- Humiture (t +u) (Henever, 1959, Winterling, 1979)
- Air baths (Mihalkov, 19 , Nevraev, 1984)
- Enthalpy and Brazol scale (1964)
- Thermal stress index (Givoni, 1963, 1968)
- Coetaneous and lung stress (Besancenot, 1974)
- Canadian humidex index (Anderson, 1965)
- Resultant temperature (Landsberg, 1972)
- Comfort equation PMV (Fanger,)
- Physioclimatic annual regime APR
- Apparent temperature (Steadman, 1984, 1994)
- ITU index

2. Working method

The evaluation and comparison of differences between the working methods, have been performed according to some formulas and diagrams. For example, it has been studied one summer month – July 1981 – normal from the thermal, hydric and dynamic point of view, at noon, when human is in maximum activity. The following bioclimatic indices have been calculated:

***Temperature-moistness index* ITU**, recommended by OMM, (Dragotă, 2003, Marinică 2006 quoted by Teodoreanu) is obtained according to the formula,

$$ITU = (T \cdot 1.8 + 32) - (0.55 - 0.0055 \cdot U)\,[(T \cdot 1.8 + 32) - 58)]$$

where: T = air temperature in close rooms or meteorological shelters (°C);

U = relative air humidity (%).

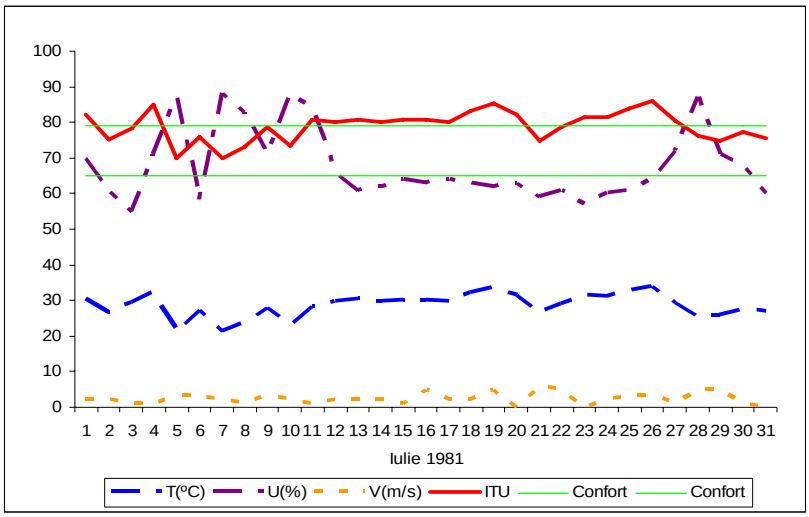

Fig. 1 Index ITU

The comfort degree is appreciated according to the following value scale: ITU≤65 comfort; 66≤ITU≥79; alert state; ITU≥80 discomfort.

Using this comfort index, it may be noticed that in a normal month from a meteorological point of view, we do not have days with thermal comfort, all days being within the limits of alert or discomfort state (fig.1).

Thom index (Thom, 1958, Licht, 1964), is based on calculating the effective temperature, without air currents, according to the formula,

$$TE = 0.4\,(tu + tw) + 4.8$$

where: TE = effective temp. without wind (v<0.1m/s);

td = dry thermometer temp. (°C) ;
tw = moisten thermometer temp. from psychrometer (°C).

The comfort limits are between 18-22°TE. When there are no air currents, it has been registered no day with thermal comfort (fig.2).

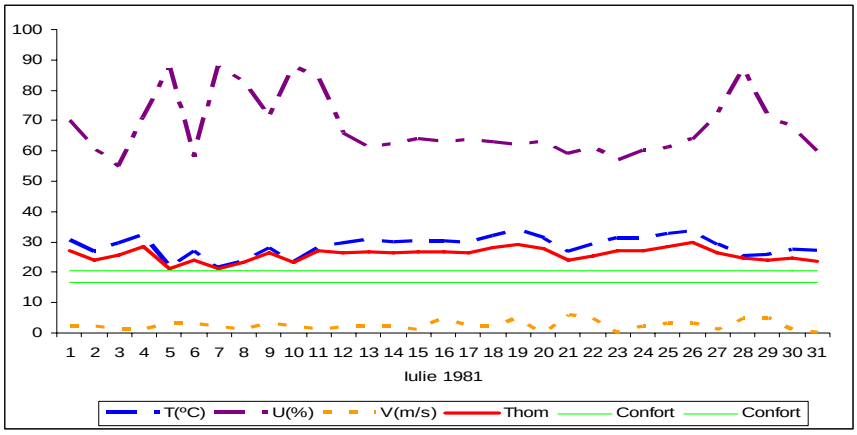

Fig. 2 *Thom index*

MISSENARD Index (Krawczyk,1975), are the comfort limits between 18-22°TE, calculated according to the formulas:

$$TEE = t_s - 0.4(t_s - 10)(1 - f/100), \text{ for wind speed} \leq 1\text{m/s}$$

$$TEE = 37 - \frac{37 - t_s}{0{,}68 + 0{,}00014f + \frac{1}{1{,}76 + 1{,}4v^{0.75}}} - 0{,}29t_s(1 - f/100),$$

t_s = temperatura aerului °C
f = umezeala relativă %
v = viteza vântului m/s.

Hentschel diagram (Licht, 1964), is used for calculating the effective temperature, having registered the dry air temperature (°C) on abscissa and humid temperature (°C) on y-coordinate and on diagonal the relative moistness (%). On the ground of these parameters the comfort limits have been determined (according to air baths, Mihailov, and others 1961) as follows:

Cold air baths 1 – 8.9°TEE
Cold moderated air baths 9 – 16.9°TEE

Cool air baths 17.0-20.9°TEE
Indifferent air baths 21.0-22.9°TEE
Warm air baths 23 - 27°TEE
Very warm air baths >27°TEE

Yakovenko diagram – normal scale (Baibakova and others, 1964, Teodoreanu, 2002).

There are used two types of nomograms with the following parameters: temperature, moistness and wind speed reduced to height of 2 m.

- Normal scale, for a normal dresses individual, according to season, who performs easy moves, having the comfort limits between 16.8...21.8°TEE.

- Basic scale, for the undressed individual, in repose, at shadow, during the airtherapy séance, having the comfort limits between 17.2...21.8°TEE.

The maximum speed of the wind may be between 3.5 m/s in the first case, and in the second case, 5 m/s, beyond which it is considered discomfort through wind, no matter the temperature and moistness conditions.

Under 16.8, respectively 17.2°TEE it is considered discomfort through cooling, over 20.6 respectively 21.8°TEE it is considered discomfort through heating.

When using these nomograms for the month under study, it has been obtained some days between the thermal comfort limits, the rest, being situated, as it is normal for a summer month, in the discomfort zone through heating (fig.3).

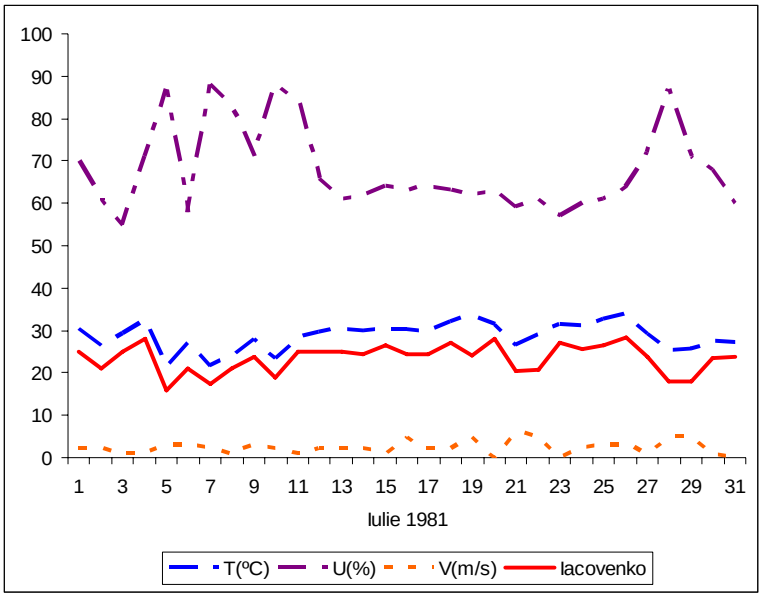

Fig. 3 Yakovenko diagram

TEER diagram (Şeleihovski,1948, Baibakova and others,1964, Teodoreanu 1995).

In order to calculate the thermal comfort in conditions of solar radiation, Seleihovski nomogramm is used, 1946, in which on the abscissa the TEE values (or TE) are inscribed, and on y-coordinate the values TEER (or TER) are determined depending on the group on diagonal, representing the solar radiation value (ρ) picked up by the human body. The ρ value (cal/cm^{2}min) is calculated according to the formula:

$P = (1 – \alpha)i$

Where: α = albedo of the skin

α = 0.11 in case of pigmented skin

α = 0.28 in case of non-pigmented skin

i = intensity of direct radiation on perpendicular surface (with a slight error, the values of the direct radiation may be replaced with the values of the total radiation)

According to the calculation of the effective temperature depending on the radiation, so when man is lying under the sun, we have no day with thermal comfort for the month under study. .

Seifert diagrams (1958) – With the help of nine nomogramms, each for different wind speed (from 0 to 8 m/s), in terms of temperature in ^{0}C, the relative humidity in %, we calculate the effective temperature (TEE), which comfort limits have been established between 18 and 22°TEE.

The values obtained, have been similar to those performed according to the formulas or nomogramms on the grounds of the data for temperature, air moistness and wind speed.

The ***bioclimatic stress*** has two components: coetaneous stress and lung stress. Both of them are using same parameters as thermal comfort (temperature, air moistness and wind), but unlike it that is using especially the hour values, the stress are underlying the monthly averages.

Cold wind index – Coetaneous stress

(Siple, Passel,1945, Besancenot,1974, Teodoreanu, Dacos, 1980)

The coetaneous stress expressed through cooling power P, in kcal/ m², represents the action of air temperature (t) and air dynamic (v), that act together on the skin, according to the formula:

$P = [10\sqrt{v}+10.45-v)(33-t)$

where: v = wind speed (m/s)

t = air temperature (^{0}C)

The limits have been established as follows:

P = 0- 299 – hypotonic index, requesting the starting of thermolisis, in the summer time

P = 300-599 – relaxing index

P > 600 – hypertonic index, requesting the starting of thermogenesis, in the winter time

After calculating the coetaneous stress, the whole months a hypotonic index has been obtained, specific to the summer months, that is starting the thermolisis.

Lung stress (scale J.P.Nicolas, Besancenot, 1974, Teodoreanu and others 1984)

This index is calculated on the ground of the fumes' tension in atmosphere, expressed in mb, which is used in the breathing process by the human body.

The limits for this index have been established as follows:

Fumes' tension (mb) < 7.5 → dehydrating index, winter

Fumes' tension (mb) between 7.5 – 11.6 → balanced index

Fumes' tension (mb) > 11.6 → hydrating index, summer

Fumes' tension (mb) >31.3 → difficulties in breathing

3. Observations and conclusions

The human being is, in general, adjusted to environment conditions, the bioclimatic indices being useful for determining the comfort or stress feature for the climate (of the human body) and for bioclimatic regionings. Our study referred only to the summer period (July 1981, temperature at noon – when it is the maximum activity outdoors)

The bioclimatic indexes have to be used in terms of the purpose in view:

- informing the population through mass-media
- indications for vacation, naturist diet
- for medical forecast (alerting the population in conditions of accentuated stress, differentiated according to stress and population category)

The bioclimatic studies are necessary as the climate influences through its parameters, globally, so that it underlines better the type of bioclimate in time and space, than a sole climatic parameter.

As a result of this study, the following observations concerning the bioclimatic index can be made:

a. Indices based only on temperature and moistness (Thom, Hentschel, ITU) are useful especially in the indoor climate.

b. The ITU index indicates, for a summer month normal from the thermal point of view, a couple of days with a discomfort state and the rest of the days in alert state – is incorrect from the bioclimatic point if view, in fact the human being is adjusted to these summer conditions at noon.

c. Seifert index – is useful especially for higher wind speeds.

d. Yakovenko, Missenard indices – are indicated for the summer months, they have a higher precision, until 3-4 m/s (July 1981, at noon - almost all the days present discomfort through heat).

The coetaneous stress and the lung stress, are indicated more for the spring and fall months. In the summer time, all days are hypotonic (coetaneous stress) starting the thermolisis process, respectively hydrating (lung stress) that are emollient for the lung mucous membranes.

The TEER index (in terms of radiation) is very close to the temperature in Celsius degrees under the sun, when there are high values of discomfort through heat at temperatures over 22°C.

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