THERMAL COMFORT WITH EVAPORATIVE COOLING FOR TROPICAL CLIMATES

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Abstract: the tropical climatic conditions that prevail in the countries located close to the equator generally has warm humid climatic conditions. This high humidity generally results due to the relatively high moisture content in the atmosphere. It is shown that warm humid climatic conditions can still offer a good possibility for the use of evaporative cooling when the beneficial effect of evaporative cooling is coupled with physiology cooling effect that is available with enhanced indoor air qualities.

Key words: Thermal comfort, cooling systems, relative humidity, air velocity

1. Introduction

Human thermal comfort is defined as the conditions in which a person would prefer neither warmer nor cooler surroundings. According to British Standard BS EN ISO 7730, thermal comfort is “the condition of mind which expresses satisfaction with the thermal environment”. Simply, thermal comfort describes a person’s psychological state of mind and is usually referred to whether someone is feeling too hot or too cold. In other words, the human body is like a complex internal combustion engine. To achieve thermal comfort, the body must balance its heat gains and losses by properly adjusting its functions (i.e. perspiration), while also responding to the prevailing environmental conditions (i.e. temperature and humidity). Under good thermal conditions, the human body can function at optimum levels, thus maintaining a good productivity [1].

In different areas of the world, thermal comfort needs may vary based on the climate. Much of the equatorial belt within the tropical climate zone experiences hot and humid weather. Because a substantial part of the Sun’s heat is used up in evaporation and rain formation, temperatures in the tropics rarely exceed 35°C; a daytime maximum of 32°C is more common. This can be coupled with relatively high humidity levels. Therefore, special attention is needed to ensure thermal comfort within the buildings located in tropical climates.

Due to the severity of the prevailing conditions in tropical climates, there are times, however, that comfort cannot be achieved by the functions of the body itself. Under such circumstances it is necessary to provide some assistance, either by natural, hybrid or mechanical means. It is important though, for rational use of available energy resources, to first exhaust all means of achieving comfort by natural or hybrid techniques before resorting to energy consuming mechanical systems.

Researches have indicated that the building sector consumes approximately 40% of the world’s energy [2, 3] and as such is a major player in the energy agenda in tropical climates. Furthermore, a recent survey has pointed out that the three main sources of energy waste in a standard office building would be air-conditioning (50 % of the power bill), artificial lighting (20 %) and computers (20 %) for a standard office building [4]. The inefficiency of existing buildings in tropical countries especially in Sri Lanka means that large amounts of energy would be required to maintain comfortable temperatures especially with future scenarios like global warming. In this context, evaporative cooling could offer many advantages as an effective low energy consuming means for providing thermal comfort.

2. Typical tropical climatic conditions

Typical climatic conditions in a tropical country could be found by using a real example. Sri Lanka, which is located with 5^0 55" to 9^0 50" N latitude and 79^0 42"- 81^0 51" E longitude is a country that is influenced by various climate based events of the world. For example, the western and southern part would get high rainfall primarily due to thunder storms and the south western monsoons. The rainfall can be as high as 2,000 - 2,500 mm per annum in many places and hence categorized as a wet zone.

The central hills located at this centre of the island makes the climate of the rest of the country consisting of east and north along with north central parts of the country to receive not much rainfall from south western monsoons. This means that the annual rainfall of these areas would be about 1,500 mm to 2,000 mm. These parts are preliminary served by north eastern monsoon which brings in less moisture and hence less rainfall. Thus, these areas are identified as dry zones. There could be an intermediate zone also as shown in Figure 1. The typical climatic data for Colombo is given in Table 1.

3. Comfort zones for Sri Lanka

It is relatively straightforward to indicate the comfort zone on a psychometric chart. For this, it is important to know the neutrality temperature. It was shown by Jayasinghe and Attalage [5] that for both wet and dry zones of Sri Lanka, the use of a single neutrality temperature of 26^0C is sufficiently accurate for developing comfort zones. It was shown by Szokolay [6] that for conditioned environments, a band of 2^0C can be used about the centre point. The recent research by De Dear and Brager [7] has indicated the use of a band width of 3.5^0C about the neutrality temperature. It was also recommended by Jayasinghe and Attalage [5] that for tropical climate conditions, it is desirable to use an upper boundary of 0.015 for humidity ratio.

Since evaporative cooling has the potential to maintain sufficient ventilation with indoor air velocities of 0.4 to 0.6m/s, especially with conditioned air delivered using ducts, the comfort zone can be further extended considering the physiolocal effects of cooling. The comfort zones developed incorporating all these features are shown in Figures 2 and 3. Figures 2 indicates that in a day with a humidity ratio of about 0.016, thermally comfortable conditions would prevail even at about 30^0C. Figure 3 indicates that even 32^0C can be tolerated when the indoor air velocity is about 0.5 - 0.6 ms^{-1}. These two figures indicate that climatic acclimatization coupled with physiology cooling effect could provide thermally comfortable conditions over a wide range of temperatures such as 26^0C to about 32^0C. this temperature range obtained by using theoretical indications have been validated by the comfort surveys carried out in Sri Lanka [8].

4. The feasibility of evaporative cooling

Evaporative cooling is particularly suitable for warm dry climates. However, certain features of warm humid climates also make it suitable especially when coupled with physiolocal cooling effect that can be obtained with enhanced indoor air velocities. People who have lived long in tropical climates have adopted them well to the various seasonal variations either with the clothes that they ware or with their expectations. This can be broadly identified as acclimatization to a particular climate.

This acclimatization is clearly indicated on the comfort zone where the center point identified as the neutrality temperature is affected by the average diurnal temperatures. Hence, the neutrality temperature for a tropical climate would be 26^0C where as it would be about 24^0C or less in a temperate climate. One feature of tropical climates is the high humidity in the early morning coupled with low outdoor temperatures such as 23^0C-25^0C. During the day, the outdoor temperatures could rise to about 30^0C-32^0C. Since, the humidity ratio of a particular day is generally constant, this rise in temperature will drop the relative humidity to about 60%.

This means that the day time could become a good candidate for evaporative cooling. The modern evaporative cooler can give a reasonable drop in temperature such as 3^0C to 4^0C with a marginal rise in the humidity ratio. Since people are generally tolerant to high humidities such as 70-75% when the physiological cooling effect is also available, evaporative cooling becomes a very good strategy even in warm humid tropical climate such as that prevails in both wet and dry zones of Sri Lanka.

5. Applications

Evaporative cooling could be a very good candidate to mitigate the adverse effects of heat islands and global warnings. Figure 4 shows an application of evaporative cooling in a factory building. Figure 5 indicates its application in a conference room. The use of ducts with properly designed and installed diffusers will allow a reasonably uniform air velocity distribution particularly at the level of the occupants. Such forced evaporation with air at 27^0C – 29^0C would have the potential to remove sweat from the skin while ensuring a pleasing air stream preventing the occurrence of dry skin. When the air supply is coupled with a suitable system of extract fans, it would be possible to ensure a continuous supply of fresh air with acceptable relative humidity.

Such a system can be considered as one with zero recycling of air. Thus, it has the potential to act as one that will not promote any diseases causing viruses or bacteria.

6. ASHRAE guidelines on envelope

Another key requirement for conditioned environments given in ASHRAE 90.1 is the requirements pertaining to the building envelop. However, such requirements would be less stringent when the energy consumption for heating and cooling is less than $15W/m^2$. In this context, the adoption of evaporative cooling offers a key advantage since the envelope could be constructed with locally available building materials without adopting the recommendation of Table 5.1 of ASHRAE 90.1

7. Conclusion

It is shown with the extended comfort zones developed for typical climatic conditions of tropical climates that evaporative cooling has the potential to become a low energy consuming active means. One of the key features is its ability to keep the energy consumption at a value less than $15W/m^2$. That will be a major achievement with respect to energy efficiency in buildings intended for factories or offices.

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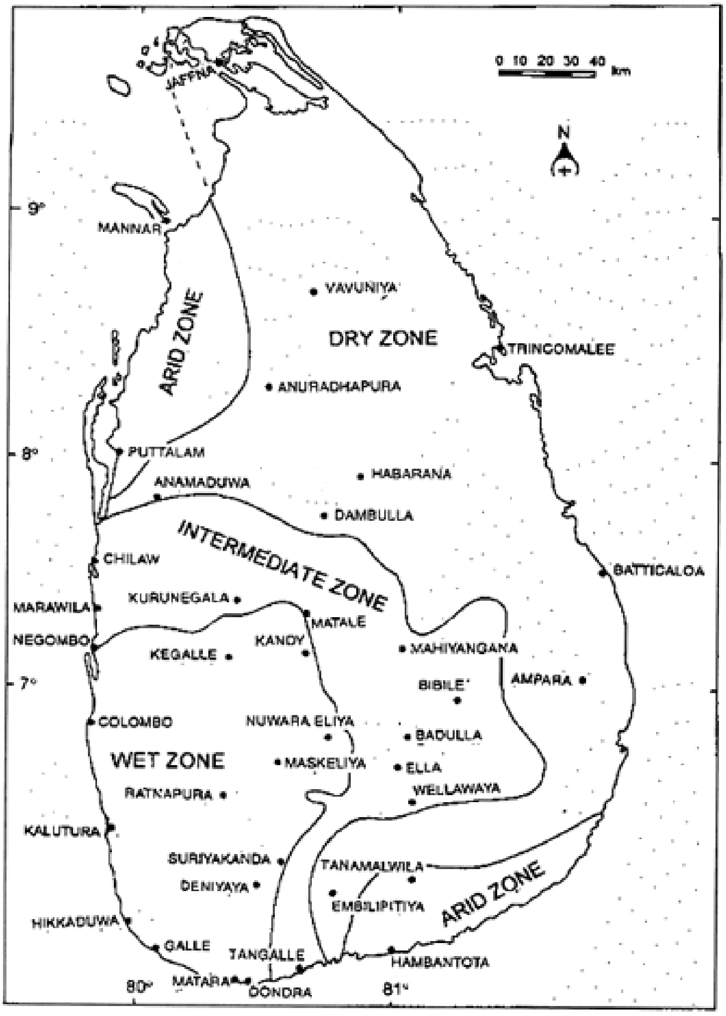

Figure 1: Climatic zones of Sri Lanka

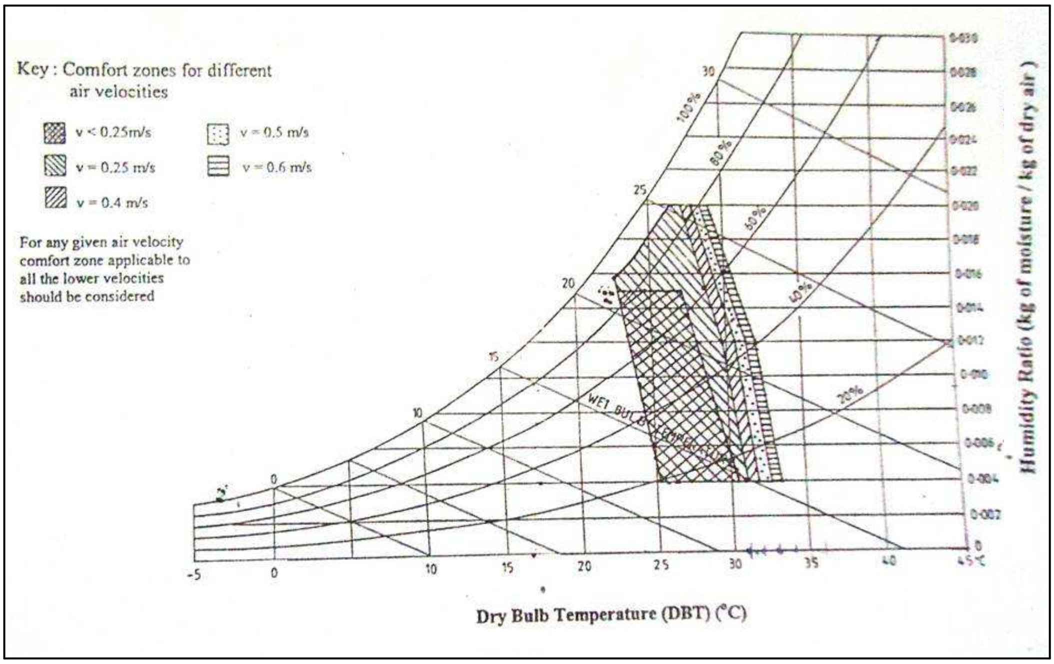

Figure 2: Psychometrics chart with extended comfort zone for Colombo in Sri Lanka

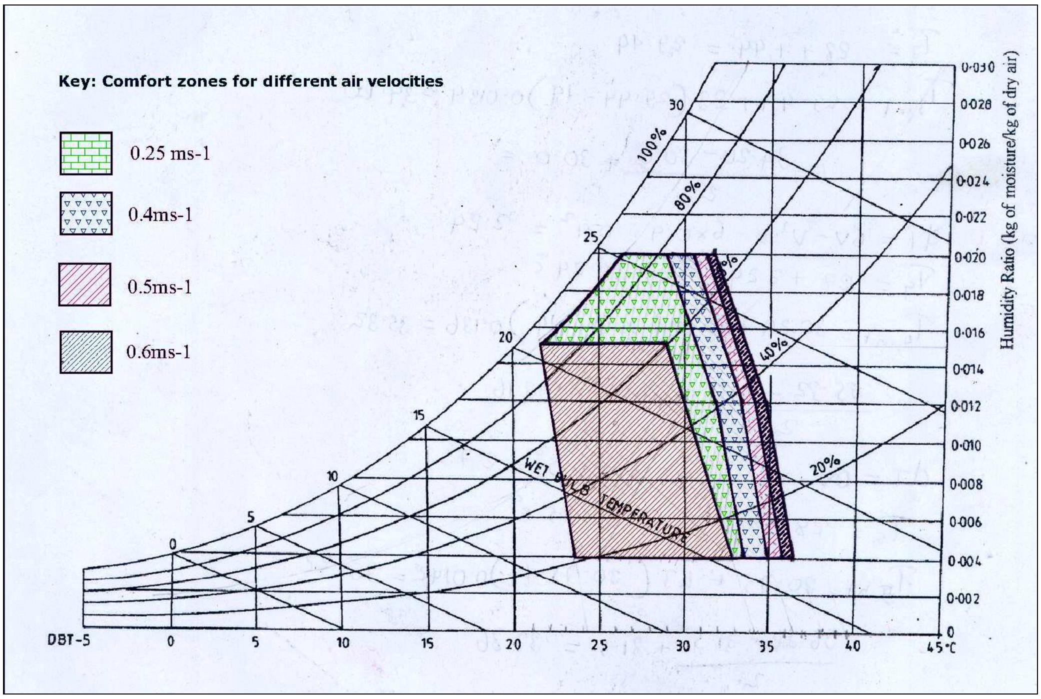

Figure 3: Psychometrics chart with extended comfort zone for Colombo in Sri Lanka

Figure 4: An evaporative coolers installed in a factory building

Figure 5: Conference room cooled by an evaporative cooling

Table 1: Average climatic data applicable to Colombo, Sri Lanka

Month	Sunshine (Hours per day)	Average rainfall (mm/month)	Mean daily temperature (^{0}C)		Minimum & maximum relative humidity (%)	
			Max (around 14.00hours)	Min (around 6.00hours)	Min (around 14.00 hours)	Max (around 6.00 hours)
Jan	7.5	87.9	30.3	22.2	58	90
Feb	8.2	96.0	30.6	22.3	59	92
Mar	8.8	117.6	31.0	23.3	64	94
Apr	7.9	259.8	31.1	24.3	68	95
May	6.2	352.6	30.6	25.3	72	92
Jun	6.6	211.6	29.6	25.2	73	93
Jul	6.1	139.7	29.3	24.9	70	90
Aug	6.5	123.7	29.4	25.0	65	90
Sep	6.4	153.4	29.6	24.7	67	91
Oct	6.2	354.1	29.4	23.8	70	92
Nov	6.8	324.4	29.6	22.9	67	93
Dec	6.9	174.8	29.8	22.4	61	91