

## Evaluating bioclimatic aspects over the Vidarbha region

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**सार** – इस शोध पत्र में श्वसन और अश्वसन वाष्पशील से होने वाली कमियों, मानव बेचैनी और हवा की टंडक के माध्यम से मानव शरीर से बाहर निकलने वाले पानी की मात्रा जैसे जैविक-जलवायु विषयक कुछ महत्वपूर्ण पक्षों का अध्ययन किया गया है।

विदर्भ क्षेत्र के कुछ अच्छी जलवायु वाले केन्द्रों के अधिकतम तापमान और वाष्प अवदाब के मासिक नार्मल्स का उपयोग करते हुए मानव शरीर से निकलने वाले पानी की मात्रा का आकलन किया गया है। थॉम्स (1959) के तापमान-आर्द्रता सूचकांक (टी.एच.आई.) अथवा बेचैनी (डिस्कम्फर्ट) सूचकांक का उपयोग करते हुए मानव बेचैनी (डिस्कम्फर्ट) की मात्रा बताई गई है और सिपले-पैसल (1945) के “हवा की टंडक सूचकांक (डब्ल्यू.सी.आई.)” का उपयोग करते हुए हवा की टंडक के विभिन्न पक्षों का अध्ययन किया गया है।

इन अध्ययनों से यह पता चला है कि श्वसन और अश्वसन से होने वाली कमियों के माध्यम से मानव शरीर से बाहर निकलने वाले पानी की कुल मात्रा ग्रीष्म ऋतु में अधिकतम (384 ग्राम प्रतिदिन) और मानसून ऋतु में न्यूनतम (116 ग्राम प्रतिदिन) होती है। तथापि, शीत ऋतु में श्वसन की अधिकतम कमी 213 ग्राम प्रतिदिन और मानसून ऋतु में न्यूनतम कमी 66 ग्राम प्रतिदिन देखी गई है। ग्रीष्म ऋतु में काफी पसीना आता है तथापि शीत ऋतु और पश्च मानसून ऋतु में पसीना बिल्कुल नहीं आता है। यद्यपि यहाँ की मार्च महीने की सुबह आरामदायक पाई गई है फिर भी शाम के समय पूरे क्षेत्र में बेचैनी का अनुभव होने लगता है। आशा के अनुरूप अप्रैल और मई के महीनों में अधिकतम बेचैनी होती है। इस अध्ययन क्षेत्र के पश्चिमी भाग अर्थात् बुलदाना जिले में शीत ऋतु और ग्रीष्म ऋतु दोनों में ही सुबह का समय आरामदायक रहता है। शीत ऋतु के दौरान विदर्भ क्षेत्र में हवा में टंडक की औसत क्षमता 342 डब्ल्यू/एम<sup>2</sup> देखी गई है। इस ऋतु के दौरान नागपुर की अधिकतम क्षमता (389 डब्ल्यू/एम<sup>2</sup>) पाई गई है। हवा में टंडक के मासिक धंटेवार मानों के आइसोप्लेथ विश्लेषण से यह पता चलता है कि शीत ऋतु के केवल अधिकतम टंडक वाले महीनों (दिसंबर और जनवरी) में नागपुर का मौसम 1300–1700 बजे के दौरान सुहावना रहता है और दिन का शेष समय “टंडे” से लेकर “बहुत टंडा” रहता है। तथापि ग्रीष्म महीने के केवल अधिकतम गर्मी वाले महीने (मई) में 0400–0600 बजे के दौरान मौसम “सुहावना” रहता है और दिन का शेष समय “गरम” से लेकर “उष्ण” रहता है। यहाँ तक कि अप्रैल महीने के दौरान जो कि ग्रीष्म ऋतु का प्रमुख महीना माना जाता है, 0300 से 0700 बजे तक का मौसम उस दौरान टंडा ही रहता है।

**ABSTRACT.** Some of the important bioclimatic aspects, outgoing water budget from the human body in terms of respiratory and non-respiratory evaporative losses, human discomfort and wind chill have been studied in this paper.

Outgoing water budget has been computed using monthly normals of the maximum temperature and vapour pressure for a number of fairly well distributed stations in the Vidarbha region. Discomfort has been quantified using Thom's (1959) Temperature-Humidity Index (THI) or Discomfort Index and wind chill aspects have been studied using the 'wind chill index (WCI)' of Siple and Passel (1945).

The study reveals that total water loss from the human body, sum of respiratory and non-respiratory losses, is maximum (384 g. day<sup>-1</sup>) in summer and minimum (116 g. day<sup>-1</sup>) in monsoon. However, highest respiratory loss of 213 g. day<sup>-1</sup> is observed in winter and that of lowest (66 g. day<sup>-1</sup>) in monsoon. Sensible sweating is very much felt in summer. However, it is not at all felt in winter and post monsoon. Though mornings are comfortable in March, yet the entire region starts experiencing discomfort in the evening hours. As expected, in April and May maximum discomfort prevails. Buldhana district, in the western part of the study region, remains comfortable both during winter and summer in the morning hours. Average cooling power over Vidarbha in winter is observed to be 342 W/m<sup>2</sup>. At Nagpur, maximum cooling power (389 W/m<sup>2</sup>) has been noticed in this season. Isopleth analysis of monthly mean hourly wind chill reveals that in peak winter (December and January) only during 1300-1700 hours Nagpur climate is 'pleasant' and rest of the day

is 'cool' to 'very cool'. However, in peak summer (May) only during 0400-0600 hours climate is 'pleasant' and remaining part of the day is 'warm' to 'hot'. Even in April, despite its being a prominent summer month, climate remains 'cool' from 0300 to 0700 hours.

**Key words** – Outgoing water budget, Human discomfort, Wind chill, Sensible sweating, Vidarbha region.

## 1. Introduction

The creation and maintenance of water need is the most essential priority for the human body. Therefore, the climatology of the outgoing water budget from the human body becomes more important. Water loss from the human body consists of loss of water vapour to the atmosphere due to breathing, called respiratory loss and the non-respiratory evaporative loss. The respiratory loss depends on the difference in mixing ratios of the expired and ambient air and the rate of breathing. This loss is controlled by two factors, namely the availability of water in the body and the transport of the vapour. The non-respiratory heat loss is a function of the fraction of the body wetted by sweat glands and the evaporative power of the atmosphere. The water requirement of a human body plays an important role in the energy budget of man.

Systematic studies of energy budget in terms of heat *viz.* the amount of heat absorbed and lost by the human body have been made, mostly in other countries (Fanger, 1972; Gagge *et al.*, 1971; and Burt *et al.*, 1982). On this aspect one of the notable studies in India, under tropical conditions, has been made by Mukherjee *et al.* (1987). They used monthly normal of the maximum temperature and vapour pressure, for a good number of stations over India as input data and computed the water loss from human body as respiratory and non-respiratory evaporative losses. Their study revealed that throughout the year large respiratory water loss from human body generally occurs over the foot hills of Himalayas, high elevated regions and central parts of north India whereas low values are observed over the coastal areas. In most parts of the country, save the foothills of Himalayas and the coastal areas, sensible sweating is felt during the summer season. Through the year, maximum total outgoing water loss is observed in central parts of north India and the peninsula.

The main meteorological factors that largely influence the physiological sensation of human discomfort are temperature, relative humidity and wind speed. A number of indices, utilizing some of these factors, have been proposed by different scientists, based on the physiological feelings of a large number of people. Some of them have been used in India by various Indian scientists (Philip and Jeevananda Reddy, 1974; Sivaramakrishnan and Rao, 1991). However, the

Temperature-Humidity Index (THI) or Discomfort Index proposed by Thom (1959) which provides an easily evaluated measure describing the degree of discomfort at various combinations of temperature and humidity (Mather, 1974) has been widely used to study the human discomfort of the major cities, health resort and tourist centres in India (Venkiteswaran and Swaminathan, 1967; Padmanabhamurthy and Parthasarathy, 1970; Banerji and Upadhyay, 1972; Menon, 1976; Prasad and Pawar, 1982; Laxmanan, 1984; Lahiri, 1986; Pandharinath, 1990; Kumar and Mishra, 1995; Deosthali, 1999; Das *et al.* 2002).

Strong winds add considerably to the discomfort during winter. Thom's Discomfort Index does not take into account the effect of the wind. In view of this, the 'wind chill index (WCI)' of Siple and Passel (1945), which takes into account the effect of wind on discomfort, has been utilized by some scientists [Mukherjee and Rao (1982) and Laxmanan (1984)] to study the wind chill aspects at some stations of India.

Keeping the above aspects in view, this paper aimed at studying the important aspects of bio-climatic environment, outgoing water budget for the human body, human discomfort and wind chill, over the Vidarbha region.

## 2. Materials and methods

### 2.1. Computation of water loss from the human body

To provide climatology of the outgoing water budget from the human body, in terms of respiratory and non-respiratory evaporative losses for the Vidarbha region, monthly normals of the maximum temperature and vapour pressure for 10 fairly well distributed stations in the region, namely Akola, Brahmपुरi, Buldhana, Chandrapur Gondia, Nagpur, Pusad, Sironcha and Wardha, have been used. The temperature data were collected from the climatological tables of observatories in India, published by the IMD (1951-1980). From the wet bulb and dry bulb temperatures vapour pressure has been calculated using hygrometric tables. While calculating the evaporative power of the environment, in the absence of appropriate data, the potential evaporation computed by Rao *et al.* (1971) has been used to compute the non-respiratory losses.

Total water loss ( $\text{g}\cdot\text{day}^{-1}$ ) from a human body is the sum total of respiratory loss ( $E_v$ ) and non-respiratory losses *i.e.*, water vapour flux through the skin ( $E_s$ ) and sensible heat sweating ( $E_{sw}$ ) which is given by :

$$T_e = E_v + E_s + E_{sw}$$

The respiratory and non-respiratory losses have been computed in the following way :

(a) *Respiratory loss*

According to McCutchan and Taylor (1951), if the air in the lungs is saturated and is at  $37^\circ\text{C}$ , the evaporative loss,  $E_v$  is given by

$$E_v = 1.725 \times 10^{-3} \times M (33 - P_c) \text{ Watt} \quad (1.1)$$

Where

$M$  = Metabolic heat, given by

$M$  = GBs'

$G$  = metabolic rate (assumed  $116 \text{ W/m}^2$ )

$B_s'$  = Body surface area.

$$= 0.202 (W_t)^{0.425} (H_t)^{0.725} \text{m}^2$$

$W_t$  and  $H_t$  being weight of the body (kg) and height (m) respectively are assumed as 55 kg and 1.55m.

$P_c$  = Partial pressure of water vapour (hPa); substituting these values in the equation 1.1, the  $E_v$  reduces to

$$E_v = 10.4258 \times (33 - P_c) \text{ g/day} \quad (1.2)$$

(b) *Non-respiratory evaporative losses*

Gagge *et al.* (1971) showed that the water vapour flux through the skin  $E_s$  is dependent only upon the evaporative capacity of the environment.

$$E_s = 0.06 E_{max} \text{ Watt}$$

or

$$E_s = 2.1436 \times E_{max} \text{ g/day} \quad (1.3)$$

where

$E_{max}$  = evaporative power of the environment.

(c) *The sensible heat sweating  $E_{sw}$  is given as follows*

$$E_{sw} = 0.94 W' E_{max}$$

or,

$$E_{sw} = 33.5837 \times E_{max} \times W' \text{ g/day} \quad (1.4)$$

where

$W'$  = proportion of body wetted by sweat glands.

In the computations, only the influence of skin temperature  $T_s$  (which has been taken as equal to the daily mean maximum temperature) is considered in determining  $W'$ . A threshold  $T_s$  below which sensible sweating is nonexistent is taken to be  $33^\circ\text{C}$ , and  $W'$  is assumed to grow quadratically with departures from this threshold. The relation used is (Burt *et al.*, 1982):

$$W' = (T_s - 33)^2 / 16 \quad 33^\circ\text{C} < T_s < 37^\circ\text{C}$$

$$W' = 0 \quad T_s < 33^\circ\text{C}$$

$$W' = 1 \quad T_s > 37^\circ\text{C}$$

2.2. *Computation of discomfort*

In order to compute discomfort, Thom's (1959) Temperature Humidity Index (THI) or Discomfort Index, based on linear adjustment applied to the average of the dry bulb (DB) and wet bulb (WB) temperature values when the air is practically still, has been applied. It is expressed as

$$\text{THI} = 0.4 \times (\text{DB} + \text{WB}) + 15 \quad (1.5)$$

Where

DB = Dry bulb temperature in  $^\circ\text{F}$ .

WB = Wet bulb temperature in  $^\circ\text{F}$ .

Thom's empirical formula modified to use directly in  $^\circ\text{C}$  is (Das *et al.*, 2002) :

$$\text{THI} = 0.72 \times (\text{DB} + \text{WB}) + 40.6 \quad (1.6)$$

Accordingly, conditions are comfortable as long as THI values lie between 65 and 75. Fifty percent (50%) of the people feel uncomfortable when THI values range from 60 to 65 and 75 to 80 due to excess cold or heat respectively. Their proportion increases to 100 when the values fall below 60 or rises above 80. This classification

**TABLE 1**  
**Respiratory and non-respiratory losses in winter and summer**

Station	Winter				Summer			
	Ev	Es	Esw	Te	Ev	Es	Esw	Te
Akola	232	7	0	239	207	14	218	439
Brahmapuri	200	6	0	206	175	11	160	346
Buldhana	228	7	0	235	195	14	160	369
Chandrapur	201	6	0	208	185	13	198	395
Gondia	212	6	0	217	200	12	153	365
Nagpur	216	6	0	222	204	11	154	369
Pusad	214	6	1	221	184	11	177	373
Sironcha	176	7	1	185	144	13	204	361
Wardha	225	6	0	231	212	11	171	393
Yeotmal	229	8	0	237	203	15	213	430
Average	213	7	0	220	191	12	181	384

of discomfort developed by Thom (1959) can be presented in the following way :

<i>Discomfort category</i>	<i>Index</i>
Discomfort	< 60
Partial Discomfort	> 60 < 65
Comfort	> 65 < 75
Partial Discomfort	> 75 < 80
Discomfort	> 80

It need to be emphasized here that though Thom (1959) has developed the above criteria for the USA, yet it has been found to be quite useful for the tropical Indian conditions as well (Venkiteshwaran and Swaminathan, 1967; Das *et al.*, 2002).

### 2.3. Wind chill computation

Wind chill has been computed using Wind Chill Index (WCI) of Siple and Passel (1945). In metric units, this index is given by the formula :

$$WC = 0.323 \times (18.97 \times \sqrt{V} - V + 37.62) \times (33 - T) \quad (1.7)$$

Where,

WC = Wind chill factor in W/m<sup>2</sup>

V = Wind speed in kmph, and

T = Temperature in °C.

The factors 18.97 and 37.62 are constants for the mathematical fit. The factor 33 is an assumed mean skin temperature in °C.

Siple and Passel (1945) classification is given as follows :

<i>Discomfort category</i>	<i>Index</i>
Hot	< 50
Warm	50 < 100
Pleasant	100 < 200
Cool	200 < 400
Very cool	400 < 600
Cold	600 < 800
Very cold	800 < 1000
Bitter cold	1000 - 1200

For Nagpur station monthly mean hourly temperature (°C) and wind speed (kmph) values are available for all the 24 hours from the autographic record. These data have been utilized to compute monthly mean hourly wind chill index values at this station.

## 3. Results and discussions

### 3.1. Water loss from human body

The geographical distribution of the bio meteorological parameters related to water loss from

TABLE 2

## Respiratory and non-respiratory losses in monsoon and post monsoon

Station	Monsoon				Post monsoon			
	Ev	Es	Esw	Te	Ev	Es	Esw	Te
Akola	73	10	54	138	172	8	3	183
Brahmapuri	53	9	43	106	129	7	0	136
Buldhana	96	9	2	106	178	8	0	186
Chandrapur	57	9	48	114	125	7	0	132
Gondia	54	8	46	108	146	7	0	153
Nagpur	62	9	42	113	158	7	0	165
Pusad	73	10	45	128	151	8	2	161
Sironcha	43	8	44	96	111	7	0	119
Wardha	69	9	42	121	164	8	1	172
Yeotmal	77	10	48	134	169	8	0	177
Average	66	9	41	116	150	8	1	158

Ev = Evaporative loss g.day<sup>-1</sup>; Es = Water vapour flux through skin g.day<sup>-1</sup>  
 Esw = Sensible heat sweating g.day<sup>-1</sup>; Te = Total water loss g.day<sup>-1</sup>

human body for different seasons are presented in Tables 1&2.

### 3.1.1. Water loss in winter

Ev : Average respiratory loss is found to be 213 g/day. It ranges from 176 g/day at Sironcha in the eastern Vidarbha to 232 g/day at Akola in the western part. East of 79° E, Ev is comparatively less than that in west of 79° E. West of 79° E lower dew point consequently lower partial vapour pressure is the main reason for the higher respiratory losses.

Es : The insensible sweating is a direct function of evapotranspiration. Over the region average Es is 7 g/day.

Esw : It is dependent on the daily maximum temperature and the evapotranspiration. In winter both of them have very low values causing the average values of Esw over the region 'zero'.

Te : Total water loss is the sum of respiratory and non-respiratory losses from the human body. During winter seasonal average is 220 g/day and it ranges from 185 g/day to 239 g/day. Like Ev, here also stations east of 79° E record lower Te values than that at the stations west of 79° E.

### 3.1.2. Water loss in summer

Ev : In this season average respiratory loss for the entire Vidarbha region is 191 g/day with values ranging from 144 g/day at Sironcha to 212 g/day at Wardha. There is a slight decrease in the Ev values compared to winter season. This may be attributed to the increase of dew point and consequently of partial vapour pressure.

Es : With the advent of summer conditions, Es over the region increases to 12 g/day.

Esw : In view of high maximum temperature and evapotranspiration Esw in this season registers substantial increase over winter season *i.e.*, from zero in winter it jumps to 181 g/day. Though average Esw over the region is 181 g/day yet values as high as 218 g/day also observed at Akola mainly attributable to very high maximum temperature and evapotranspiration. Values of comparable magnitude have been observed at Yeotmal, Sironcha and Chandrapur.

Te : Summer causes jump in Te values over winter; 220 g/day in winter to 384 g/day in this season. Highest Te is observed at Akola (439 g/day). Yeotmal and Chandrapur also have comparable Te values of 430 g/day and 395g/day respectively.

**TABLE 3**  
**THI values in winter, summer, monsoon and post monsoon mornings and evenings**

Station	THI							
	Winter		Summer		Monsoon		Post-monsoon	
	Morning	Evening	Morning	Evening	Morning	Evening	Morning	Evening
Akola	62	74	75	84	77	81	70	77
Brahmapuri	64	74	76	84	77	81	71	77
Buldana	64	72	73	81	73	77	70	74
Chandrapur	65	74	77	84	78	81	71	77
Gondia	63	72	76	83	78	80	70	76
Nagpur	63	73	76	83	77	79	71	75
Pusad	63	75	76	85	77	80	70	77
Sironcha	67	76	78	85	78	81	73	78
Wardha	65	73	77	84	77	80	72	76
Yeotmal	65	73	76	83	76	79	71	75
Average	64	74	76	83	77	80	71	76

### 3.1.3. Water loss in monsoon

Ev : Advent of monsoon causes sharp fall in Ev values mainly attributed to sharp increase of dew point and consequently of partial vapour pressure. Average Ev in this season is 66 g/day. In the eastern part of Vidarbha (East of 79° E) the values are below average. This could be due to higher dew point values consequently higher partial vapour pressure at the stations situated there.

Es : The insensible sweating also decreases compared to summer but only slightly and average drops to 9 g/day.

Esw : Due to over cast skies there is substantial drop in sensible sweating and the average value drops considerably to 41 g/day. Values as low as 2g/day, in this season, also found at Buldhana and is mainly attributed to comparatively low maximum temperature value at this station.

Te : The pattern of Te values undergoes a drastic change in this season. Compared to summer average Te value over the region falls by more than 250 g/day and reaches 116 g/day. This fall in total water loss is caused by the considerable drop in respiratory loss, Ev compared to summer season.

### 3.1.4. Water loss in post monsoon

Ev : Consequent to the fair weather conditions setting in over the region, Ev values in this season

register a rise compared to those seen in monsoon and the average Ev is 150 g/day.

Es : Average Es is found to be 8g/day.

Esw : Setting up of winter like situation in November causes drop in maximum temperature as well as evapotranspiration, which in turn further drops Esw to one. Esw values of this season can be compared with the respective winter values.

Te : Average Te value is 158 g/day and ranges from 119 to 186 g/day. Compared to monsoon, the increase in Te value, despite fall in Esw, is due to the increase in Ev values in this season.

### 3.2. Temperature Humidity Index (THI) or Discomfort index

Seasonal values of Discomfort index are given in Table 3. Data, therein, reveal the following features :

Winter mornings are comfortable only at Chandrapur, Sironcha, Wardha and Yeotmal (having THI values > 65 < 75); at rest of the stations winter mornings fall in the 'partially discomfort' category. However, winter evenings are 'comfortable' at all the stations of the region.

Summer mornings, except Buldhana (comfort category), at all the other stations fall under 'partially discomfort' category. As expected, summer evenings

TABLE 4

## THI values in October and March mornings and evenings

Station	October THI		March THI	
	Morning	Evening	Morning	Evening
Akola	73	79	70	81
Brahmapuri	74	79	71	81
Buldana	72	76	70	78
Chandrapur	74	79	72	81
Gondia	74	78	70	79
Nagpur	74	77	71	80
Pusad	73	79	71	82
Sironcha	76	79	74	82
Wardha	74	78	72	80
Yeotmal	74	77	72	80

TABLE 5

Wind chill ( $W/m^2$ ) in winter

Station	Wind chill
Akola	359
Brahmapuri	348
Buldana	371
Chandrapur	334
Gondia	320
Nagpur	389
Pusad	348
Sironcha	292
Wardha	323
Yeotmal	338
Average	342

TABLE 6

Wind chill ( $W/m^2$ ) at 0300 UTC in individual winter months

Station	Wind chill		
	December	January	February
Akola	362	388	328
Brahmapuri	355	373	317
Buldana	366	404	342
Chandrapur	351	358	294
Gondia	322	345	292
Nagpur	407	420	341
Pusad	362	368	312
Sironcha	310	313	255
Wardha	338	349	282
Yeotmal	340	373	301

invariably come under 'discomfort' category all over Vidarbha (having THI values > 80).

In general, monsoon mornings come in the 'Partial Discomfort' category except Buldhana which fall in the 'comfort' category. However, monsoon evenings are, in general, under 'Discomfort' category except at Buldhana which is 'Partially Discomfort'.

During post-monsoon season, mornings are quite comfortable in Vidarbha (average THI 71); however, evenings fall in the 'partial discomfort' category, except Buldhana which enjoys comfortable climate during post-monsoon evenings as well.

THI values of the two transition months October and March are presented in Table 4. Data, therein, reveal that October and March mornings in Vidarbha are quite comfortable. October evenings fall in the 'partially discomfort' category. However, in the evenings in March, people starts feeling discomfort, indicating the impending active summer months of April and May ahead.

### 3.3. Wind chill

Wind chill in winter has been computed for 10 stations of the Vidarbha region and presented in Table 5.

Average value of wind chill over Vidarbha is 342  $W/m^2$  ranging from 292  $W/m^2$  at Sironcha to 389  $W/m^2$  at

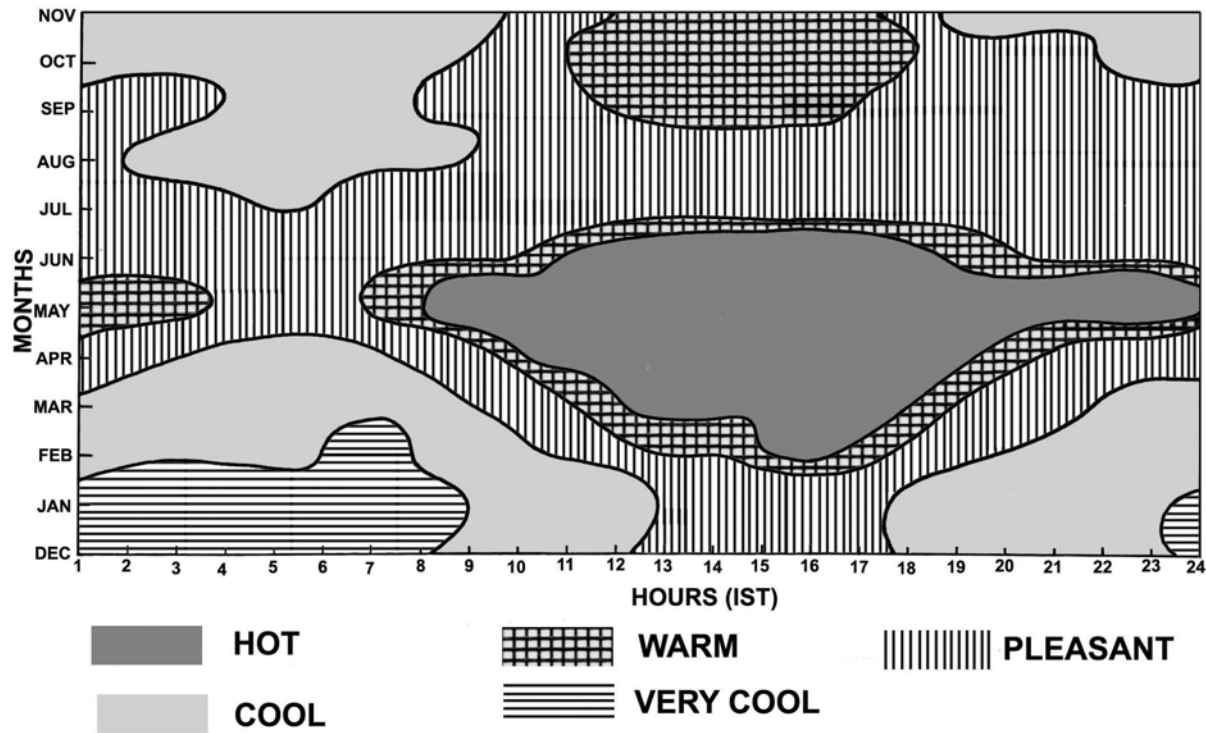


Fig. 1. Isoleths (monthly mean hourly wind chill) showing periods of different discomfort category at Nagpur

Nagpur. The value of Buldhana ( $371 \text{ W/m}^2$ ) also is close to the maximum indicating that at Nagpur and Buldhana cooling power of atmosphere, in winter, is maximum.

Wind chill has also been calculated at 0300 UTC *i.e.*, morning dry bulb temperature epoch for the winter months of December, January and February (Table 6).

Analysis reveals that in winter months WCI, in general, ranges between  $200\text{-}400 \text{ W/m}^2$  placing the winter mornings in Vidarbha in 'cool' category. However, a deeper look further reveals that January is comparatively cooler than rest of the winter months and in January (for Nagpur also December) Nagpur and Buldhana are 'very cool'.

For Nagpur station monthly mean hourly temperature ( $^{\circ}\text{C}$ ) and wind speed (kmph) values are available for all the 24 hours from the autographic record. These data have been utilized to compute monthly mean hourly wind chill index values and utilizing these values

isopleths have been drawn to find out very cool, cool, pleasant, warm and hot periods (Fig. 1).

Fig. 1 reveals that in active winter months of December and January, Nagpur remains 'pleasant' only for four hours during 1300-1700 hours and remaining part of the day climate remains 'cool' to 'very cool'. However, in peak summer in May, the scenario changes drastically: only during 0400-0600 hours people feel 'pleasant' and remaining part of the day remains 'warm' to 'hot'. It is interesting to note that even in April, a prominent summer month, climate at Nagpur remains 'cool' during 0300 to 0700 hours. During monsoon season in June, a substantial portion of the day (1000-2000 hours) remains 'warm' to 'hot'; however, remaining monsoon months are 'pleasant' to 'cool'. In the post monsoon months of October and November Nagpur remains mainly 'pleasant' to 'cool' save a few hours in the afternoon.

#### 4. Conclusions

(i) Total water loss from the human body, sum of respiratory and non-respiratory losses, is found to be



maximum ( $384 \text{ g. day}^{-1}$ ) in summer; it is minimum ( $116 \text{ g. day}^{-1}$ ) in monsoon in the Vidarbha region.

(ii) Highest respiratory loss of  $213 \text{ g. day}^{-1}$  is observed in winter and that of lowest ( $66 \text{ g. day}^{-1}$ ) in monsoon. Lower dew point consequently lower partial vapour pressure in winter is the main cause for the higher respiratory losses. Reverse is the case in monsoon.

(iii) Sensible sweating is very much felt in summer. However, it is not at all felt in winter and post monsoon.

(iv) Discomfort Index (THI) reveals that though March mornings are comfortable yet the entire region starts experiencing discomfort in the evening hours. As expected, in April and May maximum discomfort prevails. Buldhana district in the western part of the study region remains comfortable both during winter and summer morning hours.

(v) Discomfort conditions are aggravated by winds which have been taken into account by computing wind chill index (WCI). The analysis of the same indicates that over the region average cooling power in winter is  $342 \text{ W/m}^2$ . At Nagpur, maximum cooling power of  $389 \text{ W/m}^2$  has been noticed in this season. January is the worst winter month during which WCI values are higher for all the stations with Nagpur having the highest WCI values of  $420 \text{ W/m}^2$  while the lowest of  $255 \text{ W/m}^2$  is observed at Sironcha in February.

(vi) Isoleth analysis of monthly mean hourly wind chill reveals that in peak winter (December and January) only during 1300-1700 hours Nagpur climate is 'pleasant' and rest of the day is 'cool' to 'very cool'. However, in peak summer (May) only during 0400-0600 hours climate is 'pleasant' and remaining part of the day is 'warm' to 'hot'.

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