

Assessment of Heat Stress on Open Field Workers at Four Indian Coastal Stations

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ABSTRACT: Due to global warming, increase in air temperature is a growing concern at present. This rise in temperature may cause mild to severe thermal discomfortability and heat related hazards mostly for the people who are engaged in outside activity throughout the day. The present study shows the distribution of thermal loads over four coastal stations of India *viz*, Digha (22.38° N, 87.32° E), Visakhapatnam (17.68° N, 83.21° E), Thiruvananthapuram (8.48° N, 76.95° E) and Goa (15.49° N, 73.82° E). In this present study Wet Bulb Globe Temperature (WBGT) is used to estimate the thermal stresses by using last ten years' meteorological data. It is observed that 36%, 43%, 55% and 35% days of summer months are fall in the partial discomfort category (II) for Digha, Visakhapatnam, Thiruvananthapuram and Goa respectively. It is interesting to note that 2.53% and 6.82% days of winter season of Goa and Thiruvananthapuram are also in the same zone. Severe stresses are observed in the East coast during summer and monsoon months. A positive trend varying from 0.30°C to 0.45° C per year is observed for all the Coastal stations except Thiruvananthapuram. Regional based Discomfort Index (DI) scale is also proposed in this study.

KEYWORDS: Heat stress, Wet Bulb Globe Temperature, Discomfort Index, Thermal discomfort, Coastal stations

I. INTRODUCTION

Climate change which increases the global temperature is one of the most concern subjects now a day. Rapid urbanization and industrialization alters radiation balance which changes the air flow and turbulence. Moreover increased air pollution by human activities cumulatively rise the surrounding air temperature [1]. This rise in temperature leads to thermal discomfort and several heat related illness such as heat rashes, heat cramps, heat exhaustion and even sever heat stroke. Thermal stress affects the people most who are exposed directly to the sun such as soldiers, athletes, farmers, travellers and often open field workers [2, 3]. As heat stress directly affects the individuals' health, it also reduces the worker's performance and productivity [4] which may have negative impact on socio-economic status and economic development.

Comfort is a sensation and thermal comfort is the pleasant state of mind of an individual to his/her surrounding thermal environment [5, 6]. This thermal sensation depends upon two factors such as environmental factors *viz*, air temperature, radiant heat, wind speed, relative humidity and behavioural factors *viz*, total metabolic rate, clothing [7]. As this thermal comfort is also an acceptable temperature zone, it ranges 23°C to 27°C during summer and 20°C to 25°C during winter [8]. Thermal stress is the balance between a worker's net thermal load (by the work and environment) and the capacity of eliminating the heat. In the last few decades rise in global mean temperature with very fast urban and industrial development lead to increase the heat stress mostly during the summer season [9, 10, 11, 12]. Workers from construction industries, agricultural sectors, pottery industry, power plant and different unorganised sectors are mostly affected by the summer thermal stress. Active researches are going on throughout the world to indexing the thermal stress and more accurately grade it according to different climate zone [13, 14, 15, 16, 17]. In this paper, an attempt is made to evaluate the thermal comfortability of four Indian coastal regions to suggest scientific work-rest plan throughout the year for outdoor workers with Discomfort Index scale on regional basis.

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II. METHODOLOGY

Four coastal regions of India viz, Digha, Visakhapatnam, Thiruvananthapuram and Goa are selected for our study. Meteorological weather data with some data gap for last ten years are used in this study.

Study areas:

Digha (22.38° N, 87.32° E; 6m above msl), West Bengal is situated on the East coast of India. It lies under tropical wet and dry climatic zone with an average annual temperature ranges from 24°C to 37°C. Summer season starts from end of March and lasts 2nd week of June but cold wind from sea keeps the weather under comfortable zone. Monsoon starts from 3rd week of June and continues upto September. Lowest temperature found in the month of January.

Visakhapatnam (17.68° N, 83.21° E; 45m above msl), Andhra Pradesh is also situated on the East coast of India and located between Bay of Bengal and Eastern Ghats Mountain. It lies under tropical wet and dry climatic zone with the annual temperature ranges from 10.5°C to 45.4°C (upto 2010). The city has a mean annual precipitation of 968.8mm with 71.8% relative humidity.

Thiruvananthapuram (8.48° N, 76.95° E; 10m above msl) or Trivandrum is the capital city of state Kerala. It located on the western coastal part of India and extreme south of the mainland.. It lies under the tropical wet climatic zone with an average annual temperature ranges from 24.4°C to 35°C. High temperatures recorded in the month of March to June whereas low temperatures found in the month of December to February. The city located south-west monsoon path and gets the first showers of the country in the early June. It has mean precipitation of 1700 mm with 78% relative humidity however humidity reaches 90% during monsoon months.

Goa (15.49° N, 73.82° E; 6m above msl) is the smallest state of India located on western coastal part of India and coastline of Arabian Sea. It has 3702 km² area. It falls under the tropical wet climatic zone with hot and humid climate throughout the year. Hottest and coldest months of the city are May and January with an average temperature of 30°C and 26°C respectively. June to September is the monsoon period of Goa with annual mean precipitation of 2926mm.

Data analysis:

Wet-bulb globe temperature (WBGT) is computed using the most widely used index developed by Yaglou and Minard in 1957 [18]

$$WBGT = 0.7 Tw + 0.1 Ta + 0.2 Tg \dots(1)$$

where Tw, Ta and Tg are respectively the wet-bulb temperature, air temperature and black-globe temperature in °C. At indoor purpose, Tg ≈ Ta.

Discomfort index (DI) is analysed for better physiological significance [19, 20]

$$DI = 0.5 Tw + 0.5 Ta \dots(2)$$

Table 1: Five graded discomfort scale

Category (Flag)	Comfort sensation	WBGT
I (White)	Comfortable	< 27.7
II (Green)	Partial discomfort	27.8 to 29.4
III (Yellow)	Discomfort	29.5 to 31.0
IV (Red)	Severe stress	31.1 to 32.1
V (Black)	Very severe stress	>32.2

WBGT scale (five graded) as shown in Table 1 is used to quantify degree of stress after USARIEM [21] with some modifications.

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III. RESULTS AND DISCUSSION

It is observed that yearly temperature variation of four major coastal places of India viz, Digha, Visakhapatnam, Thiruvananthapuram and Goa and temperature ranges from 21.5°C to 30.8°C, 26°C to 31.4°C, 28.4°C to 31.5°C and 27.4°C to 32.2°C whereas the average annual temperatures of these four regions are 27.4°C, 28.8°C, 29.6°C and 29.9°C respectively. Annual temperature variations are given in Table 2

Table 2: Annual temperature variations of four coastal regions

	Digha	Visakhapatnam	Thiruvananthapuram	Goa
	Dry bulb temperature (°C)	Dry bulb temperature (°C)	Dry bulb temperature (°C)	Dry bulb temperature (°C)
January	21.5±1.6	26.0±0.7	30.0±1.1	29.9±1.4
February	24.9±1.7	27.1±1.5	30.7±1.1	30.2±1.6
March	27.9±1.5	29.4±0.8	31.5±1.1	30.6±0.8
April	29.5±1.3	30.1±0.7	30.8±2.0	32.2±0.7
May	30.8±1.5	31.4±1.2	30.6±1.9	32.5±0.4
June	30.3±1.8	30.5±1.9	29.4±1.8	29.3±2.3
July	29.7±1.4	29.6±1.4	28.4±1.7	27.4±1.9
August	29.3±1.3	29.5±1.7	28.9±1.6	28.1±1.4
September	29.1±1.6	29.2±1.5	28.4±1.5	27.8±1.4
October	28.3±1.7	28.9±1.6	28.7±1.5	29.7±1.8
November	25.6±1.5	27.9±1.0	28.6±2.0	31.4±1.3
December	22.4±1.3	26.2±1.4	29.3±1.8	30.4±1.6

Fig. 1 shows the seasonal variation of wet-bulb globe temperature and it is seen that 72.43%, 72.58%, 80.88% and 81.21% days are fall in comfort category (I) whereas 22.74%, 22.89%, 18.71% and 18.39% days are in the partial discomfort category (II) throughout the year for Digha, Visakhapatnam, Thiruvananthapuram and Goa respectively. 4.58% and 6.53% days of summer months (March to May) of Digha and Visakhapatnam are found in the yellow to red zone whereas only 0.81% and 0.55% days of summer season of Thiruvananthapuram and Goa are in the same category. It is interesting to note that 4.98% and 2.52% days of Digha and Visakhapatnam are also in the discomfort to sever thermal stress category during monsoon months (June to September). 27.5% days of Goa during post- monsoon season (October and November) are in partial discomfort state whereas 6.26%, 8.56% and 4.33% days of Digha, Visakhapatnam and Thiruvananthapuram are in same zone during post- monsoon months.

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(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

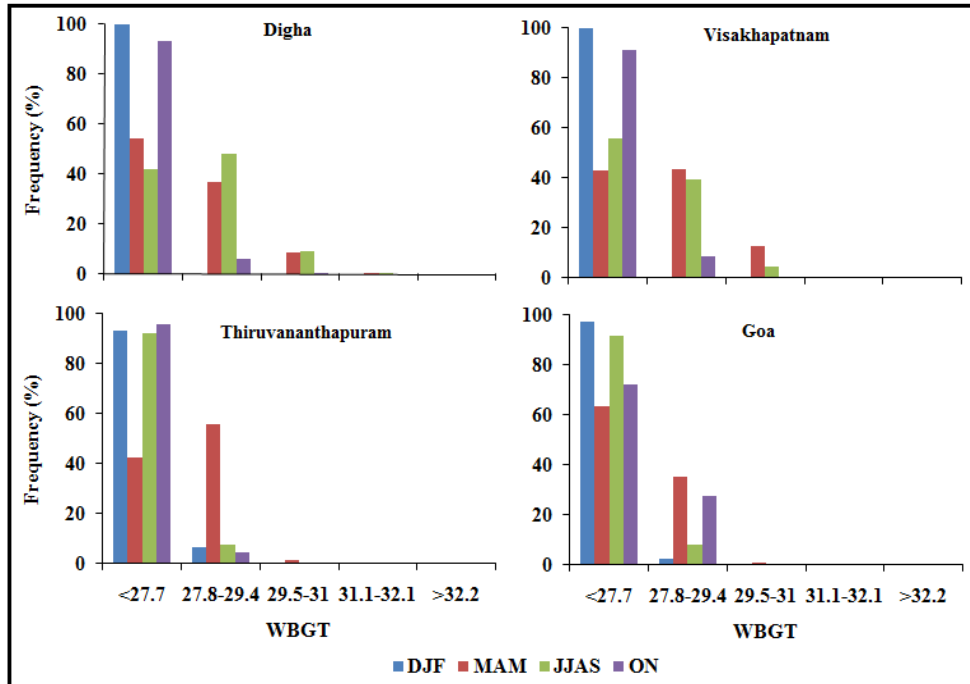


Fig. 1. Frequency distribution of WBGT

It is also found that 6.82% and 2.53% days of winter season (December to February) of Thiruvananthapuram and Goa are in the green category i.e., in the partial discomfort zone. Positive trends of 0.45°C, 0.33°C and 0.30°C per year are observed at the coastal stations whereas Thiruvananthapuram shows no significant change in WBGT during summer months (Fig. 2).

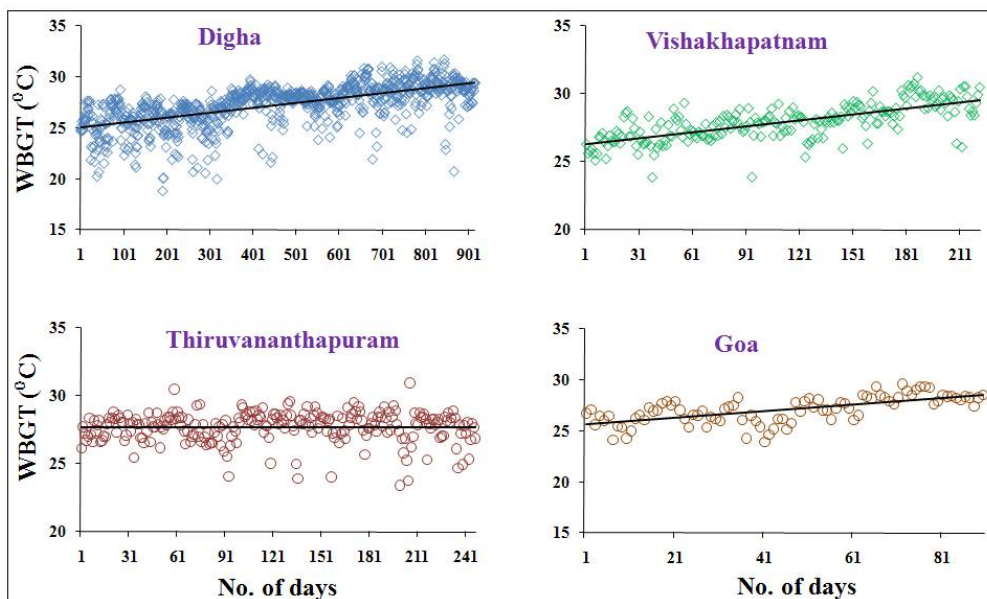


Fig. 2. Trend analysis of WBGT of four coastal stations during summer

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Vol. 5, Issue 3, March 2016

WBGT is significantly correlated ($p < 0.0001$) with DI for all the coastal stations. R^2 values ranges from 0.87 to 0.995 as shown in Fig. 3.

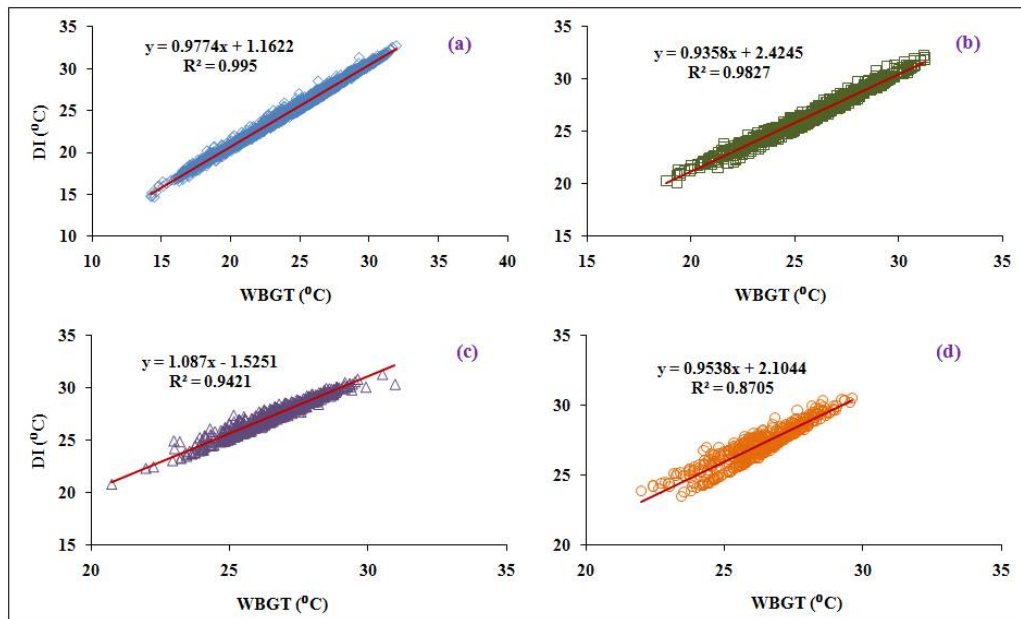


Fig. 3. Correlation between WBGT and DI over (a) Digha, (b) Visakhapatnam, (c) Thiruvananthapuram and (d) Goa

A regional based discomfort scale of DI with reference to WBGT is proposed in this study. the scale for all the four coastal cities are given in Table 3.

Table 3: Regional based scales of DI

WBGT	Digha	Visakhapatnam	Thiruvananthapuram	Goa
≤ 27.7	≤ 28	≤ 28.5	≤ 28.5	≤ 28.5
27.8 to 29.4	28.1 to 30.1	28.6 to 29.8	28.6 to 30.3	28.6 to 30.3
29.5 to 31.0	30.2 to 31.4	29.9 to 31.7	30.4 to 31.9	30.4 to 31.8
31.1 to 32.1	31.5 to 32.7	31.8 to 33.3	32.0 to 33.5	31.9 to 33.5
≥ 32.2	≥ 32.8	≥ 33.4	≥ 33.6	≥ 33.6

IV. CONCLUSIONS

From the data analysis it is noted that number of hot days is maximum in the month of May for all the locations. But heat stress is found high in West coast compared to East coast. Moreover a positive trend (0.30 to 0.45) is observed for all the Coastal stations except Thiruvananthapuram.

Human body can loses one litter/hour fluid in extreme temperature with very high relative humidity and it may lead to severe dehydration state [15]. In summer when the temperature reaches its maximum, the thermal stresses are greater

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on the people who particularly work under the open sky during day time. It not only affects the individual's health, but also at the same time reduces the performance and efficiency. 20.6% days of the year of major coastal regions of India are in partial discomfort category whereas 3.13% days of summer months are fall in the discomfort category III and IV. As heat exchange through evaporation plays a significant role in thermal comfort and remains body core temperature $37\pm 1^{\circ}\text{C}$, it is important to maintain adequate air movement in the working places. Adequate fluid intake [21], a recommended work-rest scheduled [22] and routine health check up can reduce heat stress risk particularly during summer months.

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