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APPLICATION OF OUTDOOR HUMAN THERMAL INDICES IN NABLUS, PALESTINE.

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ABSTRACT

The purpose of this study is to investigate the feeling of comfort or discomfort of human in Nablus (West Bank). Analyses are based on Net Effective Temperature (NET), Discomfort Index (DI) and Oliver's discomfort index (Temperature – Humidity Index) (THI).The meteorological data used to represent the outdoor environment were obtained from the Palestinian meteorological department gathered during 12 years periods (2000-2011).

Most of the population feels comfort in the months April, May and November, as THI value oscillate between 60-65, these months shows approximately lower relative humidity. When the air temperature and relative humidity starts to increase at the beginning of summer months, 50% of the total population feels discomfort from June to October, takes place in August as increasing of temperature and relative humidity due to intensification of Indian monsoon low, with THI value around (70.4). DI value from June to September felt under less than 50% of the total population feels discomfort while from December to March shows moderate discomfort feeling. The months from November to May observed in the (very cold) region with NET < 13, while in other months shows in the (fresh) region with 16< NET <22.The study suggests that the thermal discomfort tend to increase, especially during July and August.

Keywords: Thermal Indices, THI, DI and NET Indices, Nablus, Palestine.

1. INTRODUCTION

The different microclimates condition in the city affect also on outdoor thermal sensation. The primary environment factors that produce heat stress are temperature and humidity. [3] defined three parameters for a person to be in thermal comfort: 1. the body is in heat balance; 2. sweat rate is within comfort limits; 3. mean skin temperature is within comfort limits. These conceptual requisites for determining thermal comfort can be expressed by measurable terms as: body-core temperature within a very narrow range of 36.5–37.5°C, a skin temperature of 30°C at the extremities and 34–35°C at body stem and head, and the body will be free of sweating [18][7]. Any deviation from these assertions results in sensation of discomfort. The feels uncomfortable are caused by high temperature and sometimes by high relative humidity. The consciousness for comfort of human beings depends on conditions for the thermal balance between the body and the environment; the factors affecting thermal comfort are both environmental factors (Air temperature, Air velocity and Air Humidity) and personal factors (clothing insulation and metabolic or heat production of the body).[14] studied the effect of urbanization and industrialization processes on outdoor thermal human comfort in Egypt. He concluded that the urbanization and industrialization processes cause increase of human serious hot uncomfortable feeling while the rural conditions leads to optimum weather comfort. Thermal comfort is closely linked to human health[2]. The essential factor determining human discomfort is the thermal component of environmental conditions and was calculated by many indices using air temperature, wind speed and relative humidity [17][15][13][9][16][11][1]. A direct relationship has been found between Urban Heat

Island intensity peaks and heat-related illness and fatalities, due to the incidence of thermal discomfort on the human cardiovascular and respiratory systems. Heatstroke, heat exhaustion, heat syncope, and heat cramps, are some of the main stress events, while a wide number of diseases may become worse, particularly in the elderly and children. In a similar way, respiratory and lung diseases have shown to be related to high ozone levels induced by heat events (United States Environmental Protection Agency).

The present study aims to discusses the thermal human comfort in Nablus, Palestine. So far, no studies dealing with outdoor human thermal comfort have been conducted in the Nablus, West Bank, Palestine.

2. DATA AND METHODS

The meteorological data used to represent the outdoor environment were obtained from Nablus meteorological stations. Mean monthly air temperature (°C), relative humidity (%) and wind speed (m/s) were collected from Palestinian meteorological department gathered during 12 years (2000-2011). [19] defines temperature as a physical quantity characterizing the mean random motion of molecules in a physical body. The measurement of the air temperature were carried out by dry bulb mercury thermometer exposed to the air, reading in a place sheltered from direct solar radiation at the height of 2m above ground level with an accuracy of 0.1°C. The measurement of the wind speed obtained by anemometer situated on a standard high (10m), the analysis is based on 10 minute average stored in data logger. Hygrometer, instrument used to measure the relative humidity of air, the weight of water vapor per unit volume of air.

In the last decade, various indexes have been developed to estimate the energy balance of the human body in different environment to reach human comfort, In 1905 Haldane was probably the first in suggesting that the wet-bulb temperature is, as a single value, the most appropriate measure to express heat stress[6]. Since then a large number of indices have been suggested. Three indexes of thermal comfort were used in this study: Discomfort Index, DI [17], Net Effective Temperature Index, NET [16]and Oliver's Index or Temperature-Humidity Index, THI [13].

2.1 Discomfort Index (DI)

Thom's discomfort index (DI) is expressed by a simple linear equation based on dry- bulb (Tdry) and wet-bulb (Twet) temperatures. Its original form is given as:

$$DI\,(°F) = 0.4(T_{dry}+T_{wet}) + 15$$

If air temperature (T) as measured in degrees Celsius and relative humidity (RH) in% are given, DI can be computed by using the following equation suggested by[5]:

$$DI\,(°C) = T - (0.55 - 0.0055RH)(T - 14.5)$$

Where:

DI= Discomfort Index(°C).

T= air Temperature in (°C).

RH= Relative Humidity in (%).

Table 1: Classification of Thom's human comfort-discomfort sensation[17].

DI (°C)	Comfort Sensation
Less than 10	Extreme discomfort feeling
10 – 15	Moderate discomfort feeling
15 – 18	Relatively comfort
18 – 21	No discomfort feeling
21 – 24	Less than 50% of the total population feels discomfort
25 – 27	More than 50% of the total population feels discomfort
28 – 29	Most of the population feels discomfort
30 – 32	The discomfort is very strong and dangerous
More than 32	State of medical emergency

2.2 Net Effective Temperature Index (NET)

First introduced by[12], include the effect of air temperature (◦C) and relative humidity (%) in its calculation.

NET = T − 0.4[(1 − RH/100) (T − 10)]

Where:

T = air temperature (◦C).

RH = relative humidity (%).

NET = Net Effective Temperature (◦C).

Modifications by [19][8][16] to include the effective temperature as a function of relative humidity and wind speed, which applied as a follow:

$$NET = 37 - \frac{37 - T}{0.68 - 0.0014RH + 1/(1.76 + 1.4V^{0.75})} - 0.29T(1 - 0.01RH)$$

Where:

T = air temperature (◦C).

RH = relative humidity (%).

V = average wind speed (m/s).

Table2: Ranges of the Net Effective Temperature[4].

NET (◦C)	Level of stress	Thermal Sensation
<13	Extreme stress by cold	Very cold
13-16	Shivering	Cold
16-22	Lightly cold of the body	Fresh
22-25	Thermal neutrality	Comfortable
25-28	Quick perspiration vasodilatation	Warm
28-31	Sweating	Slightly hot
31-34	Intense sweat	Hot
>34	Fails in thermo regulation	Very hot

2.3 Oliver's Index

Oliver's formula in 1981,representing the combination of air temperature and relative humidity associated with the level of thermal stress. This formula uses air temperature (ºF) and relative humidity. The RH is divided by 100 to express the percentage in decimals.

$$THI = T - \left[0.55 - \left(0.55 * \frac{RH}{100}\right)\right](T - 58)$$

T = air temperature(ºF).

RH = relative humidity (%).

THI= Temperature-Humidity Index (ºF).

Table3: Classification ofOliver's index (THI) human comfort-discomfort sensation[13].

THI (ºF)	Comfort Sensation
< 60	Most of the population feels discomfort (cold discomfort).
60 – 65	Most of the population feels comfort.
65 – 80	50% of the total population feels discomfort.
> 80	Most of the population feels discomfort (warm discomfort).

3. STUDYAREA

Palestine is located in the Middle East between 29°and 33° North Latitude and between 35° and 39°East Longitude at the eastern ends of the Mediterranean Sea in south – west of Asia. It is bounded to the north by Lebanon, the northeast by Syria, the east by Jordan, and to the southwest by Egypt. To the west of Palestine is the Mediterranean Sea, Palestine has a small coastline on the Red Sea in the south. The northern and coastal regions of Palestine show Mediterranean climate which included in the classification of the different types of climate on Earth [10] characterized by hot and dry summers and short, cool rainy winters as modified locally by altitude and latitude .

Nablus (sometimes called Nābulus); one of the oldest cities in the world, (Located at 35º15 E and 32º13 N). Most of Nablus workforce has been employed in agriculture and local trade. Nablus is a center of olive cultivation in Palestine, and away from the Mediterranean Sea 42 km. Height of the city center is about 570 meters above sea level, the Nablus weather station is about 570m high. The relatively temperate Mediterranean climate brings hot, dry summers and cool, rainy winters to Nablus. Spring arrives around March–May and the hottest months in Nablus are July and August with the average high being 25 °C. The coldest month is January with temperatures usually at 10.3 °C. Rain generally falls between October and March, with annual precipitation rates being approximately 607 mm, the average relative humidity is about 62.4%.

Figure 1: The location of study area.

4. RESULTS ANDDISCUSSIONS

4.1 Discomfort Index (DI)

The maximum air temperature with maximum relative humidity produces high DI, and lower DI values reflect the low air temperature and relative humidity. [17]categorized DI values in the different classes as moderate discomfort feeling with DI value between 10-15,relatively comfort (15-18),no discomfort feeling (18-21),50%of the total population feels discomfort (21-24) and more than 50% of the total population feels discomfort with (25-27). In our study, as shown in Table 4, the DI value from December to March in Nablus felt under moderate discomfort feeling while from June to September felt under less than 50% of the total population feels discomfort . DI in the months November and April shows relatively comfort while in the months May and October fell within no discomfort feeling (see Figure 2).

Table 4: Mean monthly values of DI (°C) at Nablus stations for 12 years period.

Months	Average Temperature(°C)	Average Relative Humidity(%)	DI (°C)	Comfort Sensation
Jan	10.3	68.9	11	Moderate discomfort feeling
Feb	11	69.1	11.6	Moderate discomfort feeling
Mar	14.3	61.5	14.3	Moderate discomfort feeling
Apr	17.2	57.8	16.6	Relatively comfort
May	20.6	53.2	19	No discomfort feeling
Jun	23.2	56.1	21.1	Less than 50% of population feels discomfort
Jul	25.3	60.1	22.9	Less than 50% of population feels discomfort
Aug	25.2	64.3	23.1	Less than 50% of population feels discomfort
Sep	23.4	66.2	21.7	Less than 50% of population feels discomfort
Oct	21.5	65.3	20.2	No discomfort feeling
Nov	16.2	60.4	15.8	Relatively comfort
Dec	12	66.1	12.5	Moderate discomfort feeling

4.2Net Effective Temperature Index (NET)

Table 5: Mean monthly values of NET (°C) at Nablus station from 2000 to 2011.

Months	Average Temperature(°C)	Average Relative Humidity(%)	Wind Speed m/s	NET (°C)	Comfort Sensation
Jan	10.3	68.9	2.11	3.5	Very cold
Feb	11	69.1	2.16	4.2	Very cold
Mar	14.3	61.5	2.36	7.7	Very cold
Apr	17.2	57.8	2.38	10.8	Very cold
May	20.6	53.2	2.30	12.5	Very cold
Jun	23.2	56.1	2.61	17.1	Fresh
Jul	25.3	60.1	2.52	19.7	Fresh
Aug	25.2	64.3	2.55	19.7	Fresh
Sep	23.4	66.2	2.38	17.9	Fresh
Oct	21.5	65.3	1.97	16.2	Fresh
Nov	16.2	60.4	2.19	10	Very cold
Dec	12	66.1	2.25	5.2	Very cold

As shown in Table 5 and Figure 2, the months from November to May observed in the (very cold) region with NET < 13, while in other months shows in the (fresh) region with 16< NET <22.

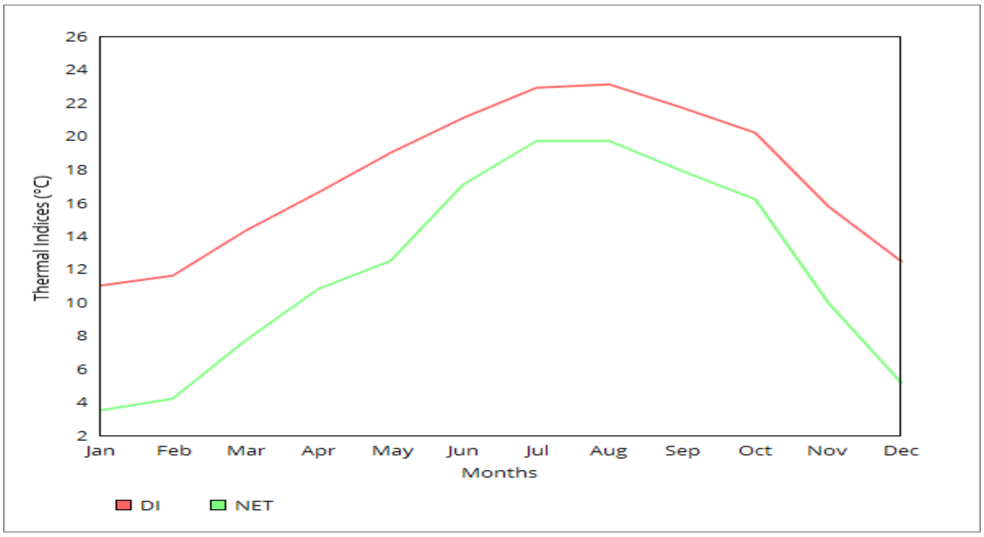

Figure 2: Average monthly pattern of Discomfort Index (DI) and Net Effective Temperature (NET) at study site for the years 2000-2011.

4.3Oliver's Index(THI)

Table 6: Mean monthly values of Oliver's Index (THI) (degrees Fahrenheit) at Nablus station from 2000 to 2011.

Months	Average Temperature(°F)	Average Relative Humidity(%)	THI (°F)	Comfort Sensation
Jan	50.54	68.9	53.08	Most of the population feels discomfort(cold discomfort).
Feb	51.8	69.1	53.91	Most of the population feels discomfort(cold discomfort).
Mar	57.74	61.5	57.83	Most of the population feels discomfort(cold discomfort).
Apr	62.96	57.8	61.17	Most of the population feels comfort.
May	69.08	53.2	64.77	Most of the population feels comfort.
Jun	73.76	56.1	67.77	50% of the total population feels discomfort.
Jul	77.54	60.1	70.35	50% of the total population feels discomfort.
Aug	77.36	64.3	70.48	50% of the total population feels discomfort.
Sep	74.12	66.2	68.49	50% of the total population feels discomfort.
Oct	70.7	65.3	66.23	50% of the total population feels discomfort.
Nov	61.16	60.4	60	Most of the population feels comfort.
Dec	53.6	66.1	55.14	Most of the population feels discomfort(cold discomfort).

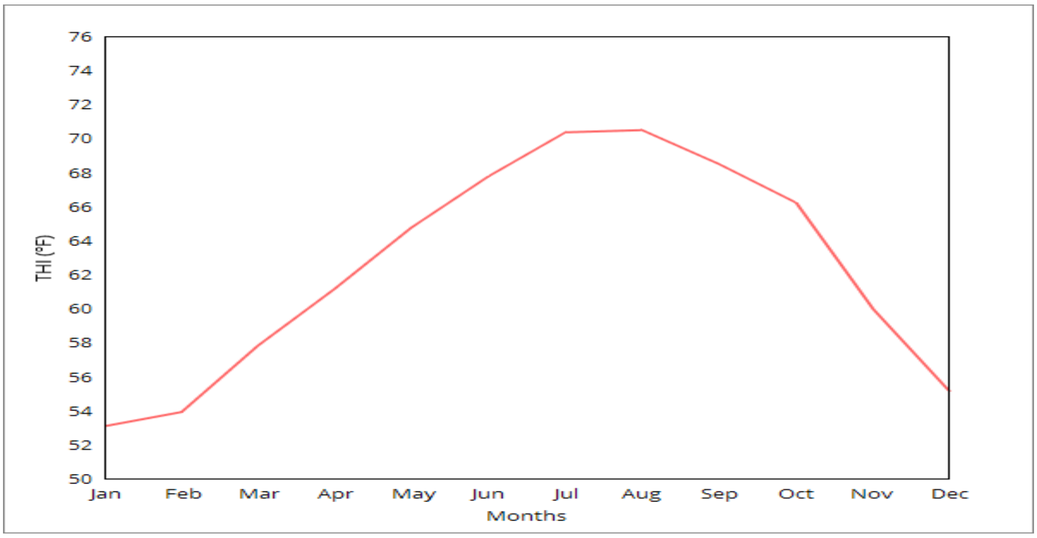

Figure 3: Average monthly pattern of Oliver's Index (THI) (degrees Fahrenheit) of Nablus station for the years 2000-2011.

Nearly all the THI values showed a similar during January to December as seen in (Figure 3).Most of the population feels comfort in the months April, May and November, as THI value oscillate between 60-65, these months shows approximately lower relative humidity. When the temperature and relative humidity starts to increase at the beginning of summer month. As shown in Table 6, 50% of the total population feels discomfort from June to October, with beak in August as increasing of temperature and relative humidity due to intensification of Indian monsoon low, with THI value around (70.4). The lowest THI value was observed in January with(53.08) as the most population feels discomfort (cold discomfort).

5. CONCLUSIONS

Humidity is affected by the temperature of the air, as the air is warmer meaning it can hold more moisture. The humidity is also affected seasonally, being lower in the winter as the air is generally cooler so the air can hold less moisture and higher in the summer as the air is much warmer. It is noticeable that in July and August, the Indian monsoon low intensified over Palestine, this intensification brings high relative humidity and high temperature. The presence of wind play essential role in human comfort sensation. The action of the wind is comfortable in high temperature and relative humidity, while discomfortable in low temperature and relative humidity. Index based on temperature and relative humidity (Thom's and Oliver's) are useful and helpful for many development planning in countries.

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