

Evaluation of Outdoor Thermal Human Comfort Between Coastal and Inland Regions Over Libya

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ABSTRACT

This study analyzed the thermal human comfort of Libya based on the Discomfort Index (DI) method. For this purpose, the average monthly meteorological data of air temperature and relative humidity were obtained from four stations (Tripoli, Benghazi, Sabha and Al Kufra) during (1981-2021) period. The result indicated that the highest value of DI obtained in Tripoli during August, with 25.3°C which fell into the category "More than 50% of the total population feels discomfort". Climate of Libya are dominated by the hot arid Sahara and Mediterranean in the thin coastal strip. With the onset of the summer months, the thermal comfort in the coastal cities decreases with the increase in humidity, so that the inner cities become more thermal comfort. The difference in mean monthly maximum air temperature between coastal (Tripoli) and inland (Sabha) areas is about 7.1 °C, while the difference was 8.3 °C between Benghazi and Al Kufra. The difference appears clear and noticeable between the minimum air temperatures between the coastal regions and the interior regions. It seems that climatic changes have begun to affect the climate and human comfort in Libya.

Keyword: - Environmental Evaluation, Heat Stress, DI, Libya.

1. INTRODUCTION

Libya is one of the countries that are not far from climate change. The diversity of the climate in Libya between desert and coastal makes it difficult to predict the magnitude of climatic changes. Tripoli and Benghazi are a coastal city with higher levels of humidity compared to Sabha and Al Kufra which considered as inland cities. Nowadays, there is great interest among scientists in the study of thermal comfort in external conditions [1-3]. The perception 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, radiant temperature, wind speed and relative humidity) and personal factors (Clothing insulation and Metabolic of the body). Many researches have been conducted to link the relationship between human thermal comfort and spatial diversity [4-8]. There are more than seventy indices applied to evaluate human thermal comfort. The principal factor determining comfortability is the thermal component of environmental conditions and was calculated by a large number of indices using ambient air temperature, wind speed and relative humidity [9-17].

The main purpose of current research is to climatic analysis and study the bioclimatic conditions of four Libyan cities using Discomfort Index (DI).

2. MATERIAL AND METHODS

2.1 Study Domain

Libya is situated in between 25° 00' North latitude and 17° 00' East longitude. The study area as seen in Figure-1, located in North Africa on the southern coast of the Mediterranean Sea with a length of about 2000 km. Libya's population is small compared to the country's area, as it is the sixteenth largest in the world in terms of area.

Table -1: Specifications and climatical variables of the studied stations

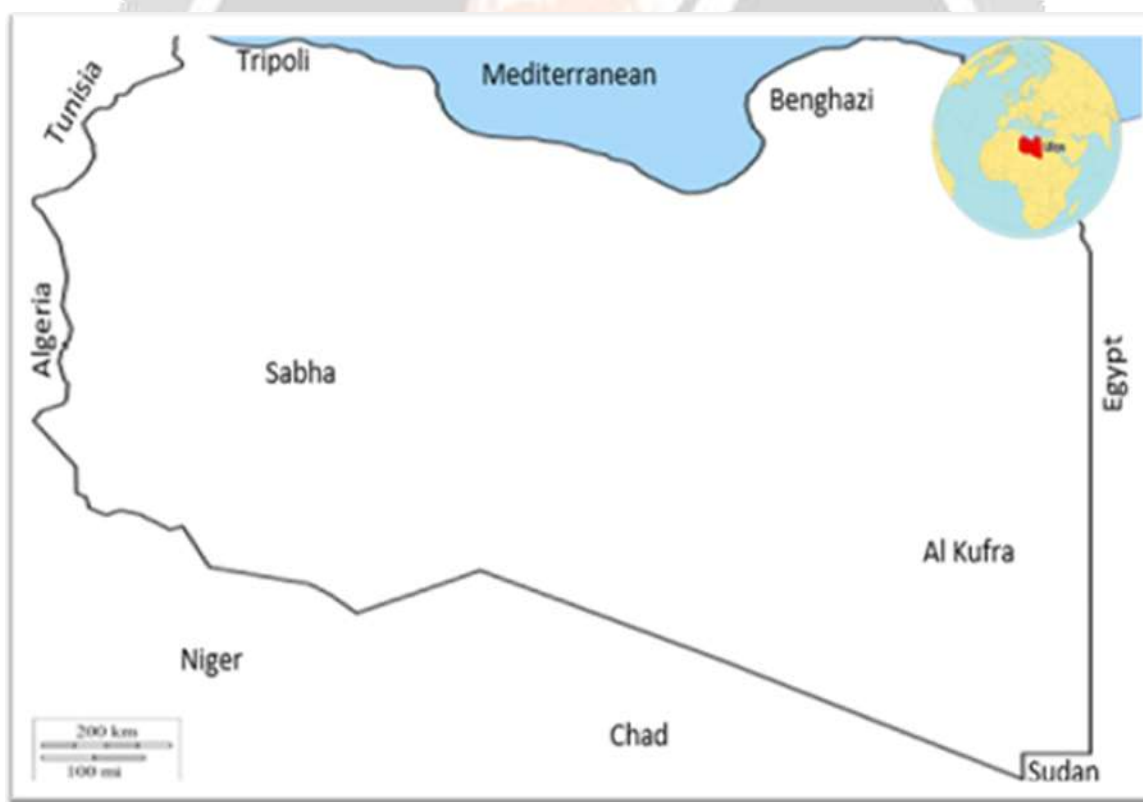
Cities/ Specifications	Latitude	Longitude	Tmax (°C)	Tmin (°C)	Td (°C)	Rh (%)
Tripoli	32.799	13.2356	37.2	9.6	14.1	67.4
Benghazi	32.0897	20.168	34.5	9.4	13.9	68.4
Sabha	27.0226	14.4661	44.3	-0.27	1.6	30.4
Al Kufra	24.014	22.2444	42.8	0.20	0.62	29.3

Tripoli is the official and political capital of the country, and the largest city with a population of about 2.2 million, located in the northwest of Libya on the North African coast, overlooking the Mediterranean Sea from the north.

Benghazi is the second largest Libyan city after Tripoli, which is 1,000 kilometers from the east. Benghazi includes two seaports and Benina International Airport.

Sabha is one of the cities located in the heart of the Libyan desert known as the Great Desert, about 600 km from the Mediterranean coast, and 470 meters above sea level. The climate is very hot in summer, and very cold in winter, and the surface of this city is a desert characterized by sand dunes.

Al Kufra is located in the southeast of Libya in the African Sahara, not far from Chad and Sudan. Al Kufra is about 995 km away from the city of Benghazi and includes more than ten oases, and its population at the present time is about 60,000 people.

**Fig -1:** Location of the study area

The climate is characterized by moderation and diversity, as it is dominated by the Mediterranean climate in the north, and the continental desert climate in the south, that is, cold in winter and hot in summer. The hot desert climate that prevails in most of the country, with the exception of a narrow strip that extends along the Mediterranean Sea.

2.2 Methods

Thom's Discomfort Index is calculated according to: $DI = Ta - (0.55 - 0.0055 \cdot RH) (Ta - 14.5)$. From the average monthly air temperature (Ta in $^{\circ}C$) and the average monthly relative humidity (RH in %). The Discomfort Index (DI) method is used to evaluate the comfortability in selected study area [18].

Table -2: Classification of discomfort index values [9]

DI ($^{\circ}C$)	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

In this research, the average monthly of air temperature ($^{\circ}C$) and relative humidity (%) were used to calculate DI values for Libya during the period 1981-2021.

2.3 Observational Data

The set of meteorological parameters applied in this study consists of monthly average of air temperature and relative humidity for the period 1981-2021 are obtained from four stations mainly located over Libya (Tripoli, Benghazi, Sabha and Al Kufra). The observational climatic data used obtained from NASA Prediction of Worldwide Energy Resources (POWER).

3. RESULT AND DISCUSSION

3.1 Climatological Analysis

According to the Table-1 and chart-2, the maximum air temperature increasing nearly from the middle of May and reaches it is maximum in July and August, the mean difference in mean monthly maximum air temperature between coastal (Tripoli) and inland (Sabha) areas is nearly $7.1^{\circ}C$. while the difference was $8.3^{\circ}C$ between Benghazi and Al Kufra. We note that the difference appears clear between the minimum air temperatures between the coastal regions and the interior regions.

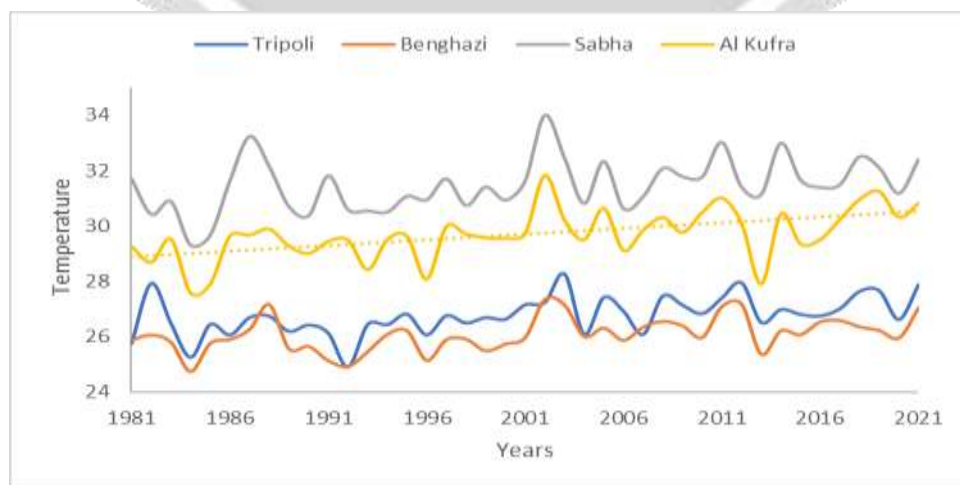


Chart -1: Trend of July air temperature over study area during 1981 to 2021.

As we note in the Chart-1, the temperature increases with the progression of time, and this is one of the signs of climatic changes, which considers Libya one of the countries affected by the results of climate changes, as is the case in the Middle East.

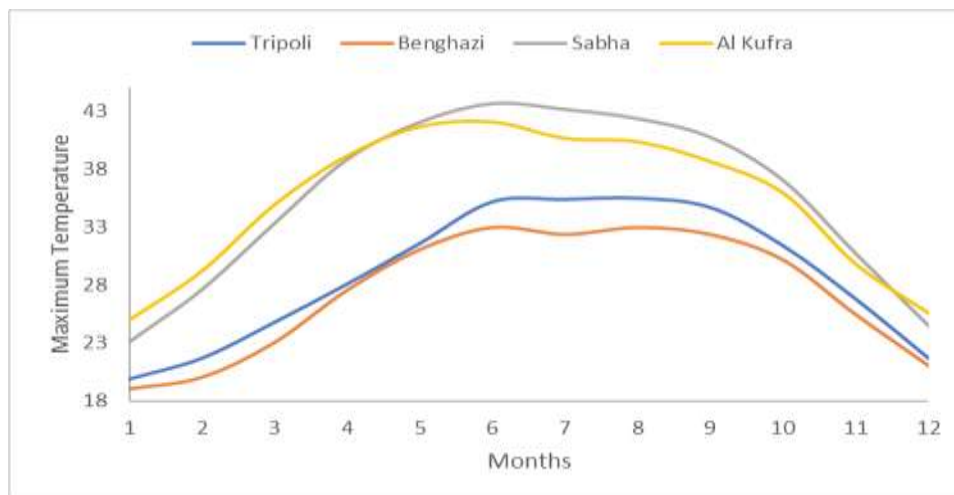


Chart -2: Monthly maximum air temperature over study area during 1981 to 2021

3.2 Discomfort Index (DI)

Highest air temperature together with highest relative humidity produces high thermal discomfort, and vice versa. As illustrated on Table-3, in December, January and February the DI value indicated that moderate discomfort nearly in the four areas. March, April and May showing no discomfort feeling, while less than 50% of the total population suffered from thermal discomfort during June to September, while more than 50% of the total population suffered from thermal discomfort in August over Tripoli.

Table -3: Monthly DI (in °C) at stations for the period 1981-2021

Months	DI (Tripoli)	DI (Benghazi)	DI (Sabha)	DI (Al Kufra)
Jan	14.33355	14.415675	11.38723	11.751865
Feb	14.3341	14.1638	13.230135	13.39092
Mar	15.50068	15.16756	16.22354	16.3021
Apr	17.24098	17.184715	19.58288	19.367215
May	19.61221	19.67152	22.0777	21.617575
Jun	22.3576	22.2444	23.74178	22.798205
Jul	24.42531	24.146775	23.991885	23.03905
Aug	25.36472	24.84718	24.07432	23.163625
Sep	24.52696	23.71176	23.179995	22.1232
Oct	22.2444	21.50599	20.44096	19.64102
Nov	18.932175	18.518735	16.412695	15.95827
Dec	15.81312	15.91763	12.5722	12.730125

In term of Discomfort Index pattern, the weather trend in Libya was alarming. The Chart-3 indicated that, in 41 years span in the four selected weather stations, showed the domination of discomfort level specially in summer months.

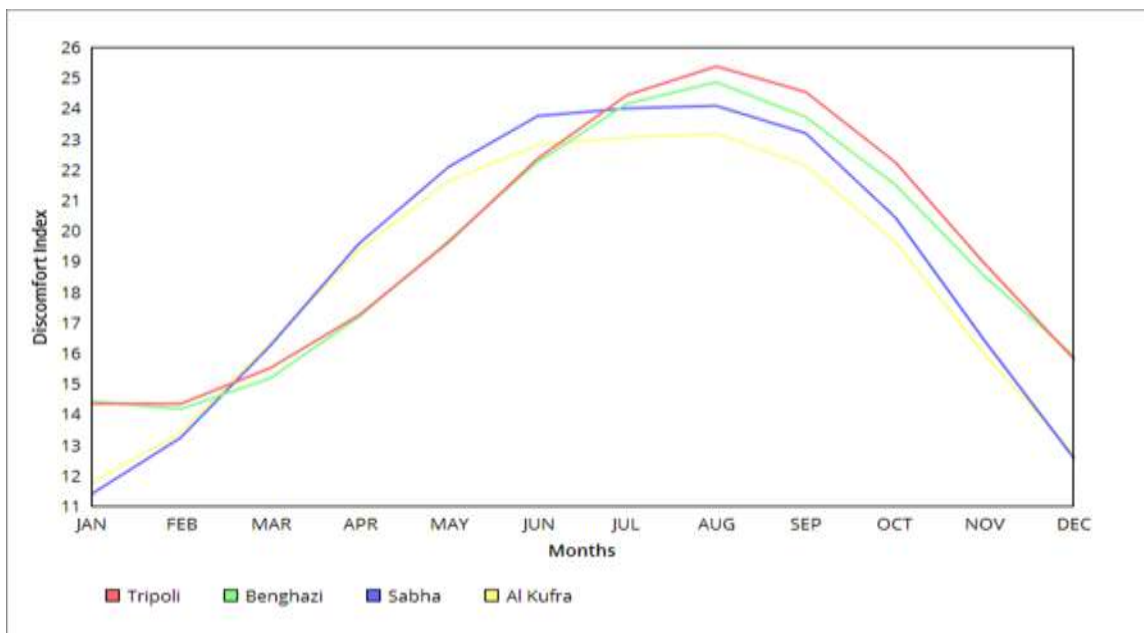


Chart -3: Mean monthly DI (°C) at stations for the period 1981-2021

The thermal human comfort indexes analyzed in this study over Libya cities are almost nearly similar representative of the thermal sensations. [19] found in Greece, that most people felt uncomfortable when DI exceeded 24°C. The city of Tripoli is almost superior to the rest of the cities in this study in terms of thermal discomfort. When the rise in temperature meets the rise in relative humidity, the thermal discomfort increases significantly.

4. CONCLUSIONS

Libya can be divided into five different climatic zones, but the predominant climates are Mediterranean climate and desert climate. High temperatures combined with high relative humidity increase thermal discomfort. Rising temperatures in coastal areas such as Tripoli and Benghazi increase the evaporation process and the air becomes saturated with water vapor, and thus uncomfortable feeling. On the contrary, Sabha and Al Kufra, which does not overlook the Mediterranean, has a dry, hot climate.

Analysis of Discomfort Index (DI) showed that there is a difference between the coastal and inland values, the highest values restricted in Tripoli especially during summer months (25.3 °C), while the lowest DI we get at Sabha during January (11.3 °C). In fact, DI showed that the majority of the days of, 41 years of study period, fell between the category “less than 50% of people feel discomfort and no discomfort feeling”.

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