Analysis of Outdoor Human Thermal Comfort within Three Major Cities in Egypt

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Abstract

In this study, two thermal comfort indices are employed to investigate outdoor human thermal comfort within three major cities of different climates in Egypt. The indices are: the Discomfort Index (DI), and the Robaa Index (RI). The three considered cities are: Alexandria which is located in the north of Egypt, Cairo which is located in the middle and Aswan city which is located in the south of Egypt. The estimations of the two indices are based on the mean wind data of the three cities, which covers the period from January 2010 to January 2011. The study results show that the thermal comfort indices values can be employed to evaluate climate differences in urban areas. The calculated indices showed that; although extreme climate conditions are not reached in Egypt in general, the climate in the north is milder than in the south. In addition, the study results show that the RI is more practical than DI in assessing the human thermal comfort in the outdoor environment.

Keywords

Thermal Comfort Indices, Egypt, Outdoor Environment

Subject Areas: **Environmental Sciences, Mechanical Engineering**

1. Introduction

Outdoor human thermal comfort is an important concept for climate control systems and beyond. It is defined as that condition of mind which expresses satisfaction within an environment. There are many factors that have relevant influence on the outdoor human thermal comfort of urban cities. Some of these factors are related to environmental conditions and others are related to personal conditions. Environmental conditions include temperature, thermal radiation, relative humidity and air speed, while the personal conditions include activity level, clothing, age and gender. However, quantitative study is required to clarify which of the above-mentioned fac-

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tors leads to thermal comfort for human.

There are many indices that have been suggested and employed throughout the open literature to assess the outdoor human thermal comfort. Throughout the literature; there are about 40 indices of thermal comfort [1]. Some of these indices, such as the Discomfort Index (DI) [2], Robaa index (RI) [3] [4], and the Predicted Mean Vote index (PMV) [5] [6] merit special mention as they appear continuously in literature. The Discomfort Index was first proposed by Thom in 1959 [2]. It is an empirical index based on a large series of observations and it is only function of air dry bulb temperature and relative humidity. The second index is the Robaa index [3]. It is suggested by Robaa [4] to account for the combined effect of the three weather elements, dry bulb air temperature, relative humidity and wind speed, on the human discomfort. The range of applicability of RI is wide and it was proven to be adequate for Egypt's climate [4]. It illustrates the integrated effect of both wind speed and relative humidity changes on the human thermal comfort. In this study, both DI and RI are employed for three major cities in Egypt in order to clarify the effect of the differences in climate at the northern, middle and southern parts of Egypt on outdoor human thermal comfort. The cities are: Alexandria city which is located in the north of Egypt, Cairo the capital of Egypt which is located in the middle and Aswan city which is located in the south of Egypt (See Egypt map in **Figure 1**). The study investigation is based on the mean hourly measured meteorological data for the three cities, over a period of thirteen months ranging from January 2011 to January 2012.

2. Thermal Comfort Indices

Various attempts have been carried out in order to estimate empirical indices for the assessment of the outdoor human thermal comfort. These indices integrate the thermal and relative humidity effects of the outdoor environment on the level of human thermal stress. These indices have been applied at a variety of scales from global to local [7]-[11].

The Discomfort Index (DI) is an empirical index based on a large series of observations. It is depending on the dry bulb air temperature and relative humidity. Discomfort increases as DI increases and it is given as follows [2]:

$$\mathrm{DI} = \mathrm{T_d} - 0.55(1 - 0.01\mathrm{RH}) \times (\mathrm{T_d} - 14.5) \tag{1}$$

where T_d is the mean hourly value of the air dry bulb temperature (˚C) and RH is the corresponding hourly value of the relative humidity (%).

The ranges and classifications of the DI values are given by [12] as presented in **Table 1**.

Recently, Robaa [3] [4] proposed a formula that considers combination effects of the three weather elements; dry bulb air temperature, relative humidity and wind speed on outdoor human thermal discomfort. The RI index is expressed as follows [3] [4]:

$$\mathrm{RI} = 1.53\mathrm{T_d} - 0.32\mathrm{T_w} - 1.38\mathrm{V} + 44.65 \tag{2}$$

where T_w is the air wet bulb temperature (˚C), and V is the wind speed (m/s).

The range of applicability of RI formula is wide and adequate for Egypt's climate [4]. The ranges criterions of RI are given by [3] as presented in **Table 2**.

In this study, comparison of the outdoor human thermal comfort in three major Egyptian cities based on two different indices is presented. **Figure 1** shows a map of Egypt where the three considered cities are shown. In addition, the coordinates of the three cities are given in **Table 3**.

The measured meteorological data of hourly-mean air dry bulb temperature, wind velocity and relative humidity are the input for determination of thermal comfort indices during the period from January 2011 to January 2012. The input data have been obtained from the Egyptian Meteorological Agency (EMA).

3. Results and Discussions

3.1. Measured Meteorological Data

3.1.1. The Variation of Air Temperature

Figure 2 illustrates the air dry bulb temperature variation for the three understudy cities; Alexandria, Cairo, and Aswan for thirteen months. The air dry bulb temperature varies very regularly from minimum values during winter season to higher values in summer season. The coldest month during the considered time is January while the hottest month is July at the three different cities. It could be noticed that the monthly mean dry temperature

Figure 1. Map of Egypt shows the three understudy cities.

Table 1. Classifications of the DI values [12].

DI (˚C)	Discomfort conditions
DI < 21	No discomfort
21 ≤ DI < 24	Less than 50% of people feel discomfort
24 ≤ DI < 27	More than 50% of people feel discomfort
27 ≤ DI < 29	Most of people feel discomfort.
29 ≤ DI < 32	Very strong discomfort
DI ≥ 32	Medical emergency

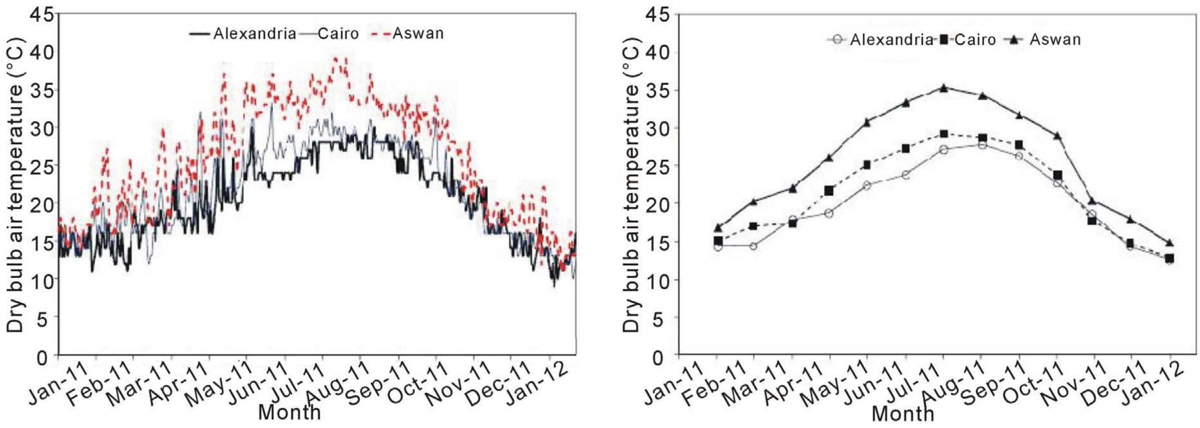
Table 2. RI values for different human feelings [3].

RI values	Discomfort conditions
RI < 60	All people feel quite uncomfortable cooling
60 ≤ RI < 65	50% of people feel partial uncomfortable cooling
65 ≤ RI < 75	All people feel quite comfortable
75 ≤ RI < 80	50% of people feel partial uncomfortable heat
80 ≤ RI < 85	All people feel quite uncomfortable heat
RI ≤ 85	All people feel extreme serious uncomfortable heat

Table 3. RI values for different human feelings [3].

City	Latitude (oN)	Longitude (oE)
Alexandria	31.2000	29.9167
Cairo	30.0566	31.2262
Aswan	24.0667	32.9167

values at Aswan are always greater than Cairo and Alexandria. In addition, the temperature values of Cairo are greater than Alexandria during almost all months. This can be attributed to high concentration of smoke and aerosols at Cairo's atmosphere resulting from more than 2 million moving cars and buses in its streets, in addition to the increase of factories in major industrial areas of Shubra-Elkheima, 6th of October, 10th of Ramadan and other heavy industrial sites. Moreover, the lower temperature values of Alexandria city compared to the other two cities are mainly attributed to the effect of sea breeze phenomena of the Mediterranean Sea. Such phenomena increase the ventilation effectiveness of air pollutants by the incident wind.



(a) (b)

Figure 2. Variation of mean air dry bulb temperature at Alexandria, Cairo and Aswan during the period from January 2011 to January 2012; (a) average daily values and (b) average monthly values.

3.1.2. The Variation of Relative Humidity

Figure 3 illustrates the characteristic features of the variation of relative humidity RH at the three cities during the period Jan 2011-Jan 2012. **Figure 3(a)** is the daily variation of RH, while **Figure 3(b)** represents the monthly value variation. As can be seen from the figure, the RH monthly distribution, a large variation in the relative humidity is illustrated between Alexandria city, which is located along the Mediterranean Sea, and Aswan city which is located at the south of Egypt. The minimum value attained in Aswan was in July (18.16%), while the maximum recorded value in Alexandria was in December (73.55%). The RH monthly distribution is as expected, to be the inverse relationship between relative humidity and air dry bulb temperature (See **Figure 3**). Also, the figure shows that Alexandria has the highest values of RH among the other cities all over the year. This is due to the evaporation processes form the Mediterranean Sea. However, Aswan city has lower value of RH compared with other cities during all over the year due to the high temperature with reduced areas of water surfaces compared to both Cairo and Alexandria cities.

3.1.3. The Variation of Wind Velocity

The mean wind speed trends of the three cities are shown in **Figure 4**. It could be noticed that; the mean wind speed values at Aswan are almost lower than Cairo and Alexandria over the study period, except for winter season months. As can be seen from the figure, the large fluctuations in the measured wind velocity are observed for each city, particularly in Alexandria and Cairo cities.

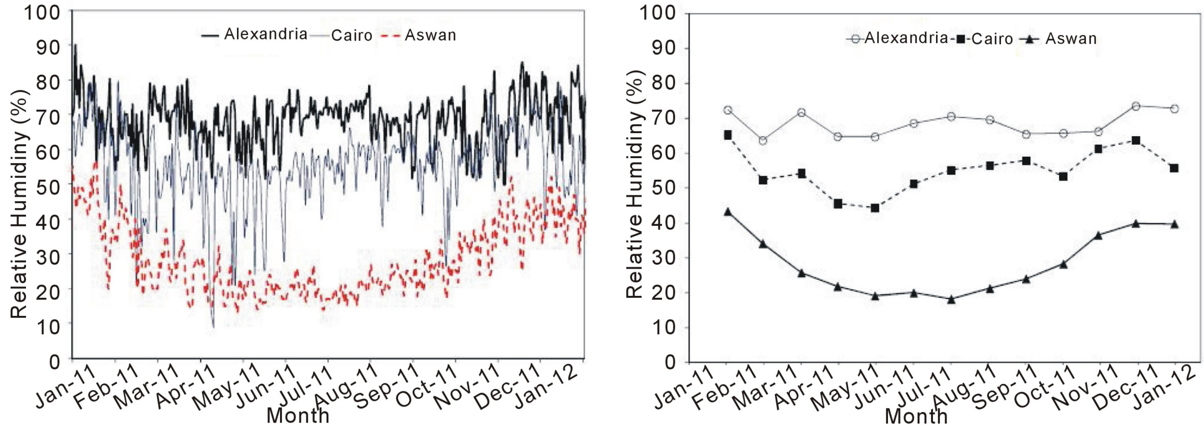
From the data presented in **Figure 4** for Alexandria city, the monthly average wind speed has the lowest value in January (2.80 m/s) and the maximum value in May (5.12 m/s). In Cairo, the monthly average wind speed has the lowest value in January (2.46 m/s) and the maximum value in March (4.97 m/s). The fluctuations in the measured wind speed in Aswan are quite small compared with Alexandria and Cairo. The monthly average wind velocity has the lowest value in January (3.03 m/s) and the maximum value in October (3.81 m/s).

The wind roses of the three cities are shown in **Figure 5**. Clearly, the fluctuations in the incident wind direction over Alexandria city are higher than the other two cities. Comparing the wind direction fluctuations in both Cairo and Aswan cities, Cairo city has more fluctuations during the study period. However, the dominant direction of the prevailing wind in the three cities is the north (N).

3.1.4. Discomfort Index (DI)

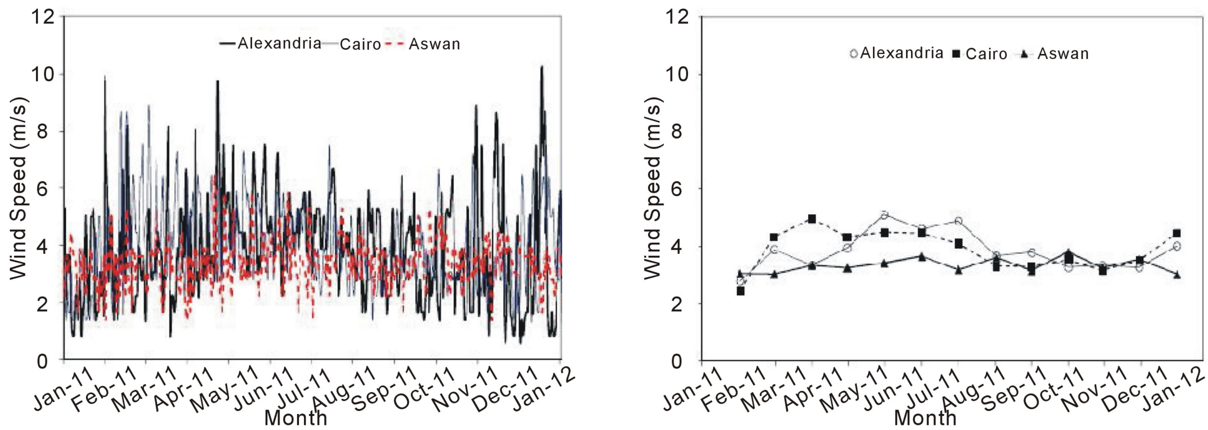
The hourly-average discomfort index values during the study period from January 2011 to January 2012 for the three considered cities are shown in **Figure 6**. In this study, the values of DI are evaluated based on the hourly-average air dry bulb temperature and relative humidity.

From **Figure 6**, it is clear that; the values of DI are fluctuating rapidly over the time. For almost all months of the study period, the lowest values of DI (comfortable weather) are observed for Alexandria city, while the highest values (discomfort weather) are in Aswan city, with Cairo city has in-between of both cities. An impor-



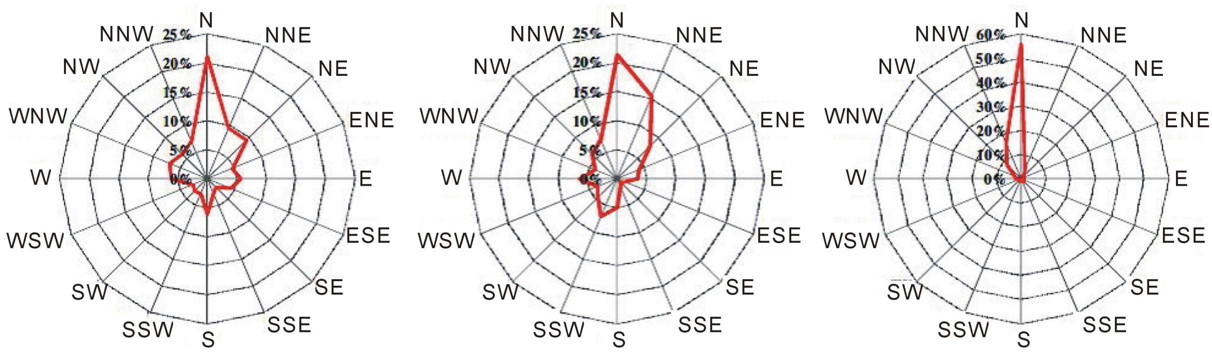
(a) (b)

Figure 3. Variation of relative humidity at Alexandria, Cairo and Aswan cities during the period from January 2011 to January 2012; (a) average daily values and (b) average monthly values.



(a) (b)

Figure 4. Variation wind velocity at Alexandria, Cairo and Aswan cities during the period from January 2011 to January 2012; (a) average daily values and (b) average monthly values.



(a) (b) (c)

Figure 5. Wind roses of the three cities.

tant point to be observed is the presence of a common discomfort period in the three cities from June to September. The trends of DI values of the three cities in such period are outside the comfort range (DI < 21). The peak values of DI for the three cities are found to be around the mid of July, which is the hottest month in Egypt.

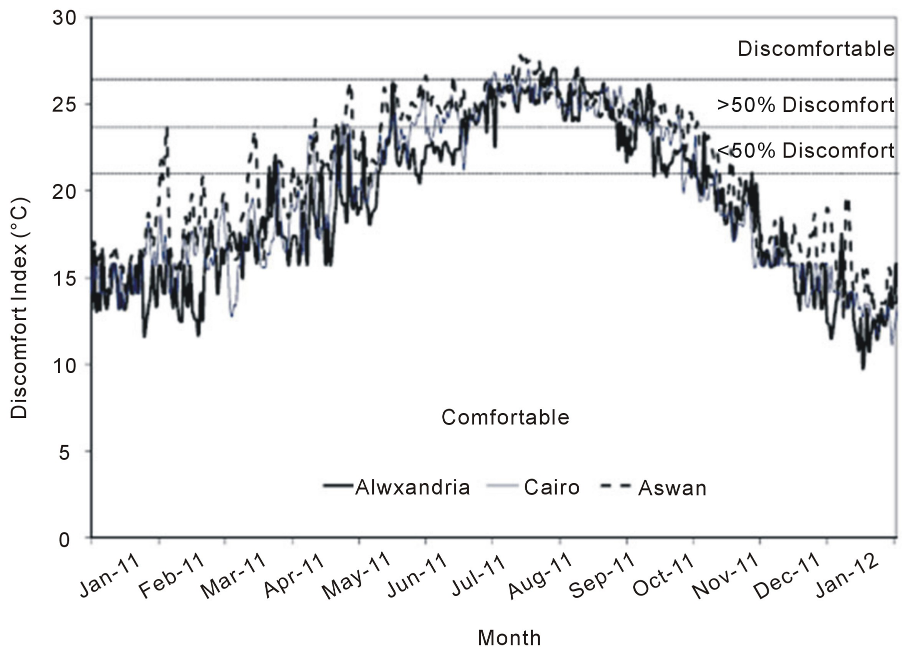


Figure 6. Variation of *DI* for the three cities during the period from Jan. 2011 to Jan. 2012.

In the comfort range, (DI < 21), in which the human in the three cities feel quite comfortable during the period from January to May and from October to next January. Also, it can be noticed the tendency of DI values for Aswan city in the range of the uncomfortable region during the period from January to May.

The number of days for different DI ranges in Alexandria for the study period is presented in **Table 4**. The index values reflect the fact that Alexandria has good climate conditions all over the year. During the study period, the number of comfort weather days (DI < 21) is 259 days, which is more than 65% of the study period. Also, for Alexandria, the first discomfort range (21 ≤ DI < 24) covers the months from March to November with most of such period is found in June month. These values represent about 18 % of the study period. The second discomfort range (24 ≤ DI < 27) covers the range from May to September with most of this period is found during July and August and represents more than 19% of the study period. Concerning the extreme discomfort conditions, it is not found in Alexandria. The discomfort index did not exceed the value of 29 during any of the months of the study period. However, this does not reflect the fact that; extreme climate conditions are not reached in Alexandria city.

The number of days for different comfort categories in Cairo city is presented in **Table 5**. Similar to Alexandria, the DI values reflect good climate conditions during 9 months of the study period. The number of comfort days (DI < 21) is 250 days, which is more than 63% of the study period.

The first discomfort range (21 ≤ DI < 24) covers the months from April to October with most of such period occurs in May and June months and represents 16% of the study period. The second discomfort range (24 ≤ DI < 27) covers the range from May to October with most of such period is found in July and August months. It represents more than 24% of the study period. The extreme discomfort conditions are not found in Cairo city since the DI values did not exceed the value of 29 during any months of the study period.

The number of days for different comfort categories in Aswan city is presented in **Table 6**. The DI values reflect good climate conditions during 8 months of the study period. The number of comfort weather days (DI < 21) is 217 days, which represents more than 54% of the study period.

The discomfort range (21 ≤ DI < 24) covers the months from February to October with most of such period occurs in April and October. This range represents about 17 % of the whole study period. The second discomfort range (24 ≤ DI < 27) covers the months from May to October with most of such period is from July to September. It represents more than 33% of the study period. Similar to Alexandria and Cairo cities, the extreme discomfort conditions are not found in Aswan since the DI noticed that; January 2011 and January 2012 months have the maximum number of quite uncomfortable cooling days (RI < 60) through the study period. This is due

Table 4. Number of different comfort categories in Alexandria from Jan. 2011 to Jan. 2012.

Month	Comfort Ranges					
	DI < 21	21 ≤ DI < 24	21 ≤ DI < 24	27 ≤ DI < 29	27 ≤ DI < 29	DI ≥ 32
Jan. 2011	31	0	0	0	0	0
Feb. 2011	28	0	0	0	0	0
Mar. 2011	29	2	0	0	0	0
Apr. 2011	28	2	0	0	0	0
May 2011	17	13	1	0	0	0
Jun. 2011	3	25	2	0	0	0
Jul. 2011	0	3	28	0	0	0
Aug. 2011	0	0	29	2	0	0
Sept. 2011	1	11	18	0	0	0
Oct. 2011	31	17	0	0	0	0
Nov. 2011	29	1	0	0	0	0
Dec. 2011	31	0	0	0	0	0
Jan. 2012	31	0	0	0	0	0

Table 5. Number of different comfort categories in Cairo from Jan. 2011 to Jan. 2012.

Month	Comfort Ranges					
	DI < 21	21 ≤ DI < 24	21 ≤ DI < 24	27 ≤ DI < 29	27 ≤ DI < 29	DI ≥ 32
Jan. 2011	31	0	0	0	0	0
Feb. 2011	28	0	0	0	0	0
Mar. 2011	31	0	0	0	0	0
Apr. 2011	24	6	0	0	0	0
May 2011	13	16	2	0	0	0
Jun. 2011	0	18	12	0	0	0
Jul. 2011	0	2	28	0	0	0
Aug. 2011	0	0	31	1	0	0
Sept. 2011	0	8	22	0	0	0
Oct. 2011	31	14	1	0	0	0
Nov. 2011	30	0	0	0	0	0
Dec. 2011	31	0	0	0	0	0
Jan. 2012	31	0	0	0	0	0

Table 6. Number of different comfort categories in Aswan from Jan. 2011 to Jan. 2012.

Month	Comfort Ranges					
	DI < 21	21 ≤ DI < 24	21 ≤ DI < 24	27 ≤ DI < 29	27 ≤ DI < 29	DI ≥ 32
Jan. 2011	31	0	0	0	0	0
Feb. 2011	25	3	0	0	0	0
Mar. 2011	26	5	0	0	0	0
Apr. 2011	12	17	1	0	0	0
May 2011	1	16	14	0	0	0
Jun. 2011	0	1	29	0	0	0
Jul. 2011	0	1	23	7	0	0
Aug. 2011	0	0	29	2	0	0
Sept. 2011	0	5	25	0	0	0
Oct. 2011	31	19	10	0	0	0
Nov. 2011	29	1	0	0	0	0
Dec. 2011	31	0	0	0	0	0
Jan. 2012	31	0	0	0	0	0

to the northerly cold air invades Egypt during the January month, in addition to the drop of air dry bulb temperatures due to the night sky radiant cooling during the long night hours in the course of diurnal variation. April and May months have minimum number of quite uncomfortable cooling days (2 days) and (5 days) respectively. On the other hand, during the study period, Alexandria city has quite comfortable weather ($65 \leq RI < 75$) in most months of the year with days number differs from month to another as can be seen in **Table 7**. It is noticed that the months of July, September and October are the most thermal comfortable months for the Alexandria city. These three months have 87 days of quite comfortable. It is also found that, all total number of hot discomfort

Table 7. Number of different comfort categories in Alexandria from Jan. 2011 to Jan. 2012.

Month	Robaa Comfort Ranges					
	RI < 60	60 ≤ RI < 65	65 ≤ RI < 75	75 ≤ RI < 80	80 ≤ RI < 85	RI ≤ 85
Jan. 2011	24	7	0	0	0	0
Feb. 2011	23	4	1	0	0	0
Mar. 2011	7	18	6	0	0	0
Apr. 2011	5	19	6	0	0	0
May 2011	2	15	13	1	0	0
Jun. 2011	0	4	26	0	0	0
Jul. 2011	0	0	31	0	0	0
Aug. 2011	0	0	26	5	0	0
Sept. 2011	0	0	28	2	0	0
Oct. 2011	0	3	28	0	0	0
Nov. 2011	6	15	9	0	0	0
Dec. 2011	23	8	0	0	0	0
Jan. 2012	29	2	0	0	0	0

days for 50% of people (75 ≤ RI < 80) in Alexandria city during the study period is 8 days. Furthermore, the discomfort index did not exceed 80 during the study period.

3.2. Robaa Index (RI)

The hourly average Robaa Index (RI) values for the three cities under investigation during the period from January 2011 to January 2012 are shown in **Figure 7**. The numbers of days for different comfort categories in Alexandria, Cairo and Aswan cities respectively, during the period from January 2011 to January 2012 are shown in **Table 7** through Table 9. As can be seen from **Table 7**, Alexandria city has quite human thermal uncomfortable cold weather (RI < 60) during eight months, from January to May and from November to January. It is also and May months have minimum number of quite uncomfortable cooling days (2 days) and (5 days) respectively. On the other hand, during the study period, Alexandria city has quite comfortable weather (65 ≤ RI < 75) in most months of the year with days number differs from month to another as can be seen in **Table 7**. It is noticed that the months of July, September and October are the most thermal comfortable months for the Alexandria city. These three months have 87 days of quite comfortable. It is also found that, all total number of hot discomfort days for 50% of people (75 ≤ RI < 80) in Alexandria city during the study period is 8 days. Furthermore, the discomfort index did not exceed 80 during the study period.

The results of RI categories estimated in Cairo city are presented in **Table 8**. It is found that Cairo city has quite uncomfortable cooling, (RI < 60), during six months of the study period. It is noticed that, January 2012 month has maximum number of quite uncomfortable cooling days (31 days), while November month have minimum number of quite uncomfortable cooling days (3 days). On the other hand, during both study periods, Cairo city has quite comfortable (65 ≤ RI < 75), in most months of the year with days number differs from month to another (See **Table 5**). It is noticed that the months of May, June, September and October are the most comfortable months for Cairo city. These months have 89 days of quite comfortable. It is also found that, all total number of partial uncomfortable heat (75 ≤ RI < 80) days for the study period is 72 days. In addition, discomfort index exceeded the value of 80 just for 3 days during the months of June and October. Fortunately, the discomfort index did not exceed the value of 85 during any month of the study periods at Cairo city.

The results of RI categories estimated in Aswan city is presented in **Table 9**. It is found that; Aswan city has quite uncomfortable cooling (RI < 60) during only three cold months (December, January 2011 and January 2012) during the study period. It is also noticed that, as occurred at Alexandria and Cairo cities, January 2012 month has maximum number of quite uncomfortable cooling days (16 days), while December month have minimum number of quite uncomfortable cooling days (3 days). On the other hand, during the study period, Aswan city has quite comfortable (65 ≤ RI < 75) in most months of the year with days number differs from month to another. It is also found that, all total number of partial uncomfortable heat (75 ≤ RI < 80) days for the study period is 51 days. In addition, discomfort index exceeded 80 during 8 months of the study period. There are 136 days of hot (80 ≤ RI < 85) and extreme hot uncomfortable (RI ≥ 85) for all people of Aswan city (103 and 33 days for hot and extreme serious hot uncomfortable respectively) occurred during the study period (*i.e.*, more than 4.5 months of continuous hot and extreme hot discomfort started by March and ended by October).

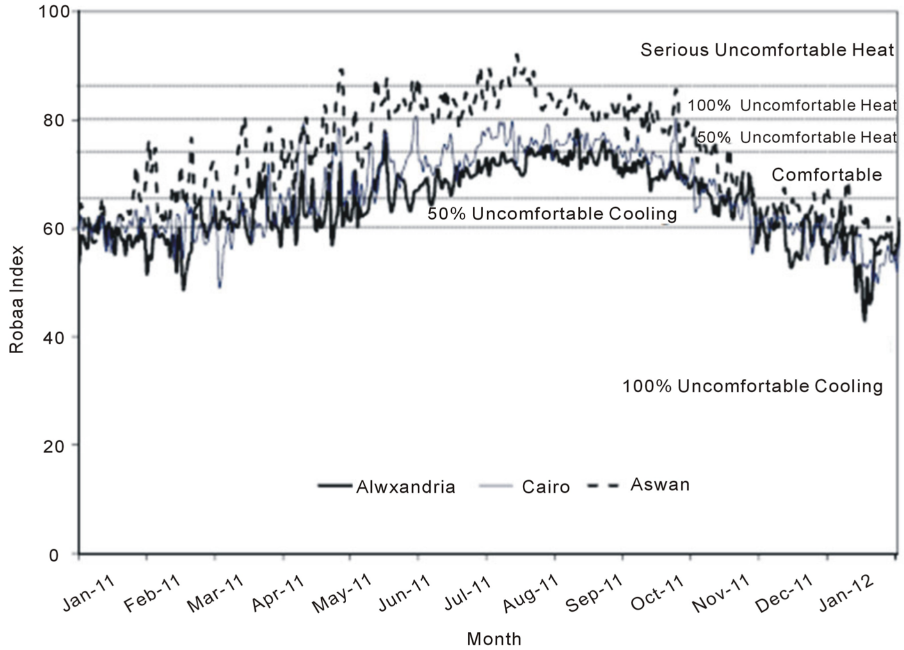


Figure 7. Hourly variation of RI for the three cities during the period from Jan. 2011 to Jan. 2012.

Table 8. Number of different comfort categories in Cairo from Jan. 2011 to Jan. 2012.

Month	Robaa Comfort Ranges					
	RI < 60	60 ≤ RI < 65	65 ≤ RI < 75	75 ≤ RI < 80	80 ≤ RI < 85	RI ≤ 85
Jan. 2011	13	18	0	0	0	0
Feb. 2011	12	16	0	0	0	0
Mar. 2011	14	15	2	0	0	0
Apr. 2011	0	15	12	3	0	0
May 2011	0	4	21	6	0	0
Jun. 2011	0	0	24	4	2	0
Jul. 2011	0	0	11	20	0	0
Aug. 2011	0	0	5	26	0	0
Sept. 2011	0	0	19	11	0	0
Oct. 2011	0	3	25	2	1	0
Nov. 2011	3	21	6	0	0	0
Dec. 2011	21	10	0	0	0	0
Jan. 2012	31	0	0	0	0	0

3.3. Comparison between DI and RI

In order to evaluate the applicability of both DI and RI in assessing the human thermal comfort in outdoor environment, comparison between their values during the study period is carried out. The comfortable feeling condition using RI is satisfied when $65 \leq RI < 75$, while the same feeling using *DI* is satisfied when $DI < 21$. Accordingly, **Table 10** presents the number of days in the three cities for comfort weather condition, as estimated by the two indices.

Clearly seen from the table, the percentage of comfort days in the three cities estimated by DI is more than that estimated by RI. For the case of Alexandria city, the percentage of comfort days estimated by DI is 65% of the study period, while the percentage of comfort days determined by RI is 44%. These values show that the; in Alexandria, (Comfort days)$_{\mathbf{DI}}$ = 1.5 (Comfort days)$_{\mathbf{RI}}$. While in Cairo and Aswan cities, the similar ratio is 2.0 and 2.2 respectively.

From **Table 10**, it is clear that the evaluation results of both indices are adverse. The comfort days evaluated by DI are uncomfortable by RI. This difference can be attributed to the deal of each index with the meteorological parameters.

Table 9. Number of different comfort categories in Aswan from Jan. 2011 to Jan. 2012.

Month	Robaa Comfort Ranges					
	RI < 60	60 ≤ RI < 65	65 ≤ RI < 75	75 ≤ RI < 80	80 ≤ RI < 85	RI ≤ 85
Jan. 2011	6	20	5	0	0	0
Feb. 2011	0	12	14	2	0	0
Mar. 2011	0	6	21	3	1	0
Apr. 2011	0	0	17	10	3	0
May 2011	0	0	7	8	11	5
Jun. 2011	0	0	0	3	23	4
Jul. 2011	0	0	0	0	14	17
Aug. 2011	0	0	0	0	25	6
Sept. 2011	0	0	0	7	23	0
Oct. 2011	0	0	10	17	3	1
Nov. 2011	0	13	16	1	0	0
Dec. 2011	3	20	8	0	0	0
Jan. 2012	16	14	1	0	0	0

Table 10. Number of comfort days in the three cities during the study period estimated by the two indices.

Month	Number of comfort weather days					
	Alexandria		Cairo		Aswan	
	DI (DI < 21)	RI (65 ≤ RI < 75)	DI (DI < 21)	RI (65 ≤ RI < 75)	DI (DI < 21)	RI (65 ≤ RI < 75)
Jan. 2011	31	0	31	0	31	5
Feb. 2011	28	1	28	0	25	14
Mar. 2011	29	6	31	2	26	21
Apr. 2011	28	6	24	12	12	17
May 2011	17	13	13	21	1	7
Jun. 2011	3	26	0	24	0	0
Jul. 2011	0	31	0	11	0	0
Aug. 2011	0	26	0	5	0	0
Sept. 2011	1	28	0	19	0	0
Oct. 2011	31	28	31	25	31	10
Nov. 2011	29	9	30	6	29	06
Dec. 2011	31	0	31	0	31	8
Jan. 2012	31	0	31	0	31	1
Total	259	174	250	125	217	99
Percent	65.4%	43.9%	63.1%	31.5%	54.7%	25.0%

According to Equation (1), the discomfort index (DI) does not include the effect of wind speed in human thermal comfort assessment. This appears clearly in the large number of comfort days, which neglect the days of gust speed that, if considered, affects the comfort feeling, which in turn, decreases the number of comfort days. On the other hand, the estimated comfort days by RI appear to be more practical than those estimated by DI. This is due to the fact that; Robaa index is accounting for the combined effects of the three weather elements (as illustrated by Equation (2)); air dry bulb temperature, relative humidity and wind speed; when assessing thermal human comfort.

4. Conclusions

The present study investigated the climate variations in Egypt through the estimation of two thermal comfort indices; the Discomfort index (DI), and the Robaa index (RI). In order to investigate the spatial variations of these indices over Egypt, three cities of different climates are considered; Alexandria city which is located in the extreme north of Egypt, Cairo city which is located in the middle and Aswan city which is located in the extreme south of Egypt. The study results showed that:

1) The thermal comfort indices values can be employed to evaluate climate differences in urban areas.

2) Although extreme climate conditions are not reached in Egypt in general, the climate in the north is milder than in the south.

3) The RI is more practical than DI in assessing the human thermal comfort in outdoor environment. This due

to that, RI accounts for the combined effects of dry air temperature, humidity and wind speed, while DI does not include the effect of wind speed in human thermal comfort assessment.

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