International Journal of Advanced Engineering Research and Science (IJAERS) [Vol-3, Issue-11, Nov- 2016]
https://dx.doi.org/10.22161/ijaers/3.11.38 *ISSN: 2349-6495(P) | 2456-1908(O)*

An Estimation of Discomfort Indices in Qena City, Upper Egypt

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Abstract*—Wind chill index WCI and temperature humidity index THI, are calculated in Qena during the period 2001-2014 using hourly data of temperature, relative humidity and wind speed collected in weather research station located in south valley university at Qena. Results of WCI indicate that the winter months are cool, while, summer months are hot. The middle of spring and autumn is pleasant. Results of THI indicate that Winter, spring and autumn months are comfortable or partially comfortable or quite comfortable. While, summer months are not comfortable due to hot and humid weather. Annual mean values of WCI indicate that Qena weather was pleasant during the period from 2001 to 2014, except the two years 2003 and 2012 was worm. The mean value of the total period indicates that the atmosphere of Qena is pleasant. the THI mean value of the study period as well as the average yearly values are located in the category 100%are quite comfortable.*

***Keywords*— Discomfort index, Wind chill index, Hathor, Dendara, Qena.**

I. INTRODUCTION

Heat stress is becoming increasingly appreciated because of its influence on living matter . Heat stress is caused by a combination of environmental factors (temperature, relative humidity, solar radiation, air movement, and precipitation). Many indices combining different environmental factors to represent the level of heat stress. These indices have been proposed by several studies [1, 2, 3 and 4]. However, their use is limited by poor availability of data.

A temperature humidity index (THI) is a single value representing the combined effects of air temperature and humidity associated with the level of thermal stress . it was originally called the discomfort index. [5]. This index was empirically obtained by experimentally subjecting a sample of people to varying temperature and humidity and polling them as to the discomfort they felt. The results were tabulated as numbers a legend indicating the degree of discomfort that a majority of people would feel in various ranges of values [6]

THI has been developed as a weather safety index to monitor and reduce heat stress related losses. Different animal species and human have different sensitivities to ambient temperature and the amount of moisture in the air. The main factor in human discomfort is the thermal component of environmental conditions and was calculated by many indices taking into consideration air temperature, relative humidity and wind speed [7,8, 9, 10, and 11].

The values of the discomfort index DI have been recorded in the past through limited studies. In Thessaloniki, Greece, [12] found that most people uncomfortable when DI was greater than 24. In Mexico, United States, [13] found that most people experienced the sense of discomfort when DI reached 24.

Qena city (26^{o} $16^{\backslash}$ N, 32^{o} $75^{\backslash}$ E) is the capital of the province (population - 2,000,000) located about 60 km north of Luxor. It is most famous for its proximity to the archeological site of Dendera. Dendera is few kilometers to the west of Qena city. The main attraction of Dendera is the temple dedicated to Hathor goddess of love, music and dancing. Visitors to Luxor may visit the famous Temple of Hathor at Dendera. In a taxi, the trip takes about 1 hour from Luxor. In addition, Qena city owes its modern prosperity to the opening of the Wadi Qena towards the Red Sea, which is a major traffic route between Upper Egypt and the Red Sea, will assuredly pass through this city. Climate of Qena is very hot, dry in summer and cold in winter [14], [15] , [16]. It rarely rains. Also it receives a large quantity of solar radiation especially in summer. Hopefully we could quantify discomfort indices, where no studies have been conducted before to estimate these indices in Qena city. This study is an attempt to start bridging this gap in Qena, it is very important and benefit study for inhabitants and tourists as well.

Aim of the present work is to quantify Wind Chill Index WCI and Temperature Humidity Index THI in Qena over the period (2001 – 2014).

II. MATERIALS AND METHODOLOGY

The hourly data of temperature, relative humidity and wind speed for fourteen years used in this investigation were procured from Qena Meteorological Agency station.

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Wind Chill Index, (WCI), the cooling sensation caused by the combined effect of temperature and wind, was computed using the chill index of Sipple and Passel (1945) [17] given by,

$$WCI = \left(10\sqrt{V} + 10.45 - V\right)\left(33 - T_a\right) \quad (1)$$

Where V is the wind speed in meters per second and T_a is the atmospheric temperature in C^0

The Temperature-Humidity Index (THI_1) was calculated for each hour using the formula developed by Kibler (1964) [18],

$$THI_1 = 1.8 \times T_a - \left(1 - RH\right)\left(T_a - 14.3\right) + 32 \quad (2)$$

Where Ta = average ambient temperature in C^0
RH = average relative humidity as a fraction of the unit.

The Temperature-Humidity Index (THI_2) was also calculated for each hour using formula developed by NOAA (1979) [19] as follows,

$$THI_2 = (1.8 \times Ta + 32) - (0.55 - 0.55 \times RH) \times [(1.8 \times Ta + 32) - 58] \quad (3)$$

Where Ta = average ambient temperature in C^0.
RH = average relative humidity.

Significance of both of Wind-Chill Index (WCI) and temperature humidity index THI are shown in Table (1) and Table (2) [5, 20]

Table.1: Significance of Wind –Chill index WCI

WCI value	Human/animal and plant feeling
< 50	hot
50 – 100	worm
101 – 200	pleasant
201 – 400	cool
401 – 600	very cool
601 – 800	cold
801-1000	very cold
> 1000	bitter cold

Table .2: Significance of temperature humidity index THI

THI value	Human/animal and plant feeling
> 80	100% are not comfortable.
75 – 80	50% are not comfortable due to hot and humid weather.
65 – 75	100%are quite comfortable.
60 – 65	50% are partially comfortable.
< 60	Almost 100% are comfortable due to cold and dry weather.

III. RESULTS AND DISCUSSION

3.1 Monthly variation of wind chill index WCI

During all the same months of the study period, the WCI is computed using equation (1). The number of days and its percentage for each Human/animal and plant feeling category of WCI are considered and is shown in Table (3). From this Table, it is obvious that: almost all summer season (June, July and August) is characterized by hot days with day's percentage ranges from 95% to 99%, while, 73% - 85% of winter (Dec., Jan., and Feb.) days are cool. Spring season is characterized by, 50% cool in March, 40% pleasant in April and 64% hot in May. In Autumn season, 68% of September days are hot, 46% of October days are pleasant, and 52% of Nov. are cool. Very cold and bitter cold categories are not recorded in Qena city. Cold days are ranged from 2% to 4% during winter season.

Fig. (1) and Table (4) represent monthly variation of average, maximum and minimum of WCI in Qena during the period 2001-2014. We can notice that the categories cold, very cold and bitter cold are not recorded during all the period of study. The cool category is recorded during all winter months as well as two months, March and Nov. Pleasant category is recorded during two months, April and October. These two months represent mid spring and mid autumn, respectively. Warm category is not recorded, while the hot category is recorded during five months including summer months, (Jun., Jul., and August) and other two months (May and Sept). May represents the end of spring and Sept. represents the beginning of autumn.

https://dx.doi.org/10.22161/ijaers/3.11.38 *ISSN: 2349-6495(P) | 2456-1908(O)*

Table .3: Monthly variation of wind chill index WCI for different human/animal and plant feeling categories in Qena during the period 2001-2014.

Categories	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct.	Nov.	Dec.	Feeling
<50	0	0	12	83	277	369	431	428	287	76	2	0	hot
	0%	0%	3%	20%	64%	95%	99%	99%	68%	18%	0%	0%	
50-100	1	4	21	88	84	20	2	5	94	141	11	2	Warm
	0%	1%	5%	21%	19%	5%	0%	1%	22%	32%	3%	0%	
101-200	13	52	161	166	70	1	1	1	31	198	185	33	Pleasant
	3%	13%	37%	40%	16%	0%	0%	0%	7%	46%	44%	8%	
201-400	362	287	219	83	3	0	0	0	8	18	219	370	Cool
	83%	73%	50%	20%	1%	0%	0%	0%	2%	4%	52%	85%	
401-600	54	47	20	0	0	0	0	0	0	1	3	27	very cool
	12%	12%	5%	0%	0%	0%	0%	0%	0%	0%	1%	6%	
601-800	3	4	0	0	0	0	0	0	0	0	0	2	Cold
	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
801-1000	1	1	1	0	0	0	0	0	0	0	0	0	very cold
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
>1000	0	0	0	0	0	0	0	0	0	0	0	0	bitter cold
	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
Total No	434	395	434	420	434	420	434	434	420	434	420	434	

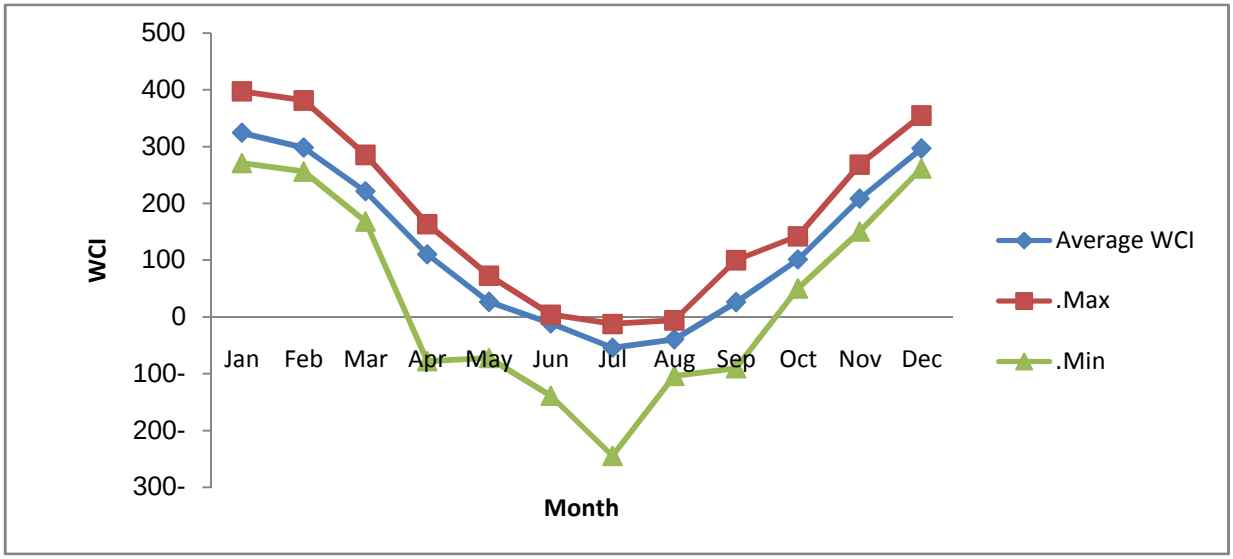

Fig.1: Monthly average, maximum and minimum of WCI in Qena during the period 2001-2014.

3.2 Monthly variation of temperature humidity index THI

The calculations of the Temperature-Humidity Index THI_1 by Kibler method (eq. 2) are considered. The results are tabulated by different THI_1 categories according to Table (2) to represent the THI_1 monthly variations. The corresponding numbers of days and its percentages for each category of THI_1 are shown in Table (5). It is obvious that:

- Summer days for all months are found almost in the category: (*50% are not comfortable due to hot and humid weather)* with percentage ranges from 81% - 88%.
- The days of winter months are mainly located in two categories: (*Almost 100% are comfortable due to cold and dry weather*) and (*50% are partially comfortable*).
- In spring season, the category (*100% are quite comfortable*) is recorded where its percentages is 57% in March, 90% in April and 62% in May.
- Autumn season days are almost found in two categories: (*50% are not comfortable due to hot and humid weather*) and (*100% are quite comfortable*). 73% of total days of Sept is found in the category

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(*50% are not comfortable due to hot and humid weather*) while, 85% and 58% of total days in Oct. and Nov. are in the category (*100% are quite comfortable*). It is noticed that, as stated before, Sept. weather is partially similar to summer weather, while, Nov. weather is similar to that of winter months. weather is partially similar to summer weather, while, Nov. weather is similar to that of winter months.

Table (6) shows THI_2 calculation by the formula by NOOA (1979). It could be seen that the days percentages for the different THI_2 categories are almost the same as found by THI_1 calculated by Kibler's formula, where, it differs only by 1-2% in some months. So, one could conveniently represent the other. This result is found also in Nigeria (16)..

Fig. (2) and Table (7) represent the monthly variations of average, maximum and minimum of $THI_{1,2}$ in Qena during the period 2001-2014. It is clear that the figure is reciprocal form of the Fig. (1) and that the feeling conditions during different months in Table (6) confirms that in Table (4). Where, winter , spring and autumn months are comfortable or partially comfortable or quite comfortable. While, summer months are not comfortable due to hot and humid weather.

Table.4: Monthly average, maximum and minimum of WCI in Qena during the period 2001-2014.

Month	Average WCI	Max.	Min.	Feeling
Jan	**324**	**397**	**271**	**cool**
Feb	**298**	**381**	**256**	**cool**
Mar	**221**	**285**	**168**	**cool**
Apr	**110**	**164**	**-78**	**pleasant**
May	**26**	**73**	**-72**	**hot**
Jun	**-12**	**4**	**-139**	**hot**
Jul	**-54**	**-12**	**-245**	**hot**
Aug	**-39**	**-6**	**-104**	**hot**
Sep	**26**	**100**	**-90**	**hot**
Oct	**101**	**142**	**50**	**pleasant**
Nov	**208**	**268**	**150**	**cool**
Dec	**297**	**355**	**261**	**cool**

Table.5: Monthly variation of temperature-humidity index (Kibler) different categories in Qena during the period 2001-2014

Categories	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Seb.	Oct.	Nov.	Dec.	Feeling
>80	**0**	**0**	**0**	**3**	**6**	**14**	**63**	**49**	**4**	**4**	**0**	**0**	**100% are not comfortable**
	0%	**0%**	**0%**	**1%**	**1%**	**4%**	**15%**	**11%**	**1%**	**1%**	**0%**	**0%**	
75-80	**0**	**1**	**5**	**31**	**158**	**339**	**371**	**384**	**305**	**59**	**4**	**1**	**50% are not comfortable**
	0%	**0%**	**1%**	**7%**	**36%**	**81%**	**85%**	**88%**	**73%**	**14%**	**1%**	**0%**	
65-75	**10**	**70**	**249**	**377**	**270**	**37**	**0**	**1**	**103**	**371**	**242**	**41**	**100%are quite comfortable**
	2%	**18%**	**57%**	**90%**	**62%**	**9%**	**0%**	**0%**	**25%**	**85%**	**58%**	**9%**	
60-65	**71**	**20**	**168**	**9**	**0**	**0**	**0**	**0**	**1**	**0**	**165**	**177**	**50% are partially comfortable.**
	16%	**52%4**	**39%**	**2%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**39%**	**41%**	
<60	**353**	**120**	**12**	**0**	**0**	**0**	**0**	**0**	**7**	**0**	**9**	**215**	**Almost 100% are comfortable**
	81%	**30%**	**3%**	**0%**	**0%**	**0%**	**0%**	**0%**	**2%**	**0%**	**2%**	**50%**	
Total No	**434**	**395**	**434**	**420**	**434**	**390**	**434**	**434**	**420**	**434**	**420**	**434**	

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Table.6: Monthly variation of temperature-humidity index (NOOA) for different categories in Qena during the period 2001-2014

Categories	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept.	Oct.	Nov.	Dec.	Feeling
>80	0 0%	00 %	0 0%	3 1%	8 2%	21 5%	74 17%	58 13%	6 1%	4 1%	0 0%	0 0%	100% are not comfortable
75-80	0 0%	1 0%	6 0%	35 8%	171 39%	338 87%	360 83%	375 86%	316 75%	69 16%	4 1%	1 0%	50% are not comfortable
65-75	11 3%	71 18%	255 59%	374 89%	255 59%	31 8%	0 0%	1 0%	90 21%	361 83%	245 58%	42 10%	100% are quite comfortable
60-65	74 17%	211 53%	161 37%	8 2%	0 0%	0 0%	0 0%	0 0%	1 0%	0 0%	162 39%	182 42%	50% are partially comfortable.
<60	349 80%	112 28%	12 3%	0 0%	0 0%	0 0%	0 0%	0 0%	7 2%	0 0%	9 2%	209 48%	Almost 100% are comfortable
Total No.	434	395	434	420	434	390	434	434	420	434	420	434	

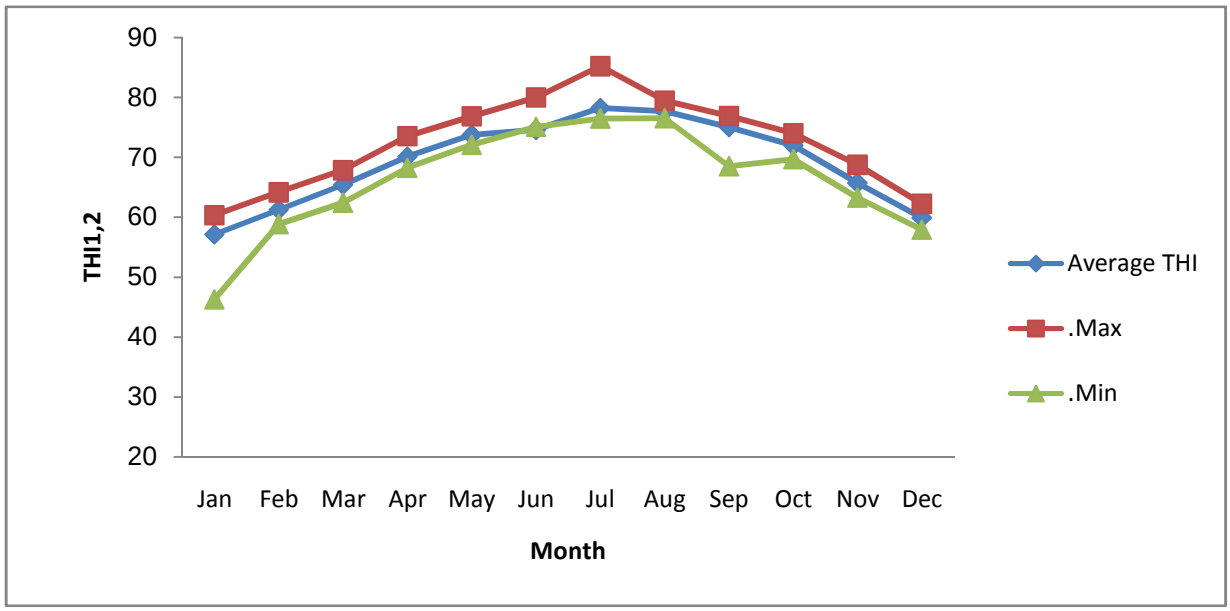

Fig.2: monthly average, maximum and minimum of $THI_{1,2}$ in Qena during the period 2001-2014.

Table.7: Monthly average, maximum and minimum of $THI_{1,2}$ in Qena during the period 2001-2014.

Month	Average THI	Max.	Min.	Feeling
Jan	57	60	46	Almost 100% are comfortable
Feb	61	64	59	50% are partially comfortable.
Mar	65	68	62	50% are partially comfortable.
Apr	70	74	68	100% are quite comfortable
May	74	77	72	100% are quite comfortable
Jun	75	80	75	50% are not comfortable due to hot and humid weather.

https://dx.doi.org/10.22161/ijaers/3.11.38 *ISSN: 2349-6495(P) | 2456-1908(O)*

Jul	**78**	**85**	**76**	**50% are not comfortable due to hot and humid weather.**
Aug	**78**	**79**	**77**	**50% are not comfortable due to hot and humid weather.**
Sep	**75**	**77**	**69**	**50% are not comfortable due to hot and humid weather.**
Oct	**72**	**74**	**70**	**100% are quite comfortable**
Nov	**66**	**69**	**63**	**100% are quite comfortable**
Dec	**60**	**62**	**58**	**50% are partially comfortable.**

3.3 Annual variations of $THI_{1,2}$ and WCI

Fig. (3) shows annual variation sof THI1,2 and WCI during the period of study. It could be seen that there is no remarkable variation in the annual values of THI1,2 . The mean value of THI1,2 ,during the study period, is 69 with standard deviation of 0.61. These value is located in the range of (65 – 75) which indicates that (100% are quite comfortable).

In the same time, obvious fluctuation is found in WCI with mean value of 123 and standard deviation 20. This value is in the category Pleasant. It is found that, during the fourteen years, from 2001 to 2014, there are seven years have mean values less than the total mean, these years are 2001, 2002, 2003, 2010, 2012, 2013 and 2014. While the rest seven years have mean values more than the total mean value.

Annual mean values of WCI, during the fourteen years from 2001 to 2014, indicate that Qena weather was pleasant except the two years 2003 and 2012 were worm. The mean value of the total period,123, indicates that the atmosphere of Qena is pleasant. This result is confirmed by THI1,2 annual mean values. Where, the THI1,2 mean value of the study period as well as the average yearly values are located in the category 100% are quite comfortable.

IV. CONCLUSION

In this study, both Temperature - Humidity Index THI and Wind Chill Index WCI are calculated in Qena during the period 2001-2014. Monthly and annual variations have been discussed. Results of WCI indicate that winter months are cool, while, summer months are hot. The middle of spring and autumn is pleasant. THI is calculated by Kibler formula and NOOA formula, The two methods lead to the same results. Results of monthly average variation of THI indicate that winter , spring and autumn months are comfortable or partially comfortable or quite comfortable. While, summer months are not comfortable due to hot and humid weather. Annual mean values of WCI indicate that Qena weather during the period of study was pleasant except the two years 2003 and 2012 was worm. The mean value of the total period indicates that the atmosphere of Qena is pleasant. the THI mean value of the study period as well as the average yearly values are located in the category 100%are quite comfortable. The monthly variation of WCI is a mirror image of that of THI. This study encourages tourists to visit the temple of Hathor at Dendara, specially during winter , spring and autumn seasons.

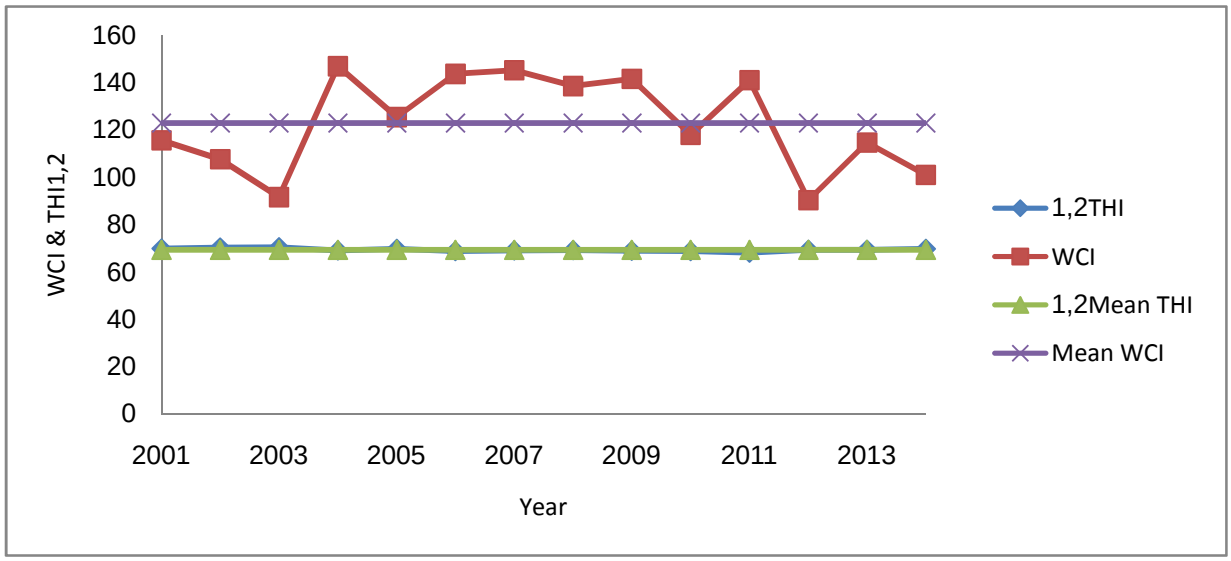

Fig.3: Annual variation of $THI_{1,2}$ and WCI in Qena during the period 2001-2014.

https://dx.doi.org/10.22161/ijaers/3.11.38 *ISSN: 2349-6495(P) | 2456-1908(O)*

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