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Assessment and Analysis of Thermal Comfort Based on Bioclimatic Indexes Case Study: Port of Anzal-Iran

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ABSTRACT

Natural environmental is regulated according to the climatic conditions. Human communities are forced to adjust themselves to these conditions. One of the important issues of humanity is environmental comfort in this century. Thermal comfort different climatic zones can be identified in the housing plan, model, architecture, programming in order to take advantage of natural attractions (ecotourism and geotourism) can help. To determine the utility of human thermal comfort based on temperature and humidity bioclimatic indexes (Humidex) and weather severity conditions (WSI) and Mann-Kendall method had used the daily data of 10 years (1996-2005) in port of Anzali. The results showed that the unthermal comfort conditions in late spring and in the middle of summer reached their maximum. But the desirability of comfort human activities began in the late of fall and early of winter ends. Process of winter and spring is increasing based on Mann-Kendall method and autumn and summer is decreasing. According to weather severity conditions, the most suitable comfort conditions are observed at the end of March 2004 and 2005.

KEYWORDS: Thermal comfort, Bioclimatic, Port of Anzali, Humidex, WSI, Mann-kendall.

INTRODUCTION

The science study of air influence on beings is called bio-Meteorology and bio-Climatology. Therefore, weather and climate based on their influences on plant, animal and human, become the background of creating independent sciences that are called agricultural bio- climatology, animal bio-climatology and finally humanity bio-climatology (Kaviyani, 1993).

One of the most important humanity problems is conditional comfort that have created more human societies in more suitable conditions (Mohammadi, 2007). Human thermal comfort is a condition of its perception that people are satisfy in this condition in view of thermal (Ghiyabklou, 2001). In other words, meaning of human comfort condition is a set of conditions that are suitable for at least 80% of people in view of thermal (Ghobadian and Feyz Mahdavi, 1997).

I n forming human comfort condition, in view of climatology 4 elements temperature, humidity, wind and radiation play the role. Among these elements temperature and humidity have more influence on health and comfort of human and because of this more models of evaluating human comfort are placed on these two elements (Alijani, 1993). In addition of conditional factors (weather temperature, speed of wind, humidity and radiation) individual factors like type of action and thermal resistance of clothes are effective (Masaee and et al., 2004). Because people have similar feeling of thermal comfort in same ecological condition, it is necessary that for each ecological condition, area of thermal comfort recognized preciously (Fishman and Pimbert, 1979).

According to high influence of ecology on human comfort, all the time human are seeking a optimize usage of their region climate and so many thinkers pay a lot of attention to it from the past to present. Researchers like Giyoni (1989), Thompson and Perry (1997), Fanker (1972), VDA (1998), Driscol (1992), Landsberg (1970), Parsons (2003) tried to analyze thermal comfort. In Iran, in recent years many studies have done about thermal comfort. Ghanbari (2010) evaluated the human comfort and discomfort in Lar city by Baker and Terjung and Wind chill and nerve pressure and thermo hygrometric. Ebrahimi and Ramezani (2009) had extracted bio-ecological comfort in Anzali pool by baker method. Nazem Al-Saddat (2008) had studied the amount of human health in Bandar-Abbas, Shiraz, Birjand and Ardebil by apparent temperature, daily and monthly. Ramezani (2006 & 2005) has studied and analyzed bio-ecological indexes by ecological data and ecological models of effective temperature and Baker and Evans in synoptic station of Babolsar and Guilan. Roshan and et al. (2008) studied the ecological comfort factors in Yazd by using of Giyoni model and process effect of changing ecology on it. Ali Akbar Shamsipour and et al. (2012) studied ecological conditions in Port Anzali in view of tourism based on tourism-ecology index CIT. Hosseini (2012)

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studied the time evaluating of comfort ecology by same physiology temperature in Anzali port. Also, researchers like Khalili (1999), Kasmaee (1999) and kaviyani (2001) had done researches in this issue. The object of this research is analyzing of thermal comfort based on bio-ecological profiles to determine desirability time of human comfort for Anzali port.

Data and Method of study

Anzali is placed between 49˚and 12 min to 49˚ and 37 min eastern length and 37˚ and 25 min to 37˚ and 34 min northern length in Guilan province. This city is in attraction of tourisms because of being near to port, natural and unique attractions like Anzali Poll and cultural-historical attractions (Figure 1). To evaluate and analyze of thermal comfort, Anzali station used climatology data of daily temperature, pressure of steam and wind speed during the statistical period 1995-2007. Results extracted base on profile formula of heat, humidity and weather severity by Excel software and time series graphs sketched.

Non-parametric Mann-Kendall test had used that presented by Mann, 1945 and Kendall, 1975 to study the existence of process with significant level 0.05 %. In other words, if P < 0.05 it is significant, otherwise it is not significant. In this test zero hypothesis (H_0) and opposite hypothesis (H_1) are the series data without process and with process, respectively. Related relationships are as follow to determine the value of Mann-Kendall statists:

1:
$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k),$$

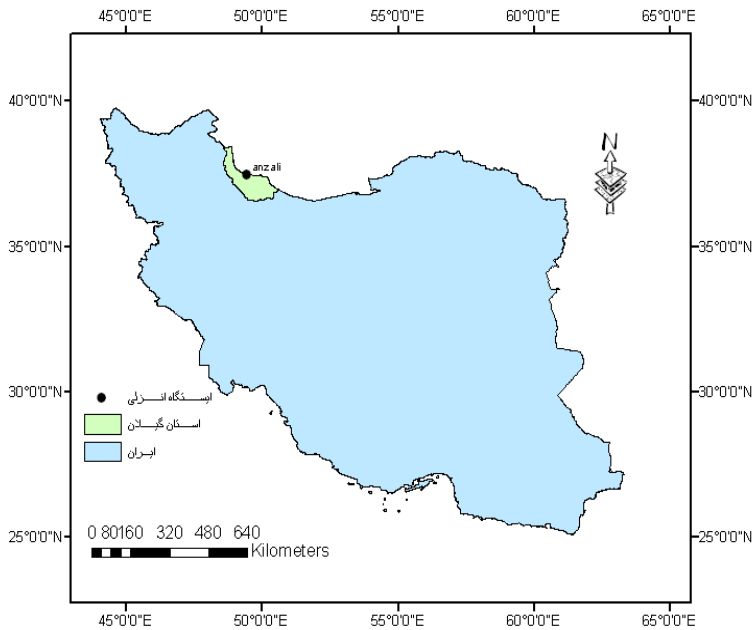
2:
$$\operatorname{sgn}(x_j - x_k) = \begin{cases} 1 & if\ x_j - x_k > 0 \\ 0 & if\ x_j - x_k = 0 \\ -1 & if\ x_j - x_k < 0 \end{cases}.$$

3:
$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5) \right].$$

4:
$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \dfrac{S+1}{\sqrt{VAR(S)}} & if\ S < 0 \end{cases}$$

Where n is the number of observed data (length of statistical period), xj that j^{th} of observed data, tp is number of equal data in p^{th} group and z is statistical value of Mann-Kendall. The amount of negative Z shows decreasing process and the positive one shows increasing process in data series. According to the significant level of 95%, if z will be more than 1.96 H_0 is rejected and time series parameter has significant process and otherwise doesn't have this process.

Figure 1: Location of Studied place



Title:

Weather Severity Index (WSI)

Winter comfort for tourisms in this season is an important factor in tourism attraction, therefore finding the degree of weather severity in a region is a necessity in tourism. One of the good indexes in this issue is weather severity. Weather severity index is used to evaluate the bio-ecological conditions in half of the year (winter). Climate temperature (T) and speed of wind (V) elements in this index are used according to following formula (Blazejczyk and Matzarakis, 2007).

Equation 5:

$$WSI = (1 - 0.04\ T)\ (1 + 0.272\ V)$$

Table 1: coefficients of determining weather severity condition (WSI)

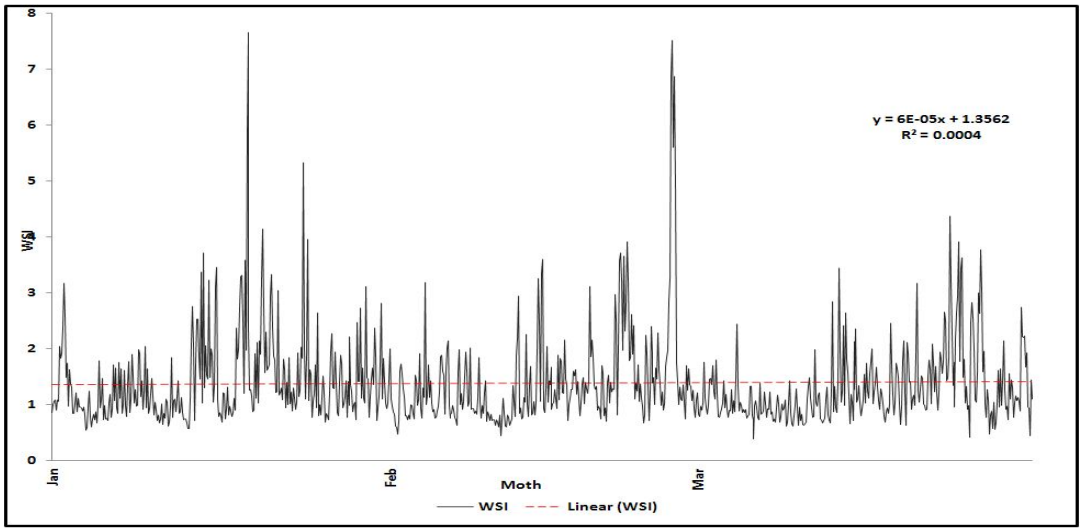
Coefficients of weather severity condition	Effects
Extraordinary hard condition	More than 7
Strongly hard condition	5-7
Very hard	4-5
Hard	3-4
Some extent hard	2-3
Almost hard	1-2
Moderate condition	Below 1

Results of weather severity index (WSI)

According to this that weather severity index is used to evaluate the bio-ecological weather condition in half of the year (winter), so the thermal comfort condition in winter of area has studied. Base on the graph, carrier of this index in 17th January and in 27, 26, 29 February showed the extraordinary hard condition and in view of cold comfort in area, it is abusive for human. Base on Mann-Kendall method and regression equation, this index in this season has increasing process, partly and according to (P=0.31) this process is not significant.

Table 2: winter amount of weather severity index in statistical period (1996-2005)

Month	Jan	Feb	Mar
Mean	1.44	1.43	1.29
Maximum	7.66	7.5	4.4
Minimum	0.55	0.44	0.39



Graph 7: amount of time series for weather severity index in winter, statistical period 1996-2005

Heat and Humidity Index

This index had used in 1965 for the first time and corrected by Masterson and Richardson (1979). This index had used by Canadian meteorologists to describe how people feel heat and humidity meanly.

Totally, a general index is the evaluation of thermal tension in terms of Centigrade degree. This index evaluates the thermal degree that will be feeling in open area and heat and humidity environment and calculate as follow:

Equation6: Humidex = T + 0.5555 (E – 10)

In this equation:

Where **E** is steam pressure and **T** is temperature.

Table 3: Determined Threshold for heat and humidity index by centigrade degree

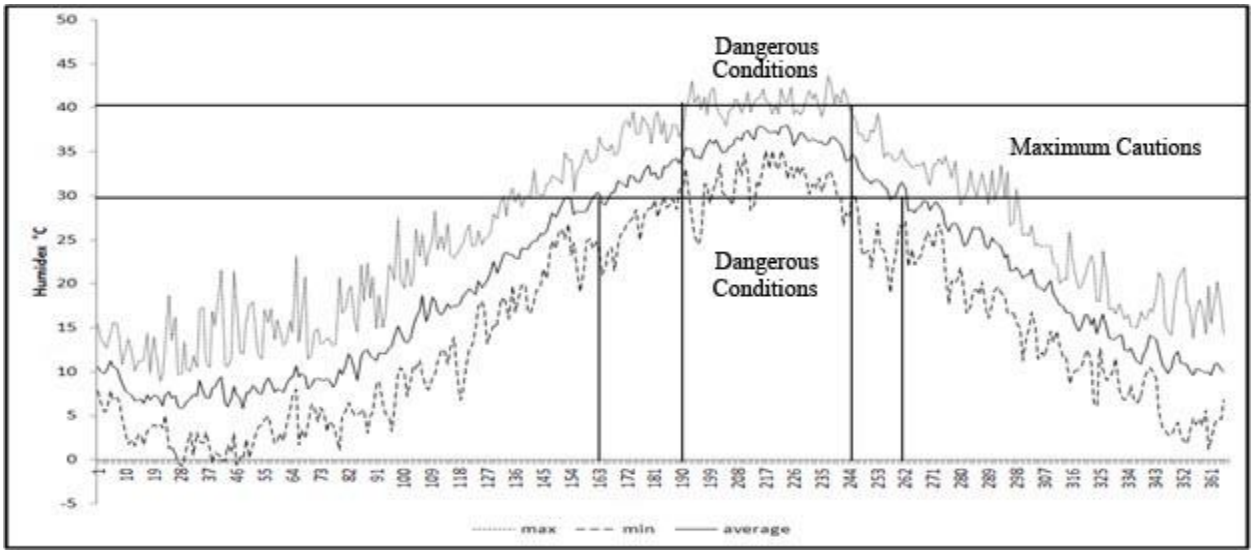
Heat and humidity coefficient in centigrade degree	Effects
Less than 30	Safe or have comfort
30-40	Maximum caution
40-55	dangerous
More than 55	Very dangerous

Resource: http://www.ec.gc.ca/meteo-weather./ (→ hazardous weather → summer weather → summer hazard → heat and humidity → humidex, 24 January 2011).

RESULTS

Heat and Humidity index

Study of thermal comfort in Anzali Port Station, according to graph 1 and table 3 showed that annual maximum, minimum and mean of this index based on daily data in statistical period 1996-2005 in 190 to 224 A.D. in summer have dangerous condition and had studied in terms of heat and humidity in area about thermal comfort upper 40˚ and there are bothering condition in this season. Also, from late of June to late of September, in 163 to 262 A.D. has maximum condition of caution. Base on Mann-Kendall method, this index has increasing process and according to this process (P=0) it is significant.

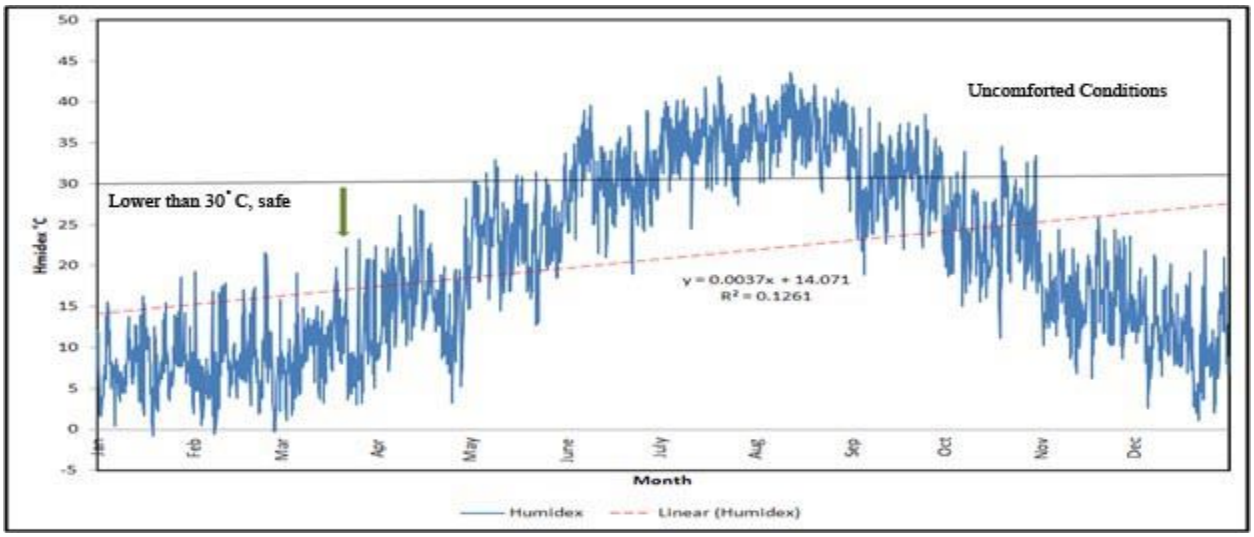


Graph 1: time series of annual maximum, minimum and mean index of heat and humidity base on daily data in statistical period 1996-2005

According to table 4 and graph 2, maximum amount of monthly heat and humidity index during statistical period 1996-2005, from of June to late of October has uncomforted conditions and in November, December, January, February, March, April, May months has comfort conditions.

Table 4: monthly amount of heat and humidity index in statistical period 1996-2005

Month	mean	maximum	Minimum
JAN.	7.840932	18.64058	-0.75016
FEB.	7.750184	21.58297	-0.61975
MAR.	9.842095	23.17533	1.120146
APR.	15.71763	28.2206	3.222688
MAY	23.57585	32.99052	12.73595
JUNE	30.46255	39.55242	19.03426
JULY	38.50335	43.06015	24.49551
AUG.	28.02482	43.58825	26.60581
SEP.	28.02482	39.39194	18.92626
OCT.	24.30648	34.57297	11.2034
NOV.	24.30648	25.85723	6.189962
DEC	6.785407	21.86282	1.145939



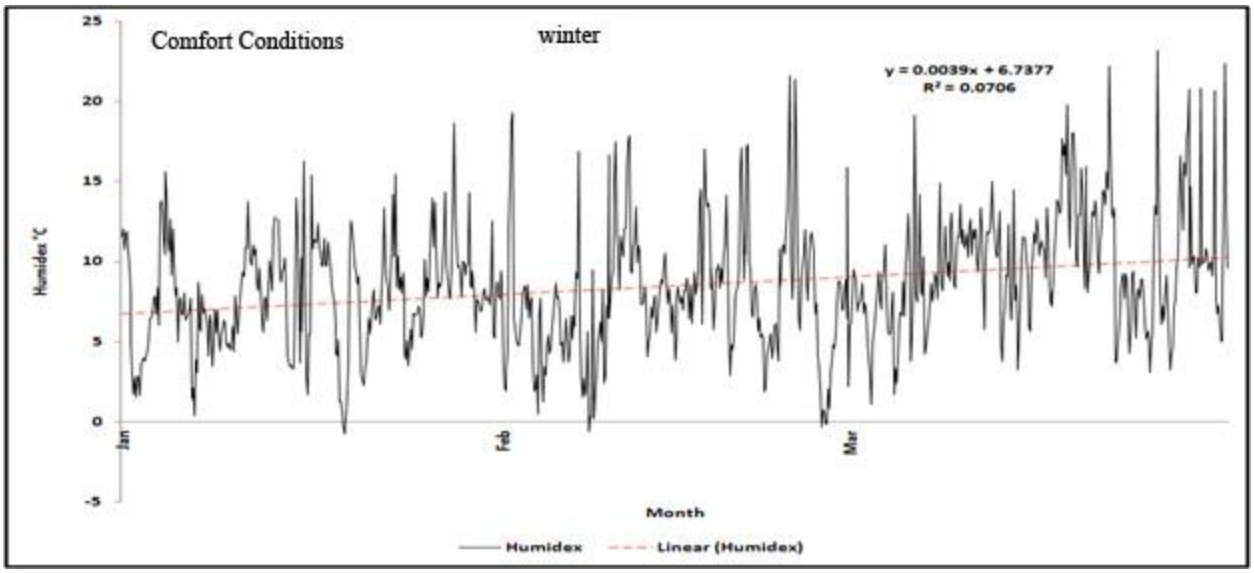
Graph 2: amount of monthly time series of heat and humidity index in statistical period 1996-2005

Winter

Graph 3 shows the coefficient of heat and humidity index in winter, in Anzali Port Station. From figure and table 5 can observe that thermal comfort during all months of winter is kept away dangerous of heat and humidity (lower than 30˚) and there are suitable condition in terms of heat and humidity in region. Base on Mann-Kendall method and regression equation, this index has increasing process in this season and it is significant according this process (P=0).

Table 5: amount of heat and humidity index in winter during statistical period 1996-2005

month	mean	maximum	minimum
JAN.	7.840932	18.64058	-0.75016
FEB.	7.750184	21.58297	-0.61975
MAR.	9.842095	23.17533	1.120146



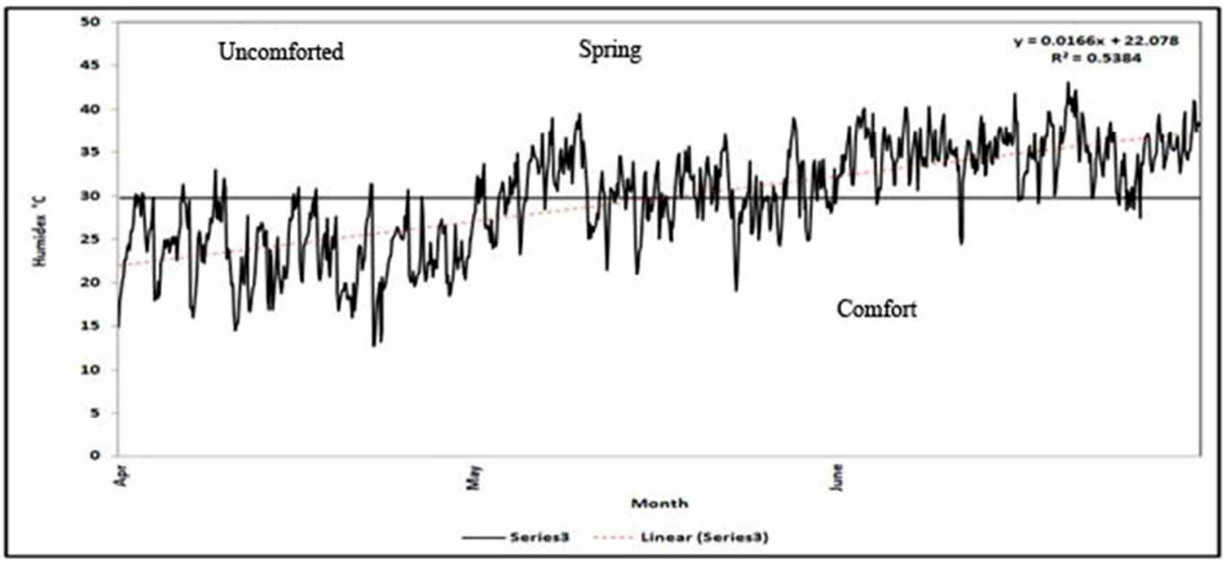
Graph 3: amount of time series of heat and humidity index in winter during statistical period 1996-2005

Spring

Base on graph 4, thermal comfort in spring shows that from second month in this season, heat and humidity has increased and in view of thermal comfort, bothering condition is started from ends of this season (table 6). Base on Mann-Kendall method and regression equation, this index has increasing process in this season and it is not significant according to this process (P= 0.31).

Table 6: amount of heat and humidity index in spring during statistical period 1996-2005

month	Mean	maximum	Minimum
APR.	15.71763	28.2206	3.222688
MAY	23.57585	32.99052	12.73595
JUNE	30.46255	39.55242	19.03426



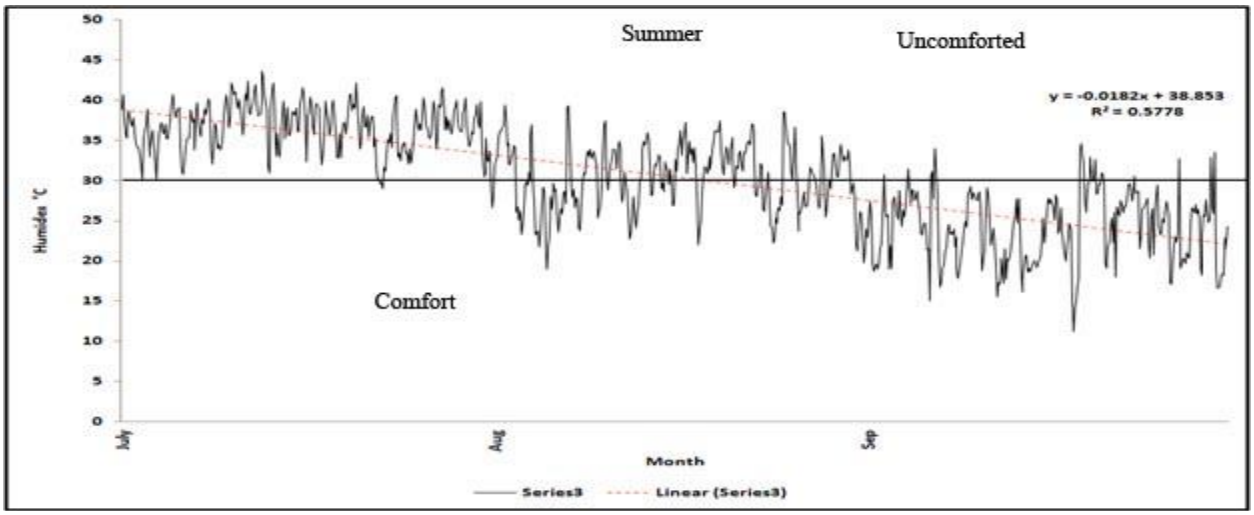
Graph 4: amount of time series of heat and humidity index in spring during statistical period 1996-2005

Summer

Graph 5 showed the coefficient of heat and humidity index in summer, in Anzali Port station during studied period. From figure and table 7 can observed that thermal comfort in first two months is so bothering and heat and humidity condition is become suitable from late of this season to activate gradually. Base on Mann-Kendall method and regression equation, this index in this season has decreasing process and it is not significant according to this process (P= 0.48).

Table 7: amount of heat and humidity index in summer during statistical period 1996-2005

month	mean	maximum	Minimum
JULY	38.50335	43.06015	24.49551
AUG.	28.02482	43.58825	26.60581
SEP.	28.02482	39.39194	18.92626



Graph 5: amount of time series of heat and humidity index in summer during statistical period 1996-2005

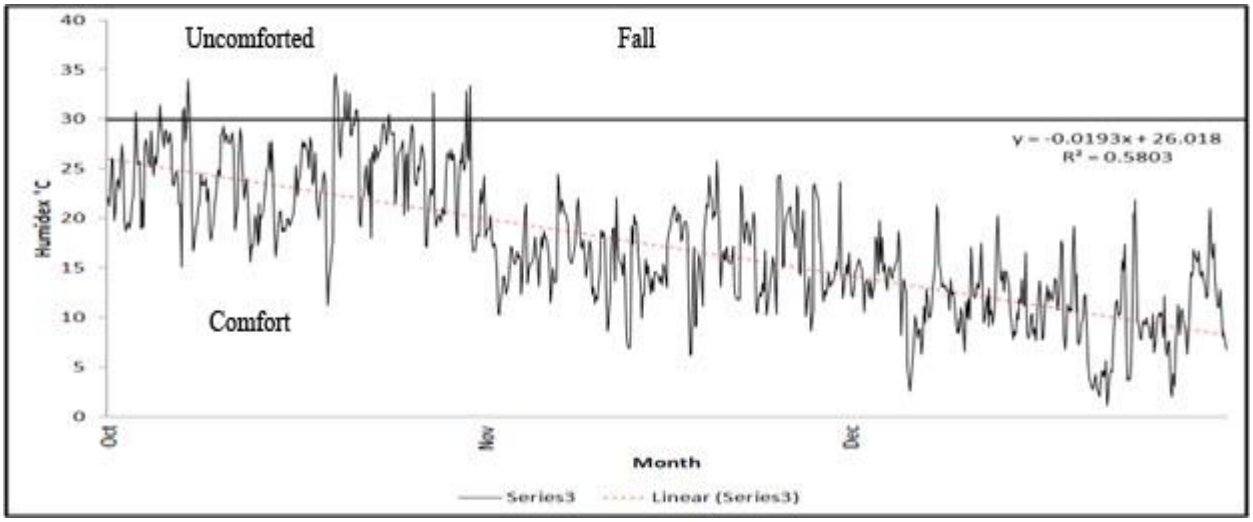
Autumn

Graph 6 showed the coefficient of heat and humidity index in fall, in Anzali Port station. From figure and table 8 can observed that thermal comfort in some days of first month in this season is bothering while in next toe month the

heat and humidity condition is suitable. Base on Mann-Kendall method and regression equation, this index is a decreasing process in this season and it is significant according to this process (P=- 0.3).

Table 8: amount of heat and humidity index in autumn during statistical period 1996-2005

month	mean	maximum	Minimum
OCT.	24.30648	34.57297	11.2034
NOV.	24.30648	25.85723	6.189962
DEC.	6.785407	21.86282	1.145939



Graph 6: amount of time series of heat and humidity index in autumn during statistical period 1996-2005

According to this issue that in northern shores, two elements of heat and humidity is possible in terms of work and activity that make some problems for human and in other words, regulating of these two elements makes suitable condition in this region in view of comfort; therefore, heat and humidity index has chosen to study environmental conditions. Base on the results of heat and humidity index except June and January, other months in chosen station has suitable condition in view of heat and humidity comfort and it is recommended to work in these months(table 9). Evaluating bio-ecological conditions in winter had done by heat and speed wind elements base on weather severity method (WSI). According to the results of this method, there are sever condition in view of heat comfort in winter, in this region. It is used Mann-Kendall method to significant recognizing of this process. Each of the chosen indexes is studies thermal comfort conditions in view of bio-ecology.

Table 9: comparison of chosen indexes results in this research

month	Heat and humidity index	Weather severity (WSI)
JAN.	comfort	Almost severe condition
FEB.	comfort	Almost severe condition
MAR.	comfort	Almost severe condition
APR.	comfort	
MAY	comfort	0
JUNE	uncomfort	0
JULY	uncomfort	0
AUG.	comfort	0
SEP.	comfort	0
OCT.	comfort	0
NOV.	comfort	0
DEC.	comfort	0

Conclusion:

Study of thermal comfort in Anzali Port station by heat and humidity method showed that the annual maximum, minimum and mean of this index, based on daily data during statistical period 1996-2005 in days 190 to 224 A.D. in summer ha dangerous conditions and it is upper 40˚ in terms of heat and humidity in region of thermal

comfort and it is bothering condition in this season. Also, from late of June to late of September in days 163 to 262 A.D. has maximum caution condition.

According to table 3 and graph 2, maximum monthly amount of heat and humidity during statistical period 1996-2005 , it has discomfort conditions from of June to late of October and has comfort condition in November, December, January, February, March, April months.

During all months of winter, Anzali station is kept away of bothering dangerous of heat and humidity and there are suitable condition in terms of heat and humidity in area. Thermal comfort in spring showed that from second month of this season, heat and humidity had increased and in view of thermal comfort the bothering condition has started from late of this season that has increasing process, but it is not significant.

Thermal comfort in first two months is so bothering and heat and humidity condition is become suitable from late of this season to activate, gradually. Base on Mann-Kendall method, this index has decreasing process that is not significant. Coefficient of heat and humidity index in autumn, in Anzali station is showed that thermal comfort in some days of first month in this season has bothering condition while in next two months it is suitable to action. Its decreasing process is significant. Therefore, processes of winter and spring are increasing and processes of autumn and summer is decreasing. Unsuitable Thermal comfort conditions are started from late of spring and became maximum in med of summer. But desirability time of comfort for human actions is started from late of autumn and ended in early of winter. According to weather severity condition, the most suitable comfort condition is observed in days of March2004 and 2005.

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