Calculation of Daily Cooling Degree for Selected Stations in Iraq

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Abstract

Cooling degree days (heating) are most important and simplest coefficients that are used in assessment of energy consumption process in buildings and residential complexes through heating and cooling processes. In this study, cooling degree days were calculated in (33) stations in Iraq by using of daily temperature data from National Aeronautics and Space Administration (NASA) through Surface Meteorology and Solar Energy Project (SMSE) from (1983-2005). This study used hourly cooling degrees method; the results show that there are real values for this parameter during nine months in Iraq from March to November and at an annual rate between (513) degrees in northern Iraq Amadiyah station and (3278) degrees in southwestern Iraq Samawah station. The highest values of this parameter were found during July while the lowest values were found during March, as the results showed that the highest values are in the southern regions of western and southern Iraq while the lowest values are in the northern and north-eastern regions of Iraq in all months of the year.

Keywords: Cooling Degree, Heating Degree, NASA, Iraq.

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حساب درجة التبريد اليومية لمحطات مختارة في العراق

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الخلاصة

تعتبر معاملات ايام درجة التبريد (التدفئة) Cooling Degree-Days من اهم وابسط المعاملات المستخدمة في تقييم عملية استهلاك الطاقة في البنايات والمجمعات السكنية من خلال عمليتي التبريد او التدفئة. تم في هذه الدراسة حساب ايام درجة التبريد في (33) محطة في العراق باستخدام بيانات درجة الحرارة اليومية وللفترة الزمنية (1983-2005) والمتوفرة في الموقع الرسمي لوكالة ناسا الفضائية من خلال مشروع (SMSE). اذ تم استخدام طريقة ساعات درجات التبريد، حيث اظهرت النتائج وجود معدلات حقيقية لهذه المعامل خلال تسعة اشهر من السنة في العراق تمتد من شهر اذار الى تشرين الثاني وبمعدل سنوي يتراوح مابين (513) درجة في محطة العمادية شمال العراق و (3278) درجة في محطة السماوة جنوب غرب العراق. وقد كانت اعلى القيم خلال شهر تموز في حين ظهرت اقل القيم خلال شهر اذار، كما اظهرت النتائج ان اعلى القيم تكون في المناطق الجنوبية والجنوبية الغربية من العراق بينما اقل القيم تكون في المناطق الشمالية والشمالية الشرقية من العراق ولجميع اشهر السنة.

الكلمات المفتاحية: درجة التبريد، درجة التسخين، NASA، العراق.

Introduction

Energy analysis studies are of great importance in the ideal design processes of the power system in buildings and residential complexes in urban cities. There are a large number of methods of energy analysis and these methods vary in complexity, but the method of days of the degree of cooling (heating) is one of the simplest and most widely used methods in the analysis of energy in buildings and it is also used in many agricultural and environmental applications. The method of cooling (heating) is defined as the sum of the differences between the outside air temperature and the reference temperature during a specified period of time [1]. Therefore, the main factor in the calculation of cooling days (heating) is the base temperature. Energy balance in the building depends on this degree as well as the energy system used. Richard Strachard is the first one who used cooling days (heating) method in 1878 [1], where the terms (Degree-day), (hour-degree) and (base-temperature) were first used by him; he focused on the process of crop growth by proposing a mathematical formula to determine Accumulated Temperature above the base temperature degree (5.6°C) where the vegetative crop above this degree begins to grow. This method was then developed to calculate cumulative temperature under reference temperature.

The first records of cooling days (heating) were in the United States by the US Gas Corporation in the 1920s. The statistics indicate that energy consumption is associated with cooling and heating days using a reference temperature of (18.3°C), this experiment was transferred to London in 1934 by the world Duven (Dufton) [3].

The researcher concluded that the ideal reference temperature in England is (15.5°C). This degree is still used to date in the studies of energy analysis. Studies in this area have continued significantly.

Calculation of cooling degree (heating) days

The simplest way to calculate the coefficient of cooling days (heating) is by calculating the difference between the reference temperatures and showing the daily average temperature of the air during the day.

Figure 1 shows the temperature change in two days at a reference temperature of (14°C) where each hourly temperature is put at the reference temperature to obtain the cumulative temperatures, which represent the days of the degree of cooling or heating during the day. The day-to-day differentials represent cooling-cycle hours (heating).

This value is divided by 24 hours to obtain the value of cooling-day days (heating) [3]. Figure 2 shows the change in temperature over four days, where the maximum temperature (**max θ**) is always lower than base temperature. Figure (1) shows that the maximum temperature passes base temperature by three days.

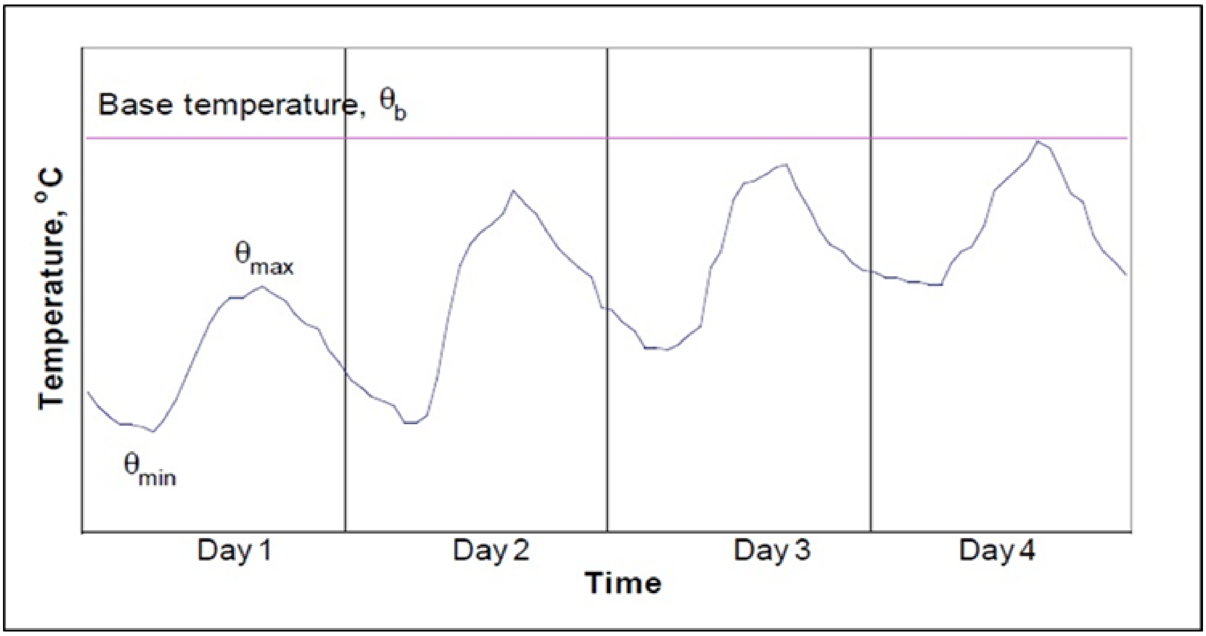

Figure 1: The basic definition of cooling days (heating) [3]

There are several ways to calculate the cooling grade (heating) as follows:

1- The average temperature of cooling (heating) hours, calculated from temperature measurements.

2- The maximum and micro temperature.

3- Daily temperature rates.

4- Direct calculations of monthly cooling or heating degree rates through the monthly temperature and monthly rates of the standard deviation of temperature.

A brief explanation of this is given below:

1. **The rate of cooling-cycle hours (heating) method:**

This method is one of the most accurate methods in calculating this rate as the differences in the hourly temperature are collected and divided on 24. Equation (1) shows the general formula of the cooling process [4].

$$Dd = \frac{\sum_{j=1}^{24}(\theta o, j-\theta b)(\theta o, j-\theta b)>0}{24} \text{ .... } (1)$$

In the case of heating:

$$Dd = \frac{\sum_{j=1}^{24} (\theta b - \theta o, j)(\theta b - \theta o, j) > 0}{24} \quad \ldots\ldots\ldots\ldots\ldots\ (2)$$

Where Dd is the days of cooling (heating) for a particular day, $\boldsymbol{\theta b}$ is the reference temperature, $\boldsymbol{\theta o, j}$ the temperature of the air outside in hours. Only positive differences are taken into account, this value is then calculated for certain periods of time, usually a month, a quarter, or a year. This method requires dealing with a large number of measurements as it deals with hourly measurements [5].

2. The meteorological office equations method:

This method is sometimes referred to as the McViker or British Gas Formula as the first method used by the British Gas Corporation. This is the standard method used in England since 1982 and is expressed through the following integration [6]:

$$Dd = \int (\theta b - \theta o) dt\theta \quad \ldots\ldots\ldots\ldots\ldots\ (3)$$

Where the maximum and minimum temperatures are used to calculate this parameter and before the electronic storage is used, a manual calculation method is used based on the daily readings of the maximum and minimum temperatures. Through the above equation we note that there are three possible relationships between daily temperatures and this relationship is [7]:

1. Base temperature exceeds the maximum daily temperature ($\boldsymbol{\theta b} > \theta max$) as shown in first day case.
2. Maximum temperature - base temperature is less than base temperature - minimum temperature **(θmax -** $\boldsymbol{\theta b}$) < (**θ**$\boldsymbol{b - \theta min}$) as shown in second day case.
3. Maximum temperature - base temperature is greater than base temperature - minimum temperature **(θmax-**$\boldsymbol{\theta b}$) > (**θ**$\boldsymbol{b - \theta min}$) as shown in third day case.
4. Minimum temperature - base temperature as the value of cooling days (heating) is as small as in fourth day case.

The formulae for these cases are shown in Table 1, while Table 2 shows the equivalent equations for cooling degree-days. In both tables Case 4 has been included for completeness.

Table 1: Equations of aerobic stations to calculate the days of the heating degree [8]

case	Condition	Daily heating degree-days
1	$\theta max \le \theta o$	$\theta b - \frac{1}{2}(\theta max + \theta min)$
2	$\theta min < \theta b; and (\theta max - \theta b) < (\theta b - \theta min$	$\frac{1}{2}(\theta b - \theta min) - \frac{1}{4}(\theta max - \theta b)$
3	$\theta max > \theta b; and (\theta b - \theta min)$	$\frac{1}{4}(\theta b - \theta min)$
4	$\theta min \ge \theta b$	0

Table 2: Equations of anaerobic stations for the calculation of cooling time days [8]

case	Condition	Daily heating degree-days
1	$\theta min \ge \theta b$	$\frac{1}{2}(\theta max + \theta min) - \theta b$
2	$\theta max > \theta b; and (\theta max - \theta b) > (\theta b - \theta min$	$\frac{1}{2}(\theta max - \theta b) - \frac{1}{4}(\theta b - \theta min)$
3	$\theta min < \theta b; and (\theta max - \theta b) < (\theta b - \theta min)$	$\frac{1}{4}(\theta b - \theta min)$
4	$\theta max \le \theta b$	0

3. Mean Daily Temperature method:

This method is used in many countries, for example in the United States of America and Germany where the days of cooling (heating) are calculated by the daily average temperature. Case (1) in table (1) and table (2) makes the calculation and definition of this coefficient very simple and also makes the assumption that the heating systems do not work in the days when temperatures exceed the external air base temperature [9].

4. Hitchins formula:

Hitchins proposed in 1983 a relative formula for the calculation of the days of the heating degree and this method has a correlation with Thoms method applied in England. This method states [10]:

$$Dm = \frac{Nm(\theta b - \theta 0,m)}{1 - e^{-k(\theta b - \theta 0,m)}} \text{ ……….. (4)}$$

Where Dm is the value of days of monthly heating, Nm is the number of days of the month, $\theta 0, m$ is the monthly average of temperature, K is a qualitative constant of the place given to the following equation:

$K = \frac{2.5}{N\theta}$ ………… (5)

Where Nθ is the standard deviation of the temperature change within a month and in general it is difficult to know this constant by any user of this method. Higgins suggested the best values for this and for different locations in London, ranging from 66.0 to Heathrow and 76.0 in Cardiff with a value of 71.0. Higgins suggested that the use of the 71.0 mean value of the interior would give little difference in the sequence. One of the benefits of this method is that it is quick to use and needs little information [11].

Table 3: Different calculation methods and their proposed applications.

calculation method	The required data	Predicted applications
The method of cooling time	measurements of temperature	In all home data systems
The meteorological office equations method	Maximum and minimum temperatures	In the absence of electronic recordings
Mean Daily Temperature method	Daily Temperature Rate	When data is only limited in daily averages.
Hitchins formula	Monthly rate of temperature	Ideal for use in energy guessing if data is not available

Data used:

In order to obtain accurate results of cooling degree days values in Iraq, this study used the rate of cooling time method, because it is the most accurate method compared to other methods, as the general formulation of this method is [12]:

$CDD = (1day)\sum_{day}(Tm - Tb)$ ……………. (6)

Where CDD is the value of the cooling degree, Tm is the daily rate of temperature, Tb is the reference temperature. 22 ^{O}C has been adopted as a reference temperature and is used in most approved studies.

This method requires the provision of a large amount of daily temperature measurements, these data are available in the National Aeronautics and Space Administration (NASA) website, the large numbers of missing data at Iraq meteorological stations are treated by using interpolation program code in MATLAB, in addition to the date of recording readings varies from one station to another. So, this study is based on the information available on the NASA space site (Surface meteorology and solar Energy (SMSE).

The data are based on measurements of satellites launched by NASA and in particular the GEOS4 satellite for 22 years from July 1983 to June 2005, with accuracy of 1-degree longitude × 1-degree latitude. In this study, the daily temperature and 23 stations were used for all areas of Iraq. Table (4) shows the geographical coordinates (latitude and longitude) of the stations used in the study. Figure (3) represents the distribution of these stations on the map of Iraq. In order to deal with this large number of samples, and in order to facilitate the calculation, a program was created for all calculations required in the study.

Table 4: Geographical coordinates of the stations used in the study.

No.	The Station	Longitude (degrees)	Latitude (degrees)
1	Emadiya	43.3	37.05
2	Salah Eldeen	44.2	36.38
3	Sulaymaniya	45.45	35.53
4	Sinjar	41.83	36.32
5	Duhuk	43	36.87
6	Zakhoo	42.72	37.13
7	Erbil	44	36.15
8	Rabea'a	42.1	36.8
9	Tallafar	42.48	36.37
10	Kirkuk	44.35	35.47
11	Elnikheb	42.28	32.03
12	Dukan	44.95	35.95
13	Mousul	43.15	36.31
14	Rutba	40.28	33.03
15	Elduz	44.65	34.88
16	Alqaim	41.02	34.38
17	Anna	41.95	34.37
18	Bejee	43.53	34.9
19	Haditha	42.35	34.13
20	Tikreet	43.7	34.57
21	Samarra	43.88	34.18
22	Heet	42.75	33.63
23	Najaf	44.39	31.95
24	Ramadee	43.32	33.45
25	Baghdad	44.4	33.3
26	Karbala'a	44.05	32.75
27	Hilla	44.45	32.45
28	Kut	45.75	32.49

29	Elhay	46.03	32.13
30	Samawa	45.27	31.27
31	Nasyriya	46.32	31.02
32	Basrah	47.78	30.52
33	Faw	48.5	29.98

Figure 2: Distribution of selected stations on the map of Iraq.

Results and Discussion

Using the method of calculation supported in this study, and shown in equation (6), the monthly values were obtained for the days of the cooling grade and the stations selected in the study (33) stations, as shown in Figure (2). Figures (4) to (12) show the contour lines for the values of the days of the cooling grade for the selected stations from March to November. These contour lines were drawn using (Surfer 8) program. These figures describe that the lowest values calculated for the days of the cooling degree are during March, and especially in the northern regions of Iraq. The gradient of contours lines is high in March to November because of the temperature gradient increasing through the spring and summer seasons; and low in winter (DEC, JAN, FEB) due to the decrease in temperature as noted in the northern of Iraq. The values increase as we head towards the south and south-west as the temperature rates are the highest in these stations throughout the year. These figures show that the highest calculated values for the days of the cooling level are during July, reaching up to the highest values and the limits of (611) in the southern stations, especially in the stations of Basra, Samawah, Nasiriyah and FAO and this is due to high temperatures in these stations during this month of the year. Figure (12) represents the annual averages days of the cooling grade in the study selected stations. These rates are distributed from Amara station (514) to Samawah station (3278). It is also noted that there is a large quantitative variation in the values of this coefficient between the northern and southern regions due to air temperature variation from north to south and from month to month. The results also show that Iraq needs to use the means or systems of cooling within six months of the year, starting from March to October as shown in figure (13). While the remaining months of the year have values of zero cooling days, due to the decrease in temperature and less than base temperature used in the study (22°C).

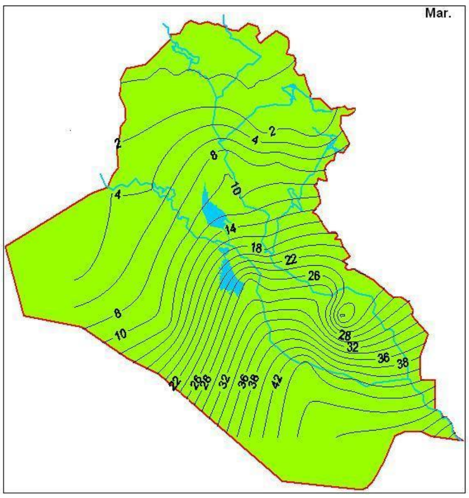

Figure 3: Cooling degree values for Selected stations during March

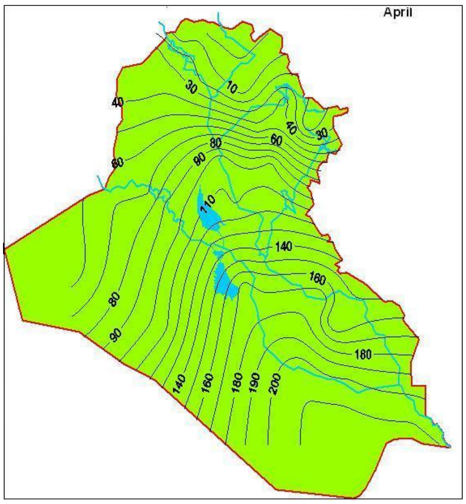

Figure 4: Cooling degree values for Selected stations during April

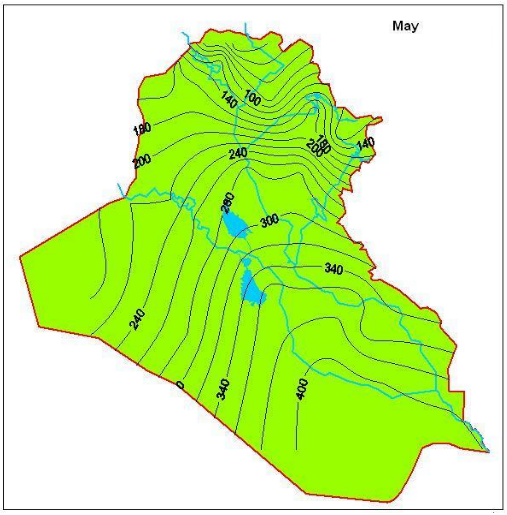

Figure 5: Cooling degree values for Selected stations during May

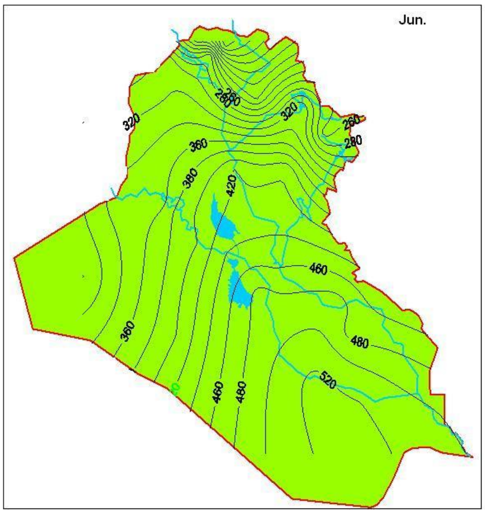

Figure 6: Cooling degree values for Selected stations during June

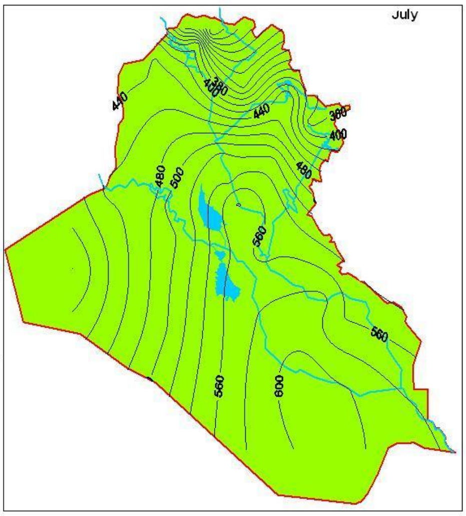

Figure 7: Cooling degree values for Selected stations during July

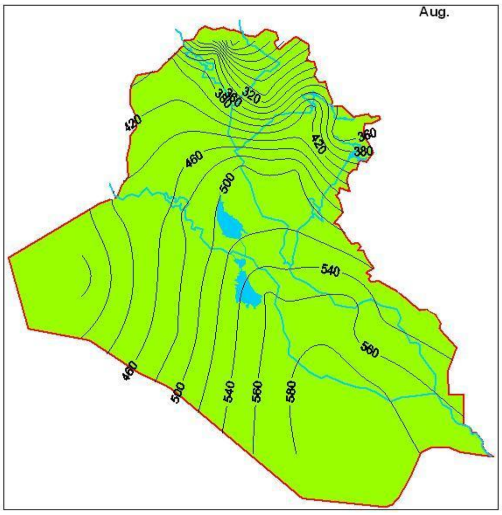

Figure 8: Cooling degree values for Selected stations during August

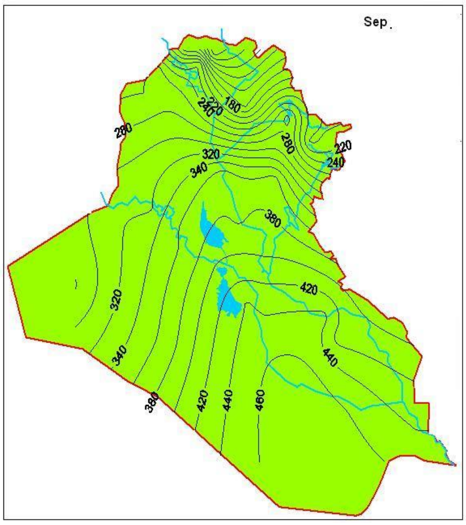

Figure 9: Cooling degree values for Selected stations during September

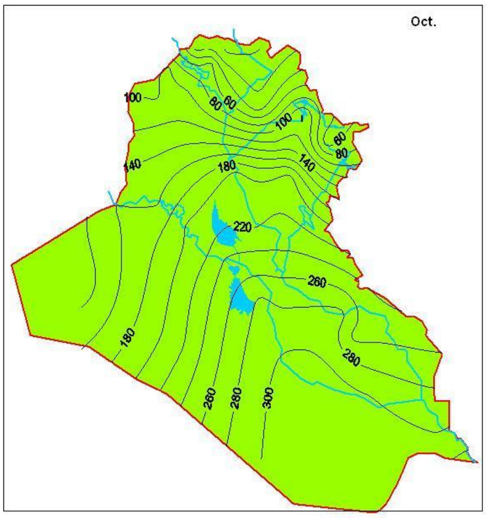

Figure 10: Cooling degree values for Selected stations during October

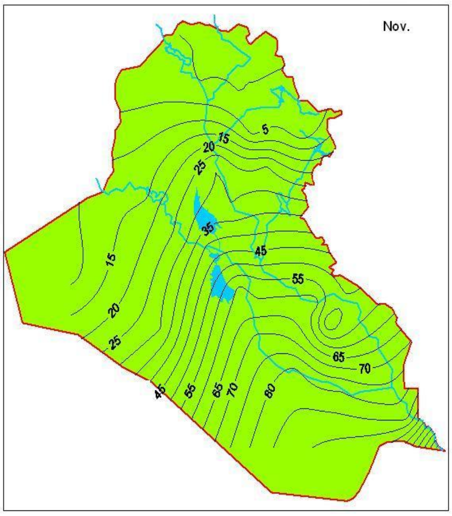

Figure 11: Cooling degree values for Selected stations during November

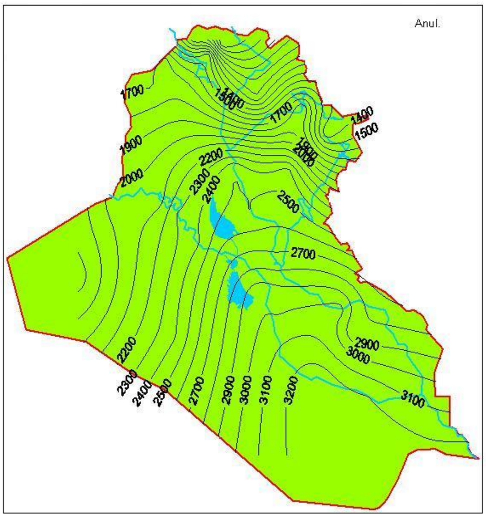

Figure 12: Annual means of cooling degree for selected stations

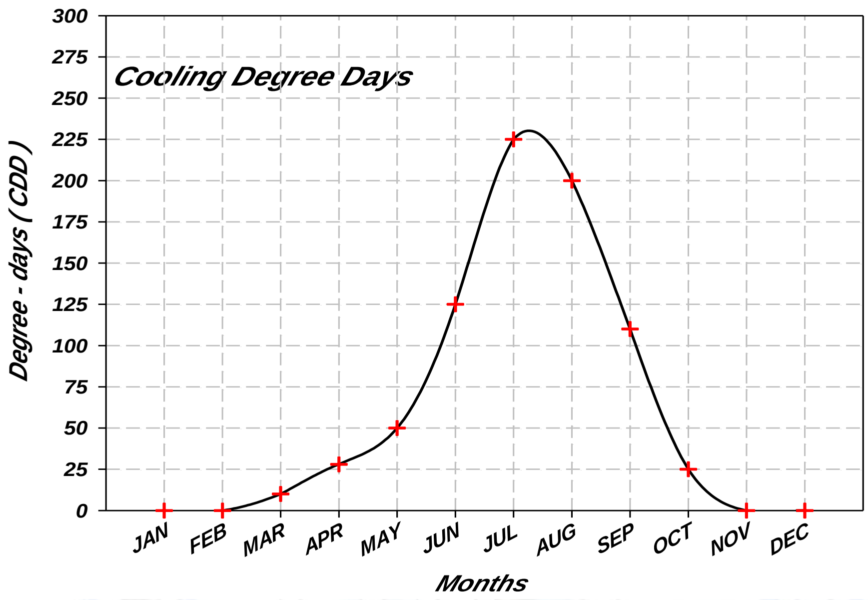

Figure 13: Cooling Degree Days (CDD) in Iraq

Conclusions

Cooling degree annual mean is one of the most accurate methods for calculating the coefficient of cooling degree days. The results showed that there are registered values of this factor during the nine months of the year from March to October, where the lowest values for these coefficients were during March, while the highest values were emerged during July, while the seasonal means of these coefficients show that there is a large difference between small values; which was at Emarah station and the limits of (519) degree and the highest value that was in Samawa station up to (3978) degree. Therefore, cooling systems should be used within nine months of the year and at varying rates according to the values of this monthly coefficient.

Suggested studies:

1. Conducting a comparative study between several methods used to calculate the cooling degree days coefficient and selecting the best method for application in Iraq.
2. Conducting a similar study to calculate the coefficient of heating days in Iraq.

3. Conducting a study to determine the quantities of energy required for cooling using the results of this study.

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