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# Solar air conditioning system using desiccant wheel technology as a solution for Iraq

Karrar Al.AHMEDI * [1]

[1]Warsaw University of Technology, Warsaw, Poland

**Abstract**

The electrical energy consumption in Iraq has increased sharply in the past few years. Modern energy efficient technologies are desperately needed for the national energy policy. The main purpose of this paper is to analyze the various cooling systems, using the readily available solar energy to cool down the buildings in Iraq during hot weather days. This paper presents the best solar cooling system which can be installed in Iraq for solar cooling. It also focuses on the type of thermally driven system which can be used for solar cooling. It is fact that many buildings in Iraq are designed far away from being energy efficient, hence this paper focuses on the standards which can be developed and can be used in the future on residential buildings from the energy point of view, with a suggestion to establish such solar cooling projects in Iraq. Systems have been used successfully in northern Europe and a number of studies have demonstrated that solar energy can be used to drive the system in this region. However, to date, desiccant cooling has not been used in Iraq. This paper presents the results of a study, in which a solar desiccant cooling model will use to evaluate the potential for using solar power to drive a desiccant cooling system in Iraq. The study demonstrates that solar desiccant cooling is feasible in Iraq, provided that the latent heat gains experienced are not excessive. However, if the relative humidity experienced are too high then desiccant cooling becomes impracticable simply because the regeneration temperatures required are excessive.

**Keywords:** Cooling, Solar electric cooling system, solar thermal cooling system

## 1 Introduction

Solar energy is considered a renewable energy source due to the fact that a small part of the radiant energy that the sun emits into space ever reaches the Earth. The growth in the energy utilization sector has led to the interest in the utilization of renewable energies including cooling techniques which focus on solar energy. Solar energy is used in two forms i.e. thermal and photovoltaic for producing heat and electricity. Solar cooling systems are attractive because cooling is most needed when solar energy is highly available. However, solar cooling systems by themselves are usually not economical at present fuel costs Basically, solar cooling is a technique which collects solar energy and converts it into the heat to provide space heating, cooling, pool heating for buildings. It's an advanced technology, which eliminates the use of electricity and natural gas. This technology is safe and eco-friendly. Desiccant cooling systems are energy efficient and environmentally benign. According to one estimate, desiccant dehumidification could reduce total residential electricity demand by 25% or more in humid regions [3], providing a drier, cleaner, more comfortable indoor environment with a lower energy bill. Desiccant systems allow more fresh air into buildings, thus improving indoor air quality without using more energy [8]. Desiccant systems also displace chlorofluorocarbon-based cooling equipment, the emissions from which contribute to the depletion of the Earth 's ozone layer. When fresh outdoor air is brought into a building, it often carries a high humidity load relative to the building 's internal latent load. Conventional vapor compression cooling systems are not suited to efficiently treat large humidity loads. To sufficiently dry the air in many applications, vapor compression systems must be operated at low temperatures, which reduces their efficiency and results in inefficient reheating of the dry, cold air to achieve some degree of comfort. Additionally, matters are made worse by the common use of oversized compressors controlled by dry-bulb set points. This leads to short-cycling, which can reintroduce condensate from a wet cooling coil back into the supply air. Currently, desiccant cooling and dehumidification systems are being used successfully in industrial and various commercial markets and provide clear advantages in many applications throughout the United States. Desiccant cooling systems are used

*Ccorresponding author: E-mail address: engkarrar0@gmail.com (Karrar Al.AHMEDI)

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to improve the indoor air quality of all types of buildings by efficiently controlling moisture in large quantities of fresh, ventilation air. In these systems, a desiccant removes moisture from the air via a process called sorption, which releases heat and increases the air temperature. A combination of heat exchange with ambient air and evaporative or conventional cooling coils then cools the dry air. Temperature and humidity loads are very effectively and efficiently met by separating them in this way. The desiccant is then dried out (regenerated) to complete the cycle using thermal energy supplied by natural gas, waste heat, or the sun. Commercially available desiccants include silica gel, activated alumina, natural and synthetic zeolites, titanium silicate, lithium chloride, and synthetic polymers [1, 6].

## 2 Climate in Iraq

The climate of Iraq is hot and dry. In Iraq temperature is generally above 48$^o$C during summer months (June, July, and August). While lowest temperature can drop below freezing point during the coldest month January.

Iraq is strongly influenced in the summer by subtropical high pressure. This high-pressure zone influences desert regions across North Africa and the Arabian Peninsula. It migrates northward in the summer. Because of increased solar radiation associated with the summer solstice. By contrast, during the winter solstice, as the northern hemisphere is tilted away from the sun, the subtropical high pressure is replaced by periodic low- pressure systems, that travel from west to east across Iraq bringing winter rains and snow in the mountain regions of the north. The summertime is commonly marked by two types of wind phenomena. Southern and south-easterly wind called (sharqi ) is a dry, dusty wind which takes place from April to early June and again from late September until November with occasional gusts of 80 kilometers per hour. This wind can last for a whole day at the beginning and end of the season and for several days during the middle of the season. This wind is often accompanied by violent dust storms. The wind may rise to heights of several thousand meters, that forces to close airports for short periods of time. From mid-June to mid-September the prevailing wind, called the (shamal), (North wind) is present throughout the country from the north and northwest. It is a steady wind, absent only occasionally during this period. The very dry air brought by this shamal permits extensive heating of the land surface, but the breeze has some cooling effect. The Ambient Air Temperature in Iraq during summer in the years, 2014-16. Shown in Fig.1[5].

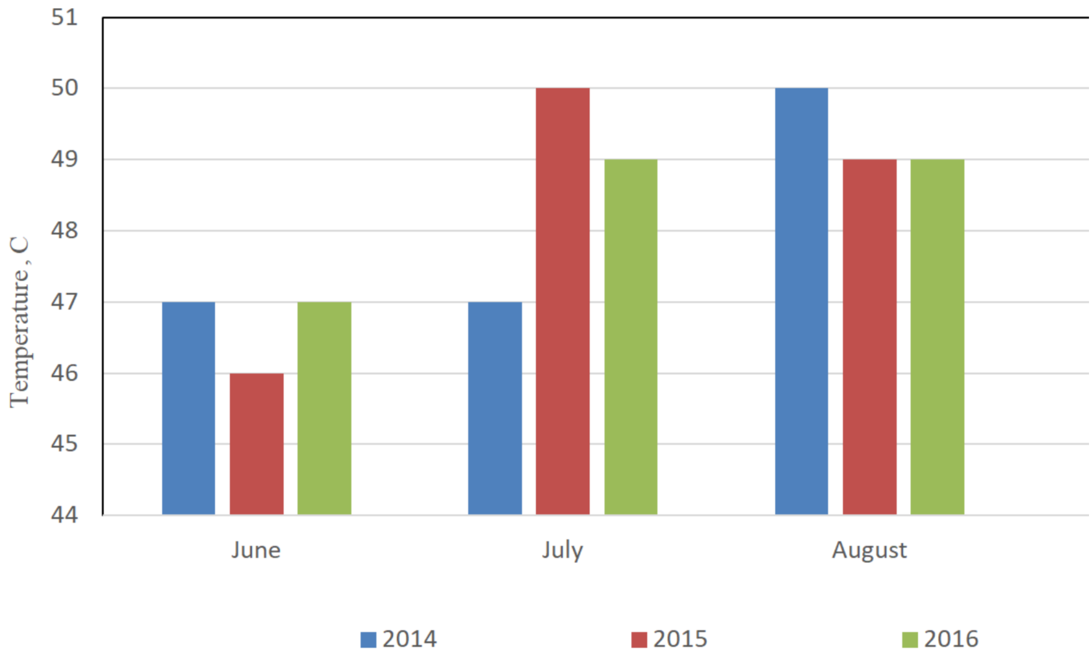


Figure 1. Ambient air Temperature in Iraq during summer in the years 2014-16

Average low temperature in Iraq during the winter months vary from near freezing point which is around 2$^o$C or 3$^o$C and 4$^o$ to 5$^o$C. While during the summer months the average low temperature ranges from 22$^o$C to 29$^o$C and commonly rise to a temperature above 48$^o$C. Temperatures throughout the country typically fall below freezing point and in previous years have fallen to as low as -14.5$^o$C at AL Rutbah in the western desert area. However, temperatures are more likely to rise above 46$^o$C in the summer months. The all-time record high temperature in Iraq of 52$^o$C (126$^o$F) was recorded near (AL Nasiriyah) city on 2 August 2011.(as the report in climate and average weather in Iraq, 2017)[13].

Iraq's climate is described as subtropical in terms of heat due to the presence of temperature rate more than 20 degrees for 4-11 months. According to Koeppen-Geiger classification, Iraqi climate is classified as BWh climate where B indicates Dry, W indicates dessert and h indicates hot climate. (as the report in The Iraqi Ministry of Environment's annual repo, 2010 [13])

Some characteristics of Iraqi climate are as follows:

- It has a continental climate which brings a wide range of temperatures.
- Mountain region of the north has cold and less humid than in the south.
- Center of the Iraq is much hotter in summer and dust storms are the main feature of the central region.
- The southern area of Iraq i.e. around the Gulf has the highest temperature recorded anywhere in the world.
- In the northeast, heavy rainfall takes place.
- Desert area receive no rainfall at all

# 3 Solar cooling technologies

Solar cooling is a technology for converting heat gained from solar energy into useful cooling for refrigeration and air-conditioning applications. Solar thermal energy is collected and used by a thermally driven cooling process, which in turn is normally used to generate chilled water or conditioned air for use in the building. A typical solar cooling scheme essentially includes three components. They include the solar collector for harnessing the solar energy by converting it into heat or mechanical work, a refrigeration or air-conditioning plant for producing cooling and a heat sink for heat rejection [10]. Basically, there are two kinds of solar cooling system [4]

- Electrically driven system (Photovoltaic).
- Thermally driven system.

# 4 Desiccant Cooling (DEC)

The desiccant cooling system basically uses water as a refrigerant in direct contact with air and dehumidifies it. Desiccant systems also known as thermally driven air conditioning systems. A desiccant is basically a substance, either solid or liquid. The desiccant initially is used to absorb moisture from the air, which later is regenerated by heating the desiccant, that releases the absorbed moisture. It improves the air quality and energy efficiency. The desiccant material absorbs moisture due to the difference in vapor pressure [14]. Figure.2 shows Working of a desiccant cooling system.

There are two basic types of desiccant systems which are as follows:

- open Desiccant Systems,
- closed Desiccant Systems.

In open desiccant systems, desiccant comes into direct contact with the air for the process of dehumidification.

Closed desiccant system, in this system the desiccant is confined to a closed chamber and then dehumidifies the air indirectly. Based on the type of desiccant used, it can be categorized into:

- solid desiccant,
- liquid desiccant.

**Solid Desiccant:** In solid desiccant, a dry desiccant is used like silica gel or zeolite, titanium silicates, alumina, molecular sieves, etc. These desiccants have a high regenerative temperature. For silica gel and alumina, it is about 200-300$^o$C, the temperature for molecular sieve is about 100$^o$C. The drying capability of solid desiccants is higher than that of liquid desiccants.

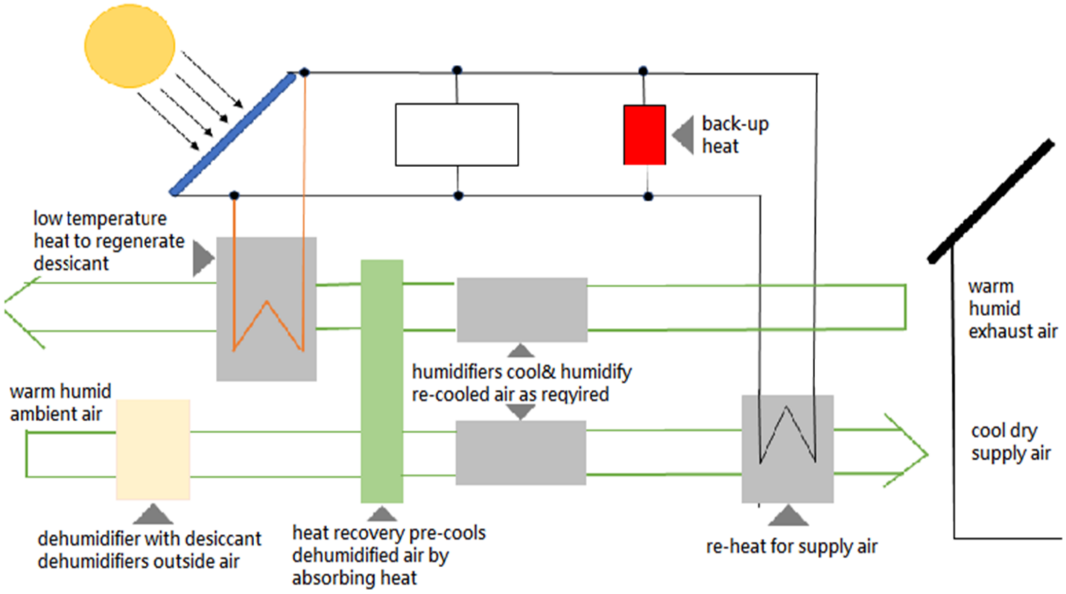


Figure 2. Desiccant cooling system [2].

**Liquid Desiccant:** Liquid desiccant system is a new and emerging technology which consists of a contact surface, which is either a cooling coil or cooling tower. Liquid desiccant comprises of lithium chloride, lithium bromide, tri-ethylene glycol, calcium chloride and potassium format. The liquid desiccants usually have a lower generation temperature than solid desiccant which is below 80$^o$C. In a cooling system, to achieve the dehumidification and cooling of air usually, a pre-cooled desiccant is used. A liquid desiccant removes extra moisture and leads to the increase of temperature. The advantage of using liquid desiccant is that liquid desiccants can be stored and used when the heat source is not available. It is quite small and compact [11].

# 5 Overall system performance of desiccant cooling system

For open cycle desiccant system, the performance can be expressed by two parameters [12]:

- Coefficient of Performance.
- Cooling Capacity.

**Coefficient of Performance (COP)**: It can be defined as the heat removed from the air stream by the energy input to the cycle

$$COP = \frac{\dot{m}_p(h_a - h_{sp})}{Q_{in}} \tag{1}$$

Where

$\dot{m}_p$ - process air mass flow (kg/s),

$h_a$ - ambient air enthalpy (kJ/kg),

$h_{sp}$ - supply air enthalpy (kJ/kg).

$\dot{Q}_{in}$ - electric energy power used to circulate air, water, and rotating desiccant wheel, and auxiliary regeneration heat flux.

$$\dot{Q}_{reg} = \dot{m}_{reg} c_p (T_{reg} - T_o) \tag{2}$$

Where

$\dot{m}_{reg}$ - mass flow rate of regeneration air (kg/s)

$c_p$ - specific heat of air $(J/(kg \cdot K))$

$T_{reg}$ - air regeneration temperature ($^o$C)

$T_o$ - outlet temperature ($^o$C)

Cooling Capacity: It is the air supplied by the system. It can usually be defined as the difference in enthalpy between the supply air and any given interior condition. It can be calculated as:

$$\dot{Q}_c = \dot{m}_p c_p (T_{reg} - T_o) \tag{3}$$

Where

$T_{reg}$ - regenerated air temperature ($^o$C)

$T_o$ - outlet temepratture ($^o$C)

The influence of ambient temperature, regeneration temperatures, temperature outlet, auxiliary energy, and the effectiveness on the performance of the desiccant cooling system can be evaluated in the terms of supply air, sensible cooling capacity and system coefficient of performance [7]. For dehumidifier performance with constant inlet ambient air, increasing the regeneration temperature reduces the moisture content from the air. The important parameter for desiccant cooling is the coefficient of performance and cooling capacity of the system.

# 6 The working principle of a solid desiccant cooling system

Solid desiccants are impregnated in a dehumidifier bed, usually a rotary disc between the process and regeneration. As the hot and humid process air passes through the desiccant wheel, the moisture is removed by the desiccant and its temperature increases. The temperature of this process air, which is now hotter and drier, is reduced to the desired comfort conditions by means of sensible coolers (e.g. rotary heat exchangers, evaporative coolers, and cooling coils). The warm and humid return air from the conditioned space is further heated up to the required regeneration temperature of the desiccant and this regeneration stream of air is passed through the desiccant wheel to remove the moisture from the desiccant. Advantages of using desiccant cooling systems include the following: (1) very small electrical energy is consumed and the sources for the regenerating thermal energy can be diverse (i.e. solar energy, waste heat, natural gas); (2) a desiccant system is likely to eliminate or reduce the use of ozone-depleting CFCs (depending on whether desiccant cooling is used in conjunction with evaporative coolers or vapors compression systems since sensible and latent cooling occur separately; and, (3) improvement in indoor air quality is likely to occur because of the normally high ventilation and fresh air flow rates employed. Also, desiccant systems have the capability of removing airborne pollutants.

# 7 Solar cooling system suitable for Iraq

The solar cooling system which is suitable for Iraq is the absorption system as it's more economical and reliable in comparison to the other solar cooling system. Other solar cooling systems are very sensitive to low temperatures and their thermal conductivity of the absorbent is quite poor as compared to the absorption system. Apart from this other system are quite heavy and complex and they require high maintenance while absorption system can be small and can operate at low temperature. It's a fact that most of the buildings in Iraq are designed to be more energy efficient and most of the solar energy produced within this hot climate regions are consumed by the buildings.

# 8 Economic Issues

All solar air-cooling technologies (SAC) system present good figures for primary energy consumption. The best performance is seen in a system with integrated heat pumps and small collector areas. The economics of these SAC systems at current equipment costs and energy prices are acceptable. They become more interested in the case of public incentives of up to 30% of the investment cost (Simple Payback Time from 5 to 10 years) and doubled energy prices [3]

# 9 Conclusion

It can be concluded that each location has its own characteristics and requirements, as in a case of Iraq. This paper also presented the absorption systems. The desiccant cooling system (DEC) can be a good solution to be used for the Iraqi location, because it's cheap and it has a very good efficiency too. Solar heating technology is getting matured. It's really important to select a heat storage tank with proper design and volume, because it improves the efficiency of the system. Hence, to establish a good solar cooling system in Iraq all the aspects should be considered including heating load, design, kind of solar collector and solar cooling system with the temperature variations [9].

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