Impact on water consumption by cooling equipment in arid region of Mexico

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ABSTRACT: The average of maximum temperatures in the summer period in Chihuahua City, located in Northern Mexico, is 32 C (90 F). This fact makes obligatory the use of cooling devices into the buildings, during five months at least. Unfortunately the use of passive and low energy for cooling has not generalized yet, and the most of buildings utilize evaporative cooling equipment operated by electricity. The high consumptions of energy generated by this equipment, has originated socioeconomic tension and the special attention of Mexican authorities. However the high consumptions of water generated by the operation of this equipment have been practically ignored. This is especially significant because it is an arid region, which presents scarce rain and recurrent periods of drought. So, the largest part of these five months, when the insufficient water is rationed in a diary tank by house, the total available water is utilized only in the operation of evaporative cooling, and other requirements (bath, cleaning, and others) are unsatisfied. The great impact on water consumption by the use of evaporative cooling equipment in this arid region of Mexico is focused in this paper, like an urgent call to attend this problem through the implementation of bioclimatic criteria in building design.

Keywords: water consume, evaporative cooling, bioclimatic criteria

1. INTRODUCTION

Each year during the summer, the subject of water shortage becomes significant in Chihuahua. Every day the people express their unconformity. Press commentaries and educational campaigns about the way of reducing water consumption are abundant. Authorities invite the people to save water and to avoid water fugues, at the same time the government offers water storage tanks and other services as support. However, nobody said that it is possible to reduce the water consumption largely, if the evaporative cooling in buildings is reduced too.

Figure 1: Map of Mexico

2. CLIMATE

The climate in Chihuahua is considered as dry and extreme, BSwh` according the Köppen classification. It is a desert climate with scarce rain in the summer. During the rainiest month the pluvial precipitation average is 10 times bigger that the driest month. The temperature is high, with annual average greater than 18 C (64 F).

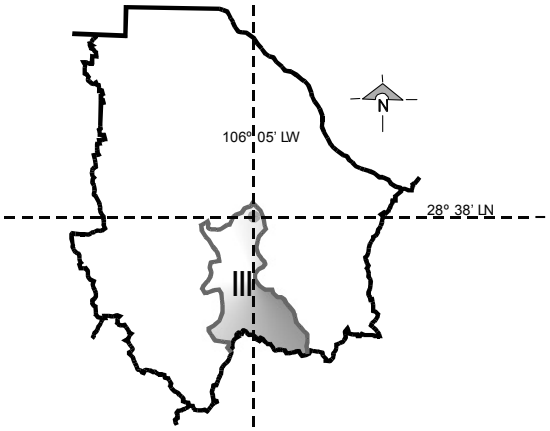

Figure 2: Homogeneous climatic area

The annual average of pluvial precipitation is close to 386 mm, equivalent to 110 billions of cubic meters. 88% of them are evaporated and 12% are drained [1]. This climate presents scarce rain and recurrent periods of drought. In agreement with information of the National Water Commission (CNA), Chihuahua suffered ten years of constant drought from 1993 to 2003. Today this problematical situation continues, although with the presence of sporadic rain during summers.

Table 1: Annual meteorological data

Climatic parameter	Average
Mean temperature	18.9 C
Maximum temperature	26.9 C
Extreme maximum temperature	41.3 C
Minimum temperature	10.8 C
Extreme minimum temperature	- 12.8 C
Oscillation of temperatures	16.0 C
Mean relative humidity	52.4%
Minimum relative humidity	14.4%
Maximum relative humidity	90.4%
Total precipitation	385.2 mm
Wind direction	Northeast
Wind speed	3.3 m/s

Summer extends from May to September, which is 153 days. This is the warmest period with 35.9% of cloudy days. The pluvial precipitation registered during this season is equivalent to 82.3% of the annual total precipitation.

Table 2: Summer meteorological data

Climatic parameter	Average
Mean temperature	24.7 C
Maximum temperature	32.0 C
Extreme maximum temperature	41.3 C
Minimum temperature	17.5 C
Extreme minimum temperature	4.5 C
Oscillation of temperatures	14.5 C
Mean relative humidity	52.8%
Minimum relative humidity	16.3%
Maximum relative humidity	89.1%
Total precipitation	313.1 mm
Wind direction	Northeast
Wind speed	2.6m/s

3. THE PROBLEM

The highest temperatures of the year occur in the summer, practically during the whole day. This fact makes obligatory the use of cooling devices into the buildings, in five months at least. The most popular device is the evaporative cooling equipment, which requires electricity and water to operate. Both resources are expensive and scarce in the northern region of Mexico. The high consumptions of energy generated by this equipment, has originated socioeconomic tension and the special attention of Mexican authorities. However the high consumptions of water generated by the operation of this equipment have been practically ignored.

In Chihuahua State there are 15 water-bearing exploited, all of them are localized in the most populated cities and in the most important irrigation zones. The hydrological balance in these aquifers shows that eleven have conditions of exploitation higher to the advisable. Five of them present the most severe conditions because they have been exploited too much. The aquifer that supplies water to Chihuahua City is between them. There, 100% of the supplied water comes from this source. [2]

Figure 3: Evaporative cooling system

The great quantity of required water to cooling purposes causes a high consumption and reduces the availability of the resource in the city. This originates that during this season, the city imposes a program that restricts water, supplying it only during 4 or 6 hours at day. Obviously, people confront troubles to store water in housing. Consequently the use of storage tanks becomes essential. These tanks are usually placed over the roof, and they supply water to the housing during the restriction time.

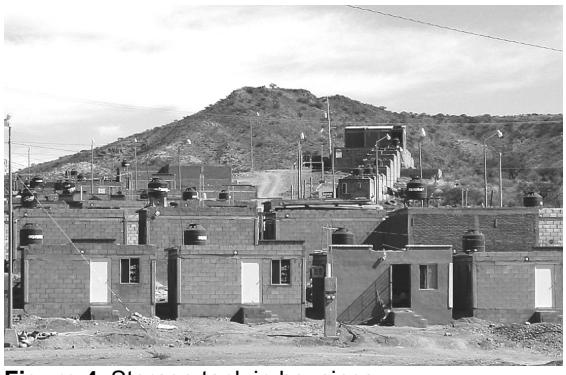

Figure 4: Storage tank in housings

The most popular evaporative cooling equipments in residential buildings in Chihuahua are the commonly called "swamp coolers", with 3,800 cubic foot per minute (cfm) of airflow. In hot desert climates, as this of Chihuahua, three to four cfm per square foot is suitable, so this equipment is appropriate to correctly insulated houses, if they occupy an area of 950 to 1265 ft2 (88 to 120 m2). Improperly sized equipments will waste water and energy and may cause excess humidity or other discomfort problems.

The average of the area of houses at Chihuahua is about 60 to 80 m2, minor than the recommended areas for this size of equipment, but its

constructive system does not include any kind of insulation generally. As the temperature conditions in the summer are 40 C (104 F) dry bulb, and 19 C (66 F) wet bulb, thermal load calculations demand about 30,000 Btu⁄hr of cooling power (8.78 kW). According to the principle of convection heat transfer, 30,000 Btu⁄hr are equivalent to 4,000 cfm of evaporative cooling. So, in a house of 60 m2 (645 ft2), and 2.7 meters (9 ft) high, it means a change of air every 1.42 minutes, or 42 air changes per hour. This amount of air flow is normal if evaporative cooling is used.

According to a local agency, the State Commission for the Saving and the Efficient Use of Energy (CEPAE), the usually installed evaporative coolers in housings consumes about 40 liters of water per hour. This is a very high amount of water, but it is at the top border of the producer's specifications. In fact, contributed data by de NAHB Research Center (subsidiary to U.S. National Association of Home Builders) confirm that this kind of equipment consume between 3.5 and 10.5 gallons (13 to 40 liters) of water per hour of operation.

In the best conditions of insulation, the lower consumption of water can be waited, but in the real conditions of the Chihuahua's buildings, the waste can be largest. The kind of used cooling equipment in Chihuahua is extremely inefficient, not only by the producers specifications and by the deficient insulation conditions, but because both the water storage and the cooling device are sunned. So, the reported consumption by the local agency, results logical. Besides, the 40 liters per hour consumption is prolonged during approximately an average of 20 hours per day on the summer season. In this sense, it is necessary to propose new regulations and standards for installation and operation of evaporative cooling devices.

If actions were implemented as those mentioned before, it would be possible to reduce a good percentage of the water consumption. However, additionally, if the housings were designed with bioclimatic approaches, a greater saving could be achieved.

We can do some suppositions to calculating the impact in water consumption by the cooling equipment from that information. First, we can consider only 130 days as typical summer days. Second, we can consider that only 20% of the 200,000 houses in Chihuahua City have evaporative cooling equipment (which is a preservative data, under the real amount):

$$130 \text{ days} \times 40{,}000 \text{ houses} = 5.2 \times 10^6 \text{ day-houses}$$

Third, each family put in function the evaporative cooling equipment 20 hours at day in this season. Fourth, the equipment consumes 40 liters per hour:

$$20 \text{ hours} \times 40 \text{ liters} = 800 \text{ liter-day}$$

As it can be seen, the required water for supply the cooling equipment per day is equal to the capacity of the storage tanks of each house. But how the water supply is restricted during the period and each house receives the equivalent to a storage tank per day, consequently the storage would be only enough to cover the water demand for cooling, and other services that require the supply of water like bath, cleaning, and others would remain unsatisfied. Then, the people must decide if they utilize the water to improve the indoor climate or they employ it in other services. The temperature conditions compel to the people to choosing the cooling subject, and they must sacrifice any other use of water.

Figure 5: Air conditioned in housings

If this situation affects each family in particular, also it generates an environmental and social conflict, by the enormous consumption of water in the city, during the summer:

$$5.2 \times 10^6 \times 800 = 4.16 \times 10^9 \text{ litters}$$

Finally, the water consumption for cooling purposes in this period results in 4.16 billions of liters. According to this calculation, the residential sector of Chihuahua would consume 3.7% of total annual precipitation. If we consider other non residential buildings which employ evaporative cooling equipment too, the water consumption would increase substantially. So, the menace over the availability of the resource increases every day.

These data indicate the urgency of treating this matter in a research project, in order to propose architectural options that reduce the excessive consumption of water for cooling, but without affecting the conditions of thermal comfort of the inhabitants.

4. ARCHITECTURAL RESPONSE

Architecture should decrease the outdoor high temperatures so that its inhabitants achieve thermal comfort inside the buildings. However, the current model of buildings doesn't achieve it frequently; on the contrary, in many cases it increases it.

This fact does that inhabitants must resolve their climate requirements through the continuous use

of evaporative cooling equipment, which increases the water consumption in alarming way.

This excessive consumption is produced principally by a deficient thermal performance of architectural envelop, which can tempt that this problem achieves irreversible consequences in a short term.

Figure 6: Architectural response?

On the other hand, the energy consumption is a very significant problem in the region, because its cost is expensive, and this fact puts limitations to the use of energy for climatic purposes, as much in the summer as in the winter. So the passive and low energy architecture is the most appropriate solution.

The topic of ware saving has been frequently treaty. As a rule it is linked to concepts of efficiency of cooling equipment, devices to save water, systems of recycling water, new strategies of passive cooling, etc. However the necessity to practice a sustainable architectural design as a strategy to reduce the consumption of water is mentioned infrequently and it is never focused on the relationship among the thermal performance of the building and the request of evaporative cooling.

Often, the thermal performance of architectural envelopes has been evaluated with the objective of obtaining the conditions of thermal comfort and of reducing the energy consumption. Currently, subjects like the reduction of CO_2 emissions, the health of inhabitants, the reductions of the heat island effect, the elaboration of data bases of the power consumption, the water saving between others have been incorporated to the concern of architects.

People in Chihuahua have a very great concern about the water consumption, water use and water supply. Several institutions have dedicated their efforts to the study of water situation in the last 15 years as the State Commission of the Tarahumara, the State Commission against the Drought, the Water National Commission and the Faculty of Engineering of the University of Chihuahua, among others. However, the problem of water consumption has not been treated as a result of the excessive use of evaporative cooling equipment. None scientific research has been made about the impact of bioclimatic performance of the architectural envelopes over the water consumption. So, we consider that the architects must add the variable of water consumption in his work, especially in warm dry climates, because the excessive water consumption for the operation of climate equipment is generating a great impact over the ecological balance.

Consequently, we propose some questions that can serve from base to a scientific research whose answers would help to architects and engineers, and they can include the water variable in their designs and calculations of passive cooling:

a. What is the relationship among the thermal performance of the architectural envelope and the water consumption for cooling?

b. What quantity of water can be saved with passive air conditioning strategies?

c. Is it possible to use the water consumption variable to evaluate the efficiency of the thermal performance of architectural envelopes?

5. CONCLUSIONS

Regulations for the production and installation of evaporative cooling equipment are a priority in our country to achieve a bigger efficiency and consequently to reduce the water consumption in dry and warm seasons.

Educational campaigns are necessary also so that people can learn how to improve the devices operation.

Additionally, the bioclimatic approach application in architecture may help more to reduce the consumption which is extremely high today.

For it, new research projects should be undertaken to generate the necessary knowledge to incorporate the variable of water consumption in the calculation procedures of thermal balance in buildings.

6. REFERENCES

[1] INEGI. Carta hidrológica. Diccionario de datos de hidrología superficial (alfa numérico). 2001
[2] Comisión Nacional del Agua. www.cna.gob.mx/ disponibilidad de agua/agua subterránea. 2003.
[3] Herrera L. C. “El uso de aleros y partesoles como estrategia de bajo impacto para espacios habitables. *Estrategias arquitectónicas para el ahorro en el consumo de energía y agua*”. Memorias XXVII Semana Nacional de Energía Solar. Article. pp. 139-147. Octubre 6-10, 2003.
[4] NAHB Research Center information at: http://www.toolbase.org/techinv/techDetails.aspx?technologyID=184 (19/06/2006)