EVALUATING PRACTICAL VS. THEORETICAL WATER CONSUMPTION IN MODIFIED AIR COOLERS

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ABSTRACT

This study aimed to investigate the impact of increased water flow and two different air speeds on water consumption and cooling performance in modify air coolers. An experiment was conducted using an air cooler with an additional water pump to facilitate increased water flow. One Way ANOVA with regression and Tukey was used. Findings revealed that practical water consumption significantly surpassed theoretical estimates, primarily due to heightened resistance encountered by water as it traversed the cooling pads. Notably, the implementation of two water pumps improved cooling, effectively lowering room temperature by7-10 °C (Δt of 9.4°C); however, this enhancement was accompanied by increased power consumption. Statistical analysis showed significant differences in practical water consumption between different treatment groups (Q1S2-Q1S1,Q1S2-Q2S2,Q1S2-Q2S2,Q2S2-Q1S2, Q2S1-Q1S2)(P<0.0003). This research underscores the critical need for effective water management strategies within evaporative cooling systems, particularly in arid regions where water scarcity is a pressing concern. Future research should explore sustainable energy solutions to optimize both water and energy use.

Key words: evaporative cooling, Temperature reeducation, increase water flow, cooling, sustainable solution

تقييم الاستهلاك العملي والنظري للمياه في مبردات الهواء المعدلة

فائز فوزي مجيد المخيول سامر بدري سلمان البدري
مدرس أستاذ مساعد
قسم المكائن والآلات الزراعية/ كلية علوم الهندسة الزراعية/ جامعة بغداد

المستخلص

في المناطق التي تتميز بمناخ حار وجاف مثل العراق, تلعب أنظمة التبريد بالتبخير دورا حيويا في تحقيق درجات حرارة داخلية مريحة. تهدف الدراسة الى تقييم شامل لتاثير زيادة تدفق المياه على كل من استهلاك المياه وتخفيض درجات الحرارة في مبردات الهواء المعدلة. طبقت التجربة باستخدام مبردة هواء مزودة بمضخة ماء إضافية لتسهيل زيادة تدفق الماء. أظهرت النتائج ان الاستهلاك العملي للمياه تجاوز تقدير الاستهلاك النظري وقد يعود السبب في ذلك الى زيادة المقاومة التي واجهتا المياه اثناء مرورها فوق الوسائد عند استعمال السرع العالية. ومن الجدير بالذكر ان استخدام مضختين للمياه أدى الى تحسين تخفيض درجات الحرارة بمقدار 7−10 درجات مئوية (Δt بمقدار 9.4 درجة مئوية) ومع ذلك كانت هذه التحسينات مصحوبة بزيادة في استهلاك الطاقة. بينت النتائج الإحصائية ان هنالك فروقات معنوية بين الاستهلاك العملي للمياة بين المتوسطات حيث بلغت (P<0.0003). تسلط هذه الدراسة الضوء على الحاجة الماسة لستراتيجيات إدارة المياه الفعالة داخل أنظمة التبريد بالتبخير, خاصة في المناطق الجافة حيث تعد ندرة المياه قضية ملحة. ينبغي ان تركز التحقيقات المستقبلية على دمج حلول الطاقة المستدامة لتقليل كل من استخدام المياه والطاقة وبالتالي تعزيز الاستدامة للبيئة.

الكلمات المفتاحية: التبريد البتخيري، تخفيض درجات الحرارة، زيادة تدفق الماء، التبريد، الحلول المستدامة.

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INTRODUCTION

Iraqi weather is hot and dry during summer (1) and requires a cooling method that helps reduce the temperature of home residences (2,3), poultry barns (4,5), and fruit storage (6,7,8,9) as well as vegetable storage (9). Air coolers are widely used in Iraq because they are inexpensive, perform better, and require less energy than Ac unit. Evaporative pad cooling is a common method used to reduce temperature in the agricultural sector (10). Researchers have extensively studied various factors influencing evaporative cooling efficiency (11), including pad type, (4,13,14,15,16), heat transfer (17,18,19), water consumption (13), water quality (20,2), pad material (21,22,23) pad thickness (24, 25) , and water temperature (28,18). However, few studies have focused on water flow (19,30). The amount of water evaporated from the evaporative pad cooling system was used to provide cool air (31). The water removed from the pads was then used to clean the system from high-concentration salt(21).The amount of water was calculated based on the external temperature and RH (4).Flushing the water system is an essential method for reducing water salt and cleaning the pad from dust because the pad works as a filter to prevent any other objects from sticking to the air (31). These objects, including dust and salt, return to the tank with water because the air cooler is a closed water system operates, as a closed system, recalculating the water that drips from the pad (22). As the outside temperature increased, the air held more water and more evaporation occurred, resulting in more cooling (33,34). This study investigates the impact of increased water flow on water consumption and cooling efficiency in modified air coolers, commonly use in hot and dry climates (35) such as Iraq (12).

MATERIALS AND METHODS

The experiment involved modifying an air cooler with an additional water pump to increase water flow. Measurements were taken for practical water consumption, and temperature, water temperature relative humidity, the thermotical water consumption was calculated. The air cooler had a flow rate of 2500 m^3/ h. The air cooler is widely used in Iraq because it has two variable speeds that can reduce power usage. A water pump was added to the air cooler to work side-by-side with the original pump. Records were taken every 10 min, from 1-3 pm for the outside and inside temperatures, water temperatures, water consumption, and power consumption. The air-cooler motor had two speeds. Kestrel weather meters were used to measure the outside and inside temperatures, and the difference in the temperature was calculated (Δt) (12).

Δt = Outside temperature - Inside temperature ……………...…. (1)

$\eta = [(To - Tin) / (To - Tw)] (100)$..……… (2) by (24)

Theoretical water consumption: Theoretical water consumption was calculated by using psychrometric charts online.

Researchers put outside conditions temperature and Wet Bulb On the output side select g/kg and m3/kg

The air flow rate was calculated by $Q = A * V$ ……………. (3) by (37).

where Q is the airflow rate $m^3.sec^{-1}$, A is the pad area, and V is the airflow (m/s).=

We work to convert it for hours

Then, divide the number by the $m^3.kg^{-1}$ (Digital Psychrometric). The result is kg of air per hour. Multiplying this by $g.kg^{-1}$ (from the spreadsheet), the result in grams (g) of water in the air entering the pad every hour. The calculation was repeated for air once it traveled through the pad, and we obtained grams of water in the air leaving the pad hour. The amount of water evaporated = grams of water in the air leaving the pad every hour - grams of water entering the pad every hour. One way ANOVA with Regression use and Tukey comprise to see the difference. Kestrel 3000 weather meters measured temperature, RH %, and airflow velocity (m/s). A thermocouple measured the water temperature. Water consumption and practical water consumption were measured. These records were recorded every 10 min, from 1p.m to 3p.m. The theoretical water consumption was calculated as the difference between the practical and theoretical values origin 2018 was used to plot the 3-D figures, and SAS 9.4 was used to analysis the data.

RESULTS AND DISCUSSION

The 3-D model in Figure (1) indicates a negative relationship between the temperature inside the room and the water temperature and water consumption. Because hot water contains less moisture and slow air speed allows more time for water to evaporate from the pads, the temperature within the room and the water temperature in the tank decreased as the water usage increased. These results are consistent with the results obtained by (32) as the air flow rate was reduced, which gave more time to evaporative water from the pad, which was also confirmed by (24). The amount of water consumed was 52 L/h , the room temperature was 28-38 °C, and the water temperature was 14-18 °C. These results are based on the following (13).

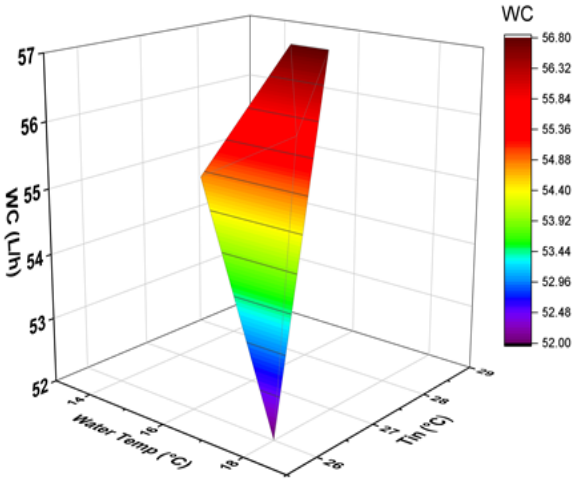

Figure 1. shows the relationship between the water temperature, water consumption, and temperature inside the room when one water pump was used at one speed

The 3-D model in Figure (2) shows a negative relationship between the temperature inside the room and the water temperature and consumption. As the water consumption increased, the temperature inside the room decreased, and the water temperature in the tank decreased because the hot water had low moisture, and the slow air speed provided more time for water to evaporate from the pads. Similar results have been reported in the present study(32). The average water consumption was 54 L/h, the room temperature was 25-37 °C, and the water temperature was 14-18 °C. These results agree with those of previous studies (32.16).

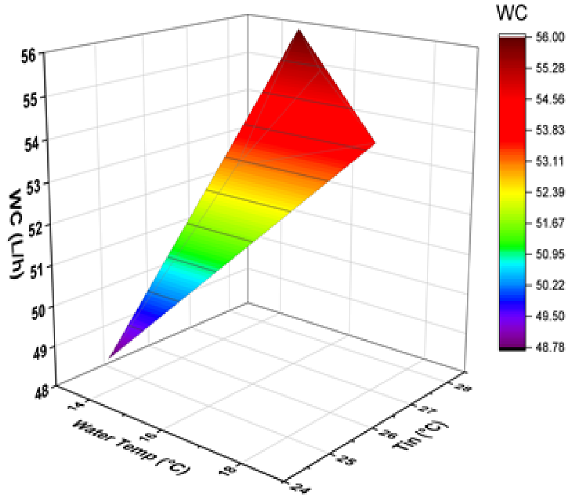

Figure 2. shows the relationship between the water temperature, water consumption, and temperature inside the room when two water pumps with one speed were used

The 3-D model in Figure (3) shows that there was a negative relationship between the temperature inside the room and both water temperature and water consumption. Water consumption increased, which led to the decreased temperature inside the room and water temperature in the tank. Because the hot water has low moisture to hold, the slow air speed gives more time for water to evaporate from the pads (12,38). The average water consumption was 56 L/h, the room temperature was 18-32 °C, and the water temperature was 14-17 °C.

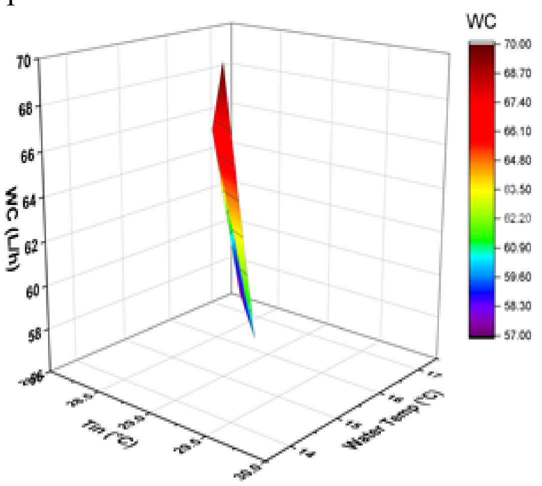

Figure 3. shows the relationship between the water temperature, water consumption, and temperature inside the room when one water pump was used at two speeds.

The 3-D model in Figure (4) illustrates that there was a negative relationship between the temperature inside the room and both water temperature and water consumption. As water consumption increased, which led to the decreased temperature inside the room and water temperature in the tank, because the hot water has low moisture, the slow air speed gives more time for water to evaporate from the pads (26). The average of water consumption was 52 L/h, the room temperature was 24-34 °C, and the water temperature was 14-17 °C.

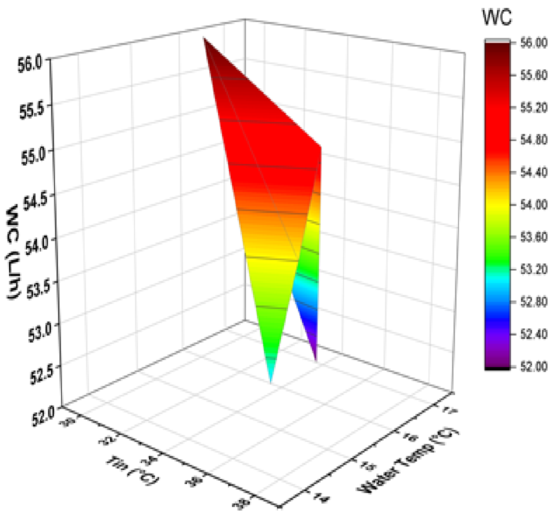

Figure 4. shows the relationship between the water temperature, water consumption, and temperature inside the room when used two water pumps with two speeds are used

Figure 5. illustrates the temperature differences between the outside and the inside temperature for using water pumps with air speed. The lower delta t was 9.4 °C which reduced the temperature to 7-10°C, indicating that the system did well.

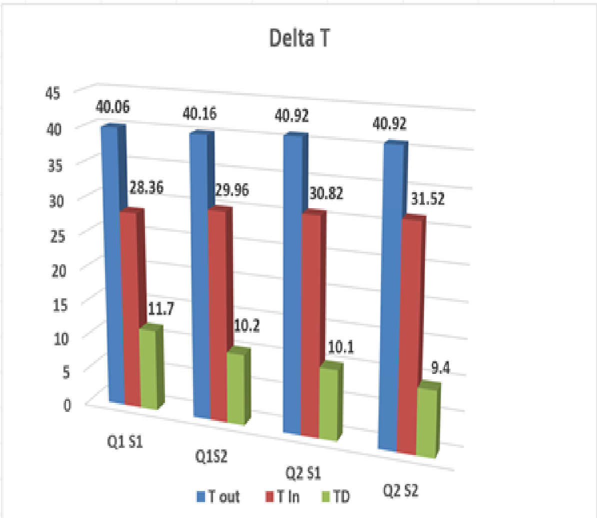

Figure 5. illustrates the average temperature difference between the outside and inside temperatures.

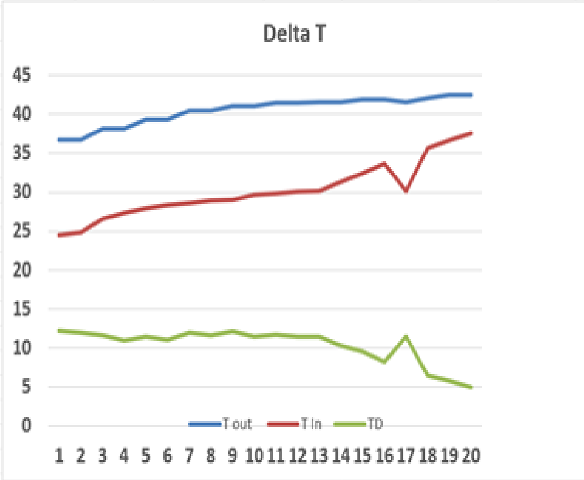

Figure6. illustrates the temperature difference between the outside and inside the cooling room

There was a significant difference between practical and theoretical water consumption. Practical water consumption is greater than thermotical water consumption. The reason behind this may be related to a sheet film of water flowing down the pad area, which increased the resistance to airflow rate and led to the moving part of the free water inside the room, which agrees with the result obtained by (39). Another issue is that the water flow pipe needs to be upside down, and the most common method of water drop over the pad is one pipe with a small hole to drop the water over the pad directly, while the better method is to flip the pipe hole up, which helps the water to drop by gravity and prevent hole clogging (20). As the result shown in the table below there was a highly significant difference for the overall model was highly significant (df $_{(3,19)}$ *=11.21*, p<*0.0003)*.

Table1. One-way ANOVA for practical WC

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	3	351.3500	117.116 667	11.21	0.000 3
Error	16	167.2000	10.4500		
Corrected Total	19	518.5500			

R- Squares	Coeff Var	Root MSE	y Mean
0.677562	5.706348	3.232646	56.65000

As we can see on the table -1 - below there were highly significant differences between mean which was 8.400 for the treatment Q1S2-Q1S1 which was donated by***. There were highly significant differences between mean which was 8.400 for the treatment Q1S2-Q1S1 which was donated by***.

There were highly significant differences between the mean, which was 10.40 for the treatment Q1S2-Q1S1 which was donated by***.

There were highly significant differences between the mean, which was -9.800 for the treatment Q2S2 - Q1S2which was donated by***.

There were highly significant differences between the mean, which was -10.40 for the treatment Q2S1 - Q1S2 which was donated by***.

Table 2. show the significant comparisons at the 0.05 level are indicated by *.**

Treat Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
Q1S2-Q1S1	8.400	2.551	14.249	***
Q1S2-Q2S2	9.800	3.951	15.649	***
Q1S2-Q2S1	10.400	4.551	16.249	***
Q1S1-Q1S2	-8.400	-14.249	-2.551	***
Q1S1-Q2S2	1.400	-4.449	7.249	
Q1S1-Q2S1	2.000	-3.849	7.849	
Q2S2- Q1S2	-9.800	-15.649	-3.951	***
Q2S2- Q1S1	-1.400	-7.249	4.449	
Q2S2- Q2S1	0.600	-5.249	6.449	
Q2S1- Q1S2	-10.400	-16.249	-4.551	***
Q2S1- Q1S1	-2.000	-7.849	3.849	
Q2S1- Q2S2	-0.600	-6.449	5.249	

Comparisons significant at the 0.05 level are indicated by ***

Figure (7) shows a significant difference between the treatment. The **Q1S1**was given a blue color significantly different from the other three treatments.

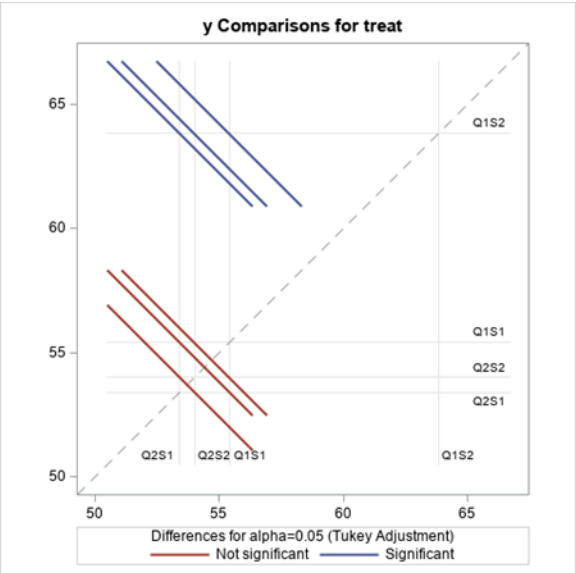

Figure 7. illustrates the Tukey Groping

Figure 8. illustrates the difference between practical and theoretical water consumption

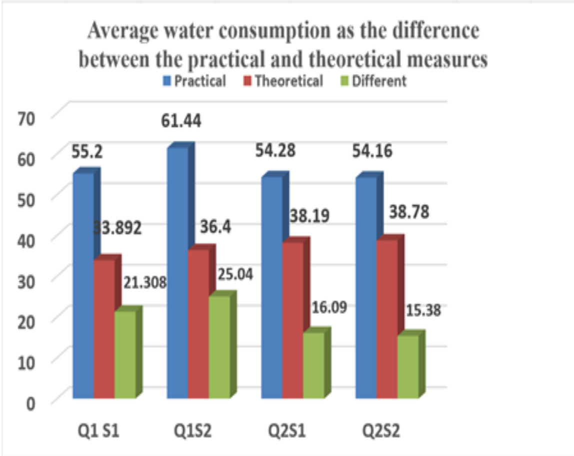

Figure 8. illustrates the average water consumption difference between the practical and theoretical for water pumps with air speeds.

As the result shown in the table below, there was a non-significant difference for the overall model (df $_{(3,19)}$ = ***0.83***, p<*0.4990)* the reason for that due to this test depends on the optimal weather conditions without any drops of water which results by high air speed that was confirmed by (22).

Table3. One-way ANOVA for theoretical WC

Source	DF	Sum of Squares	Mean Square	F Value	Pr>F
Model	3	69.7500	23.2500	0.83	0.4990
Error	16	450.8000	28.1750		
Corrected Total	19	520.5500			

R- Squares	Coeff Var	Root MSE	y Mean
0.133993	14.40438	5.308013	36.85000

Table 4. shown that there were non-significant comparisons

Treat Comparison	Difference Between Means	Simultaneous 95% Confidence Limits	
Q1S2-Q1S1	0.600	-9.005	10.205
Q1S2-Q2S2	2.400	-7.205	12.005
Q1S2-Q2S1	4.800	-4.805	14.405
Q1S1-Q1S2	-0.600	-10.205	9.005
Q1S1-Q2S2	1.800	-7.805	11.405
Q1S1-Q2S1	4.200	-5.405	13.805
Q2S2- Q1S2	-2.400	-12.005	7.205
Q2S2- Q1S1	-1.800	-11.405	7.805
Q2S2- Q2S1	2.400	-7.205	12.005
Q2S1- Q1S2	-4.800	-14.405	4.805
Q2S1- Q1S1	-4.200	-13.805	5.405
Q2S1- Q2S2	-2.400	-12.005	7.205

Comparisons significant at the 0.05 level are indicated by ***

According to the results obtained, this study suggests that the use of two water pumps with one motor air speed improves the air quality by decreasing the inside temperature and can prevent water from falling inside the room.

Although, the results indicate that there is a highly significant difference in the use of one water pump with two air speeds that is a sign of increasing the water consumption. Finally, water quality needs special attention because the water in Iraq is highly salty.

Power consumption

The RPM was 950, which was consumed at 1 A, and the second RPM was 1400 which consumed 1.9 amp. As we can see, the power used increased when we added the second water pump and when the motor was used at two speeds. The power consumption increased from 1.4 amp when one motor speed was used with the original water pump to 3 amp when two speeds were used and two water pumps.

CONCLUSION

This study investigated the impact of increased water flow, facilitated by an additional water pump, and varying air speeds on water consumption and cooling performance in modified air coolers. The finding revealed that practical water consumption significantly exceeded theoretical estimates, likely due to increased resistance encountered by water traversing the cooling pads and water loss. The implementation of two water pumps improved cooling effectively by lowering room temperature about 7-10 °C. That means you get a good performance for your evaporative cooling system, while the results illustrate that the average practical consumption per hour was 56 liters and the theoretical was 36.8. Based on these findings it is recommended to incorporate a supplemental water pump.

Future study and work

Let depend on the lower number in our recommendation and assume that the air cooler will work 12 h daily, and the summer length in Iraq starts from May to September(28).

Air cooler work about 12 h /day Water consumption average 18.4 L /h	
Daily water consumption	220.8 L
The monthly water consumption	6624 L
The total water consumption during summertime	33120 L
*The number of Air cooler	*1 million
The total amount of water	22080000 million/L daily

*Assumed this number of Air cooler in Iraq, but the reality was greater than this. The amount of water each person used was approximately 92 liters daily, and the amount of water used by each air cooler was 220.9 liters. This means that each air cooler is sufficient to provide water for 420 000 people yearly. Therefore, our duty is to look for ways to integrate solar power to run air conditioning (AC) units. This offers a promising alternative to traditional evaporative cooling systems, which consume significant amounts of water. This approach not only reduces water consumption but also provides sustainable energy sources.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DECLARATION OF FUND

The authors declare that they have not received a fund.

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