Valuation of Chilled Water Condensate through Air Conditioning to Diminish Water Scarcity

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***Abstract*— Water scarcity is a problem of the future. The conservation of water becomes a priority for most countries around the world. This problem is more serious in Gulf area and in particular UAE due to limited water resources. However, these countries experience hot and humid climate and uses air conditioning machines almost all year round. As a result, a huge amount of condensate water through cooling coils of air conditioning machines is generated and is typically wasted to municipal sewerage systems. It is envisaged that an extensive amount of low temperature condensate water can be harvested through the commercial and residential high rise building's large cooling capacity plant.**

This paper presents a study that focuses UAE's five years hot & humid climate's air psychometrics. This study provides information that could be used to estimate the amount of chilled water condensate that could be generated during the cooling and dehumidification process in the air conditioning machines, particularly through the fresh air handling units for conservation of potable water.

This alternative source can be utilized in various drainage, irrigation and cooling applications to reduce the use of considerable amount of municipal potable water. This source not only takes part in controlling control the water scarcity, but also in saving energy and to reducing the carbon footprint.

Keywords*— *Air Psychrometry, Cooling & Dehumidification, Chilled Water Condensate, Energy & Potable Water Saving, Water Scarcity

The United Arab Emirates (UAE) geographically [1] is situated in Southwest Asia, bordering the Gulf of Oman and the Persian Gulf, between Oman and Saudi Arabia. The UAE lies between 22°50′ and 26° north latitude and between 51° and 56°25′ east longitude. The climate of the UAE is classified as arid climate [2], as can be seen in Fig. 1 the UAE lies in the arid tropical zone [3]. The summer temperatures remain high, and can be as high as 48°C (118.40° F) inland, but it is lower by a few degrees along coasts. The humidity touches over 90% in the summer and autumn.

The UAE [4] has limited annual rainfall and a hot & humid climate. Significant energy has embodied in potable water due to desalinization. The water conservation is a priority for the UAE. The potable water demands energy and enormously curtailed by using the water conservation techniques. It is a distinct possibility that the UAE will become even drier due to the effects of global warming.[5] Coupled with projected population increases, the importance of accelerating water conservation and reuse efforts is clear.

The Environment Agency Abu Dhabi (EAD) [6] has explicated very clearly in the Abu Dhabi Water Resources Master Plan 2009, that one of the most important challenges for the Emirate is to balance water supply and demand as efficiently as possible, given that the per capita consumption of fresh water is among the highest in the world and new water supplies are expensive. According to Population Action International [7], based upon the UN Medium Population Projections of 1998, more than 2.8 billion people in 48 countries will face water stress or scarcity conditions by 2025, and stress or scarcity conditions will increase to four billion people by 2050.

Bahrain, Kuwait, Saudi Arabia and the United Arab Emirates have resorted to the desalinization of seawater further from the Gulf.

The availability of ground water in many parts of the UAE has been reduced drastically due to the lack of significant replenishment, intensive abstraction by increase in municipal well field's production and increase in agricultural development [8]. The water status of the UAE groundwater is decreasing and desalinated water and treated water is increasing. The population growth has increased the stress on the water resources by increasing the production of desalinated water, which is a costly affair, and decreasing the production of groundwater. To meet the high demands, desalination plants and wastewater treatment plants were established in many parts of the country.

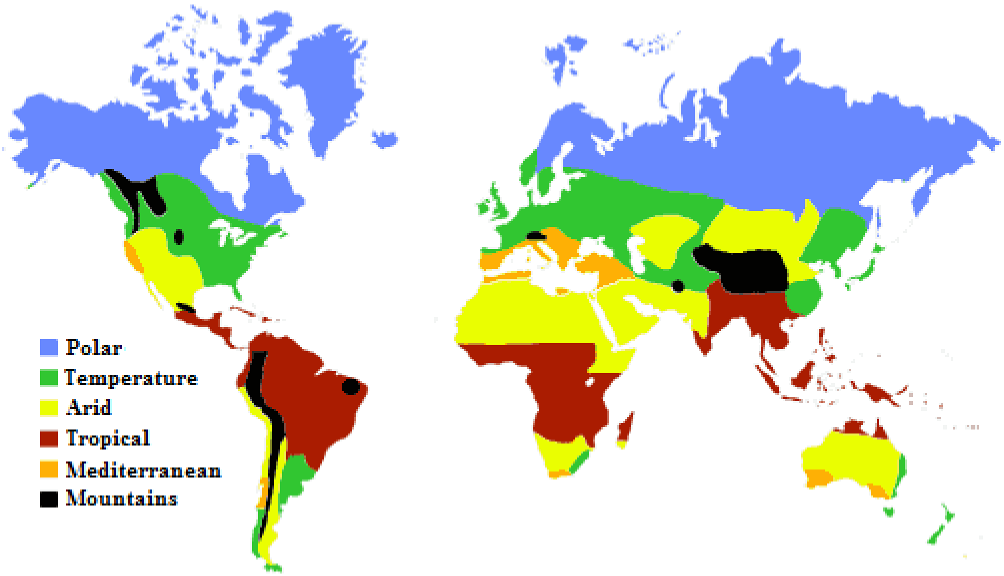

Figure-1: Assorted Climate Zones

The UAE recently spent $2.7 billion and opened its largest power and desalination plant in Jebel Ali to provide electricity and water for Dubai [9]. It has the ability to produce 140 million imperial gallons (168 million gallons) of potable water daily to overcome about one-fifth of Dubai's requirements.

The conservation of potable water by using condensate water is an exceptional considerable source in this region. This is because the UAE's hot and humid climate offers a considerable environment for generations of condensate water, through cooling coils of air conditioning machines and can be utilized for conservation of potable water.

The ASHRAE standards 62.1[10], 189.1[11] and 90.1[12] addresses the fresh air requirements for the buildings to maintain a healthy indoor environment and to control sick building syndrome. The prerequisite fresh air gets cooled by using air conditioning machine to serve the building and produces condensate during cooling and dehumidification process at cooling coil. The standards also explain the energy saving protocol

in context to fresh air requirements in the buildings.

The required ventilation rates to occupied space further increased by 30% to meet the requirements of LEED - Indoor Environment Quality Credit-Increased Ventilation [13], which is further favorable for the generation of condensate water through a cooling coil. The use of condensate chilled water will also take part in LEED for achieving water efficiency credit, innovative waste water technology by reducing potable water use for building sewerage conveyance.

The water conservation is a priority for Estidama [14] because of Abu Dhabi's as well as UAE's limited annual rainfall, hot climate, and the significant energy embodied in potable water due to desalinization. The Estidama focus on minimum interior potable water use reduction to qualify the required credit PW-R1: Minimum Interior Water Use Reduction and PW-2.1: Exterior Water Use Reduction: Landscaping. This can be achieved by utilizing condensate water in toilet flushing systems, irrigation and similar other internal applications.

Dubai Green Building Regulations & Specifications, [15]. gives credit on chilled water condensate water use as described in section six: Resource Effectiveness: Water: Chapter 1: Conservation and Efficiency section 601.03 Condensate Recovery.

Methodology & Analysis

Matrix for Maximum Relative Humidity

From January to December 2007-2012

Figure 2 presents the maximum relative humidity matrix in UAE for last several years. The data has been collected from Dubai Air Navigation Services [16]. .The succeeding graphs and table shows the RH trend per month for the above mentioned period for 24 hrs.

VAC Summary - 3Towers G+2P+7 Residential floors+ Gymnasium Building						
Total Conditioned Building Area	Total Bldg. Cooling Capacity	Recirculated Air Volume	Fresh Air Volume	Total Air Volume	Heat Gain/m2	Air Volume/m2
m^2	kW	$l.s^{-1}$	$l.s^{-1}$	$l.s^{-1}$	$W.m^{-2}$	$l.s^{-1}.m^{-2}$
22848 $x10^3$	3.730 $x10^3$	193.94 $x10^3$	24.680 $x10^3$	218.62 $x10^3$	163.20	9.569

Table 1: Ventilation & Air-conditioning (VAC) Summary

In Figures 2, it is observed that the UAE environment through the year is extremely humid. The outside air RH level was high during the morning, evening and night times throughout the year. This high level of humidity is a major source of latent load and cause for substantial chilled water condensate generation, during the cooling and dehumidification process at the cooling coils (evaporators) of air conditioning machines.

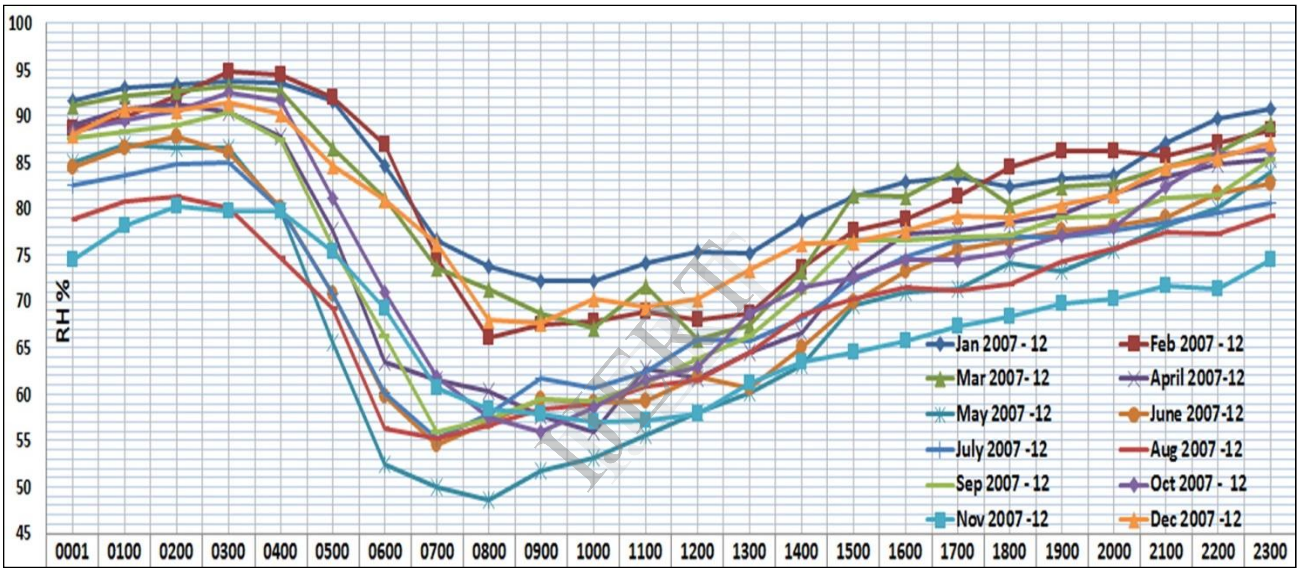

Figure 2: Mediocre Maximum Relative Humidity Matrix (%) Years 2007-2012

The UAE has large numerals of high rise buildings. Thousands of liters of condensate water can be collected and utilized for non-potable application.

A typical residential building consisting of 3Towers+Ground+2Parking+7 Residential floors+ Gymnasium building VAC design was used as a case study for illustration purposes in this study. The design was based on a unitary system along with fresh air handling units to serve the building and maintaining IAQ. The brief summary is as shown in Table 1.

The subsequent analysis as displayed in Table-3 has performed using equation 1 for evaluation of recirculated and fresh air for condensate calculation per annum. Assuming diversity shoulder 20 percentage (%) AC machines off cycle for summer operation (6 months) and 60 percentage (%) off cycle for winter operation (6 months). It is estimated that 3138$x10^3$ liters condensate water can be generated through air conditioning machines recirculated air. While considering average fresh air out door temperatures 46.10/31.20 DBC/WBC for summer and 30.0/23.60 DBC/WBC for winter months, 6605$x10^3$ liters can be generated through fresh air.

***mw** = **V ρ** (**w** on coil outside air or return air – **w** off coil leaving air)* …… …… *(Eq-1)*

Annual Condensate Generation 3 Towers G+2P+7 Residential floors+ Gymnasium Building											
Air Conditioning Machines Air Volume Category	Air Volume		On Coil Conditions			Off Coil Conditions			Condensate Generation (Liters)		
	LPS	MCS	DB	WB	W	DB	WB	W	Summer with 20% off cycle operation	Winter with 60% off cycle operation	Total estimated Annual condensate Generation
Total Recirculated Air Volume	193.94 $x10^3$	193.94	24.44	17.22	0.00935	12.80	12.20	0.00863	$2092x10^3$	1046 $x10^3$	$3138x10^3$
Total Fresh Air Volume	24.68 $x10^3$	24.68	46.10	31.20	0.02292	12.80	12.20	0.00863	$5283x10^3$	-	-
	24.68 $x10^3$	24.68	30.00	23.60	0.01578	12.80	12.20	0.00863	-	$1322x10^3$	$6605x10^3$
Annual estimated Condensate Generation											$9743x10^3$

Table 2: Annual Condensate Generation

The analysis of this case study suggested that huge amount of water $9743x10^3$ liters ($2573x10^3$ US gallons or $9.743x10^3$ m^3) per annum could be collected from a typical residential building that could result in reducing the use of municipal water and achieving the saving of AED 102920 (USD 27994) per annum as per DEWA [17] price of the tap water is 0.04 AED (0.01 USD) per gallon. The cost of infrastructure needed for harvesting this amount of condensate water is shown in Table-3.

UPVC Pipe Dia (mm)	Pipe length(m)	Estimated Unit rate($/m)	Total cost($)
25	300	5.0	1500
50	1000	6.0	6000
75	450	7.0	3150
100	450	8.5	3825
Total cost ($)			15675
Underground tank estimated cost ($)			3000
Labor cost estimated ($)			2000
Grand total cost ($)			**19475**

1AED=0.272 $

Table 3: Estimated Cost for Condensate Water Harvesting

Hence the analysis shown demonstrate that considerable amount of condensate water can be harvested through air conditioning system which is a substantial amount of water through this building. This water can be utilized for non-potable application and can reduce the consumption of extensive amount of distillation water coming from municipal authority. As the UAE is at a high extreme water security risk index of Maplecroft rate,[9] rank nine (9) the potable water conservation is extremely necessitated. The chilled water condensate can play an extremely important role in this context.

CONCLUSION

- The UAE environment is extremely hot and humid throughout the year. Practically, this climate is

controlled by huge number of air conditioning machines resulting in considerable amounts of chilled water condensate during cooling and dehumidification processes at the cooling coils.

- This is wasted condensate water, at a low temperature. This study showed that it can be captured, stored and utilized to reduce the use of potable water, decreasing initial and operational cost and can play a vital role in controlling water scarcity, sustainability and reducing the consumption of extensive amount of distillation water.

- The case study presented in this paper demonstrated that considerable amount of water 9743x10^3 liters (2573x10^3 US gallons or 9.743x10^3 m^3) per annum per annum could be collected from a typical residential building that could result in saving AED102920 (USD 27994)per annum while the installation cost is estimated at $19475 for installation of piping and storage arrangement. The payback period is less than one year.

- There are thousands of high and low rise buildings in the UAE; the stringent government authorities' polices can implement the proper condensate water management system. This opportunity must be used and will be a step towards sustaining the future of humanity and governing water scarcity.

VARIABLES AND ACRONYMS

AHU	Air Handling Unit
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
DXU	Direct Expansion Unit
DB	Dry Bulb Temperature ^oC
DP	Dew Point ^oC
EAD	Environment Agency Abu Dhabi
FAHU	Fresh Air Handling Unit
FCU	Fan Coil Unit
LEED Design	Leadership in Energy and Environmental
LPS	Liters per Seconds
MCS	Meter Cube per Seconds
mw	Mass of condensate water $kg.sec^{-1}$
Q	Cooling Capacity kW, W
RH	Relative Humidity (%)
UAE	United Arab Emirates
UN	United Nations
V	Volume flow of air $m^3.sec^{-1}$, $l.sec^{-1}$
WB	Wet Bulb Temperature ^oC
w	Specific humidity of air $kg.kg^{-1}$
ρ	Density of air, 1.2041 $kg.m^{-3}$ at 20^oC $kg.m^{-3}$

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