Condensate Water Collection for an Institutional Building in Doha, Qatar: An Opportunity for Water Sustainability

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ABSTRACT

In almost all modern buildings today, HVAC equipment is used to provide a conditioned indoor environment while using large amounts of energy to cool, filter, and dehumidify the air in these structures. This is especially true for buildings located in hot and humid climates around the world. International engineering organizations, such as ASHRAE, have developed indoor air quality standards which stipulate substantial requirements for fresh outside air to be introduced into a building's air conditioning system. Internal loads and additional outside ventilation air all generate considerable latent loads on these systems and exacerbate the already difficult moisture control problem. A manifestation of this load is the liquid water condensate that is typically drained away from the air conditioning equipment and routed to the nearest sanitary drain. This project investigated sustainability issues associated with the collection and storage of this condensate water from selected air conditioning equipment for an institutional building located on the Education City Campus in Doha, Qatar. Simplified modeling of the condensation potential from the existing air conditioning systems, means for tapping into existing condensate drainage systems for re-routing to a storage facility, metering of collected condensate water, and potential impact for this water capture and re-use technique were studied. This project demonstrated the potential to capture over 6 million liters (1.6 million gallons) of condensate water each year from the air conditioning systems for this building.

INTRODUCTION

35 years ago, Qatar was a British Protectorate and the main industries were fishing and pearl production. Today, Qatar is a country with the world's 3rd largest proven reserves of natural gas and a significant oil production capacity. Economic growth continues at about 18% per year and with this growth comes coincident growth in water and power demand. Currently, the predominant means of water production is through the desalination of seawater as a by-product of energy production. As of summer of 2008, there are approximately 7,000 MW of natural gas fired electrical generating plants in Qatar (EIA, 2007). Each of these plants utilizes the waste heat stream from the gas turbines to produce water through flash-desalination of sea water.

Production of desalinated water in Qatar is estimated at about 200 million gallons per day (MGPD) and this goes towards satisfying water demand that continues to grow at about 16% per year (ArabianBusiness.com, 2008). The increasing demand for water has spurred the liberalization of ownership and contracting to allow more foreign investment in water and electrical projects in the country. Qatar and other countries in this Persian Gulf region are among the world's largest consumers of water. The current consumption metric stands at about

750 liters per person per day (lpp) (200 gallons per person) which compares to about 425 lpp per day (115 gallons per person) in the United States. Unlike the U.S. however, ground water supplies in Qatar are extremely limited and there are no surface water supplies available at all. Annual rainfall is less than 80 mm (1.5 in.) and usually occurs during the December to February timeframe.

This level of water consumption in a region with such poor natural water availability is clearly not sustainable. Any disruption in water production due to mechanical reasons or because of a contamination of the source water from the Persian Gulf would result in a very real water emergency. Current strategic water storage capacity is approximately 550 million liters (145 million gallons) which, at current consumptions levels, would last a matter of days. Interestingly, many people in this region feel that since water is in the ground or "comes from the sky" that it should be provided free.

The climate in Qatar can be characterized as very arid with hot and humid summer conditions. Maximum daytime temperatures rarely exceed 45°C (113°F) in the summer and 25°C (77°F) in the winter. However, humidity levels soar as summer sets in. By the end of June, there is only a 20° temperature range as the high humidity prevents radiation cooling at night. Dewpoint temperatures in the mid 20's°C (mid 80's°F) are common from July through September. With such conditions, air-conditioning of buildings is required to maintain comfort conditions.

All modern construction in Qatar is heavily air conditioned with a variety of different equipment being used. In residential work, mini-split units are preferred. Most large commercial buildings in Qatar make use of chilled water systems that use either large air handler or smaller chilled water fan coil units for distributed cooling. In any air conditioning system operating with elevated outside dew point temperatures, there will be quite a bit of condensed water generated at the chilled water heat exchanger (either in the air handler or fan coil) that must be disposed. As with chilled water systems in the U.S., it is common to route condensate discharge piping to the nearest sanitary or storm drain.

The objective of this study was to monitor the condensate production from several air handling units serving a classroom/laboratory building on the Education City campus in Doha, Qatar. Issues with tie-in to the existing condensate drain system, quality of the condensate water, collection and metering of condensate, and disposal are discussed in the following sections of this paper. A simple model is proposed to predict the amount of condensate available from typical air handling systems served by chilled water.

DESIGN AND INSTALLATION OF COLLECTION SYSTEM

Choice of Building

The facility chosen for this study is a two story, concrete construction building enclosing about 32,500 m^2 (350,000 ft^2). The building houses classrooms, laboratories, lecture halls, offices, and has a full tuck-under parking area. This building hosts two university programs and a post-secondary academic program. It is a typical day-campus facility with heavy use during the day with activity tapering off by 9pm in the evening. This schedule is followed for weekday use with the building essentially un-used during the weekends. The air conditioning and ventilation for this building is supplied through 25 separate air handling units. These units receive chilled water from a remote chilled water plant located within Education City. The air handlers are all roof mounted.

A survey of the condensate removal system for this building showed that condensate collection at each air handler (AHU) was routed via external piping from the AHU to a nearby roof overflow drain (OFD). The OFD system consisted of 300 mm (4") PVC piping routed down from the roof to floor drains in the tuck-under parking garage. Figures 1 and 2 show a typical roof condensate drain and parking level floor drain outlet for the OFD piping.

Figure 1. Condensate Piping from AHU to Roof Drain, Typical of all Units

Figure 2. Floor Drain and Down Section of OFD Piping in Parking Garage, Typical for all Units.

Choice of AHU Equipment

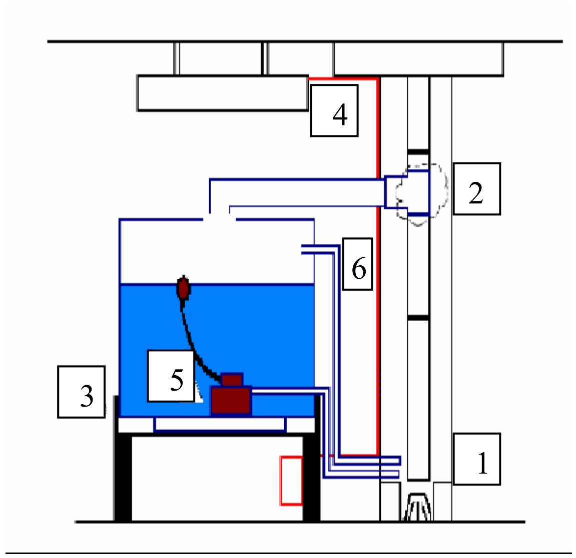
Two AHU systems were chosen for monitoring and condensate collection; AHU #6 serving mostly classroom and office space and AHU #23 that served chemistry, physics, and biology laboratories. AHU #6 was had a rated airflow rate of 8,000 CFM (3,775 l/s) and with modulating dampers to control the amount of outside air introduced into the system. AHU #23 was a 100% outside air unit that provided makeup and conditioned air to laboratory spaces. The single fan AHU had a rated airflow capacity of 17,500 CFM (8259 l/s).

These units covered the type of typical use that air conditioning units might see in an educational setting (both units) or in an office building setting (AHU #6). Both of these air handlers are controlled through a central building management system and are operational 24 hours each day.

Collection Test Stand

The condensate collection apparatus had to be constructed with minimum impact on the existing facility. The Facility Plant personnel were very helpful with our questions and gave complete access to their plan room and to their equipment on the roof of the subject building. However, the facilities personnel could not support installation of a system that might be disruptive to the existing system or installed in an unsafe manner.

After the two AHU's were identified, design of the collection system was started. A schematic of the basic design is shown in Figure 3.



KEYED NOTES
1. Cap existing roof OFD with removable plug.
2. Tie-in new drain piping.
3. 750 liter tank mounted on steel stand
4. 220V power from existing light fixture.
5. Submersible pump w/float switch to pump condensate to existing drain
6. Emergency overflow drain

Figure 3. Schematic of Condensate Collection Apparatus, Typical of two Locations.

All components were obtained from local sources except the steel stand which was fabricated for this project. In essence, this apparatus was installed in series with the existing condensate (roof drain) system. To collect condensate, the OFD opening at the garage drain level was capped, and the pipe would fill with condensate. As soon as the condensate level reached the new drain pipe, it would be directed to the storage tank. .As the tank filled to a given level, the pump float switch would activate and pump out the tank contents into the existing floor drain and into the sanitary collection system. Figure 4 shows the completed set-up for AHU #23. Figure 5 shows the apparatus for AHU #6. This installation was a bit different because of the location of the OFD piping on the exterior of the building. In addition, the perimeter of the parking garage had a sloped concrete finish from garage level up to finish grade. Thus, the steel support stand and piping arrangement are slightly different than that for AHU #23.

Data Acquisition and Digital Scale

The storage tank rested on a stainless steel digital scale that had a capacity of 600 kg. The digital head on the scale had a 0 – 10 Vdc output option that was connected to a portable battery powered data logger. A voltage divider was installed to limit the input voltage at the logger to a maximum of 2.5 Vdc. Thus, at full load the output signal from the digital scale would not overdrive the data logger input. A data logging interval of one minute was used to collect time-series data on condensate water. The logger memory allowed for continuous data collection of about 30 days before it needed to be down-loaded. Once the data were loaded into the logger's software program, it could be output as a comma separated value (CSV) file and imported into spreadsheet or statistical software as needed.

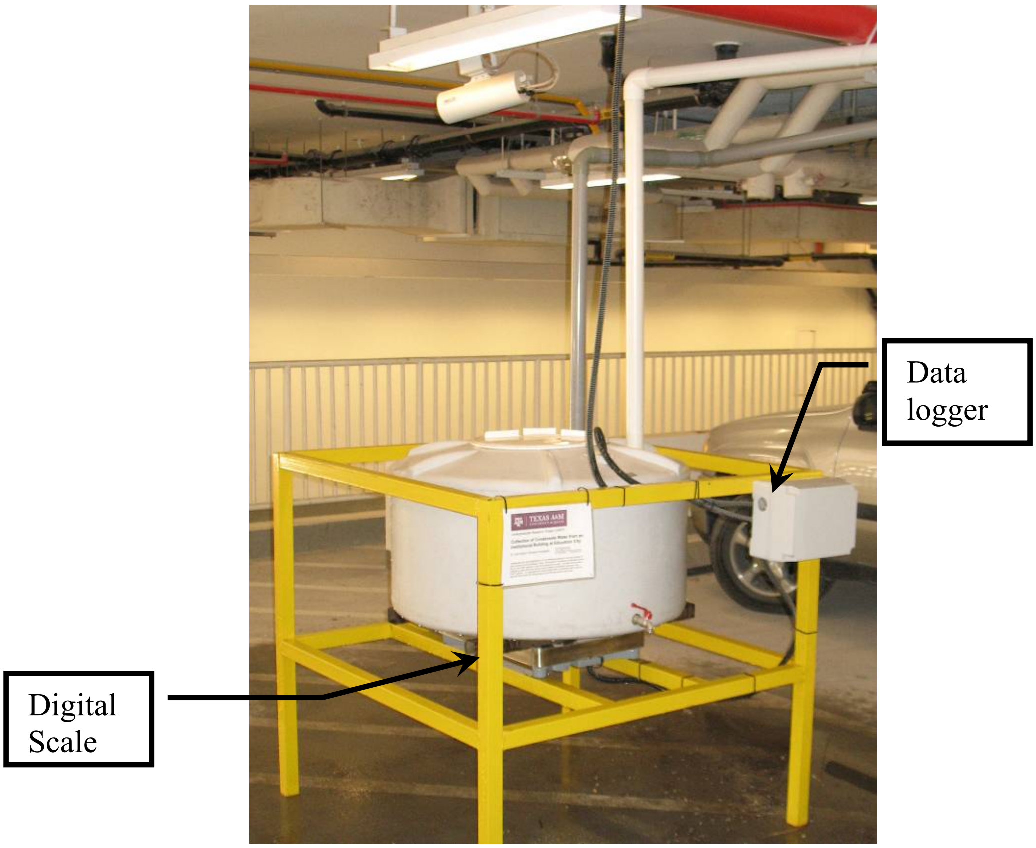


Figure 4. Condensate Collection System for AHU #23

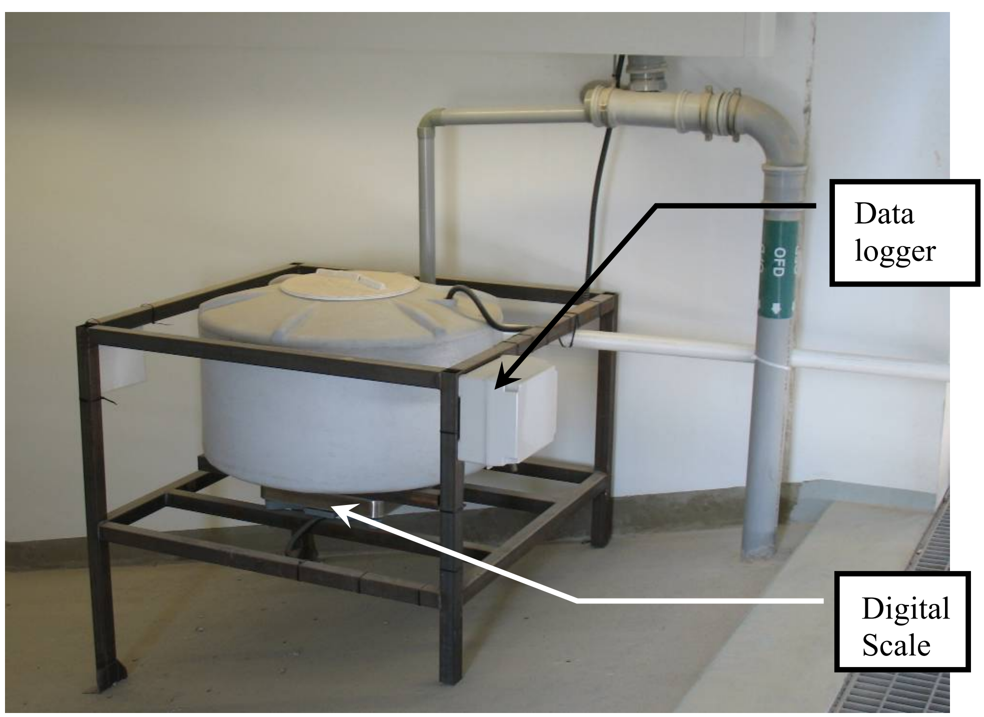


Figure 5. Condensate Collection System for AHU#6

Difficulties with Installation

As with any experimental work, there are always interesting diversions. Though challenged on finding pipe fittings and electrical connectors, local sources were eventually found. After the installations were complete and data were being collected, the rigs were allowed to run for two weeks. After this initial period, a very strange pattern in the data was revealed. Figure 6 shows what the data time series looked like. For some reason, both tanks were showing that no water accumulated overnight for either AHU #6 or AHU #23. Closer inspection showed that the weight from both loggers dropped to zero at about 11 pm each evening and, depending on tank level, "popped" back to some level at about 6:30 am in the morning. About the same time, the Facilities personnel complained about the "leaking tanks" in the parking garage. After some investigation, it became apparent that alternate lighting banks in the garage were being turned off automatically by the BMS each evening then turned back on each morning. Unfortunately, these light circuits were the same ones that were used to power the digital scales in both tank set-ups. The power circuiting was moved to adjacent 24 hour lights and the problem was solved.

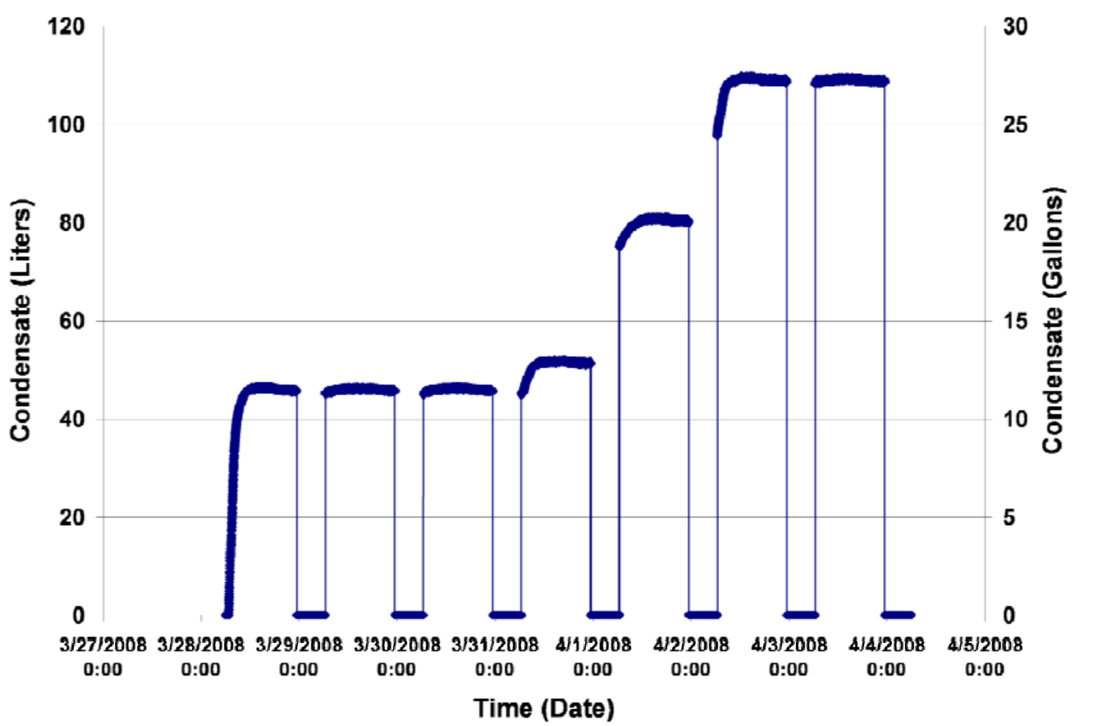


Figure 6. Time Series Condensate Collection at Low Dew Point Temperatures.

The preceding section on installation might be instructive to those who would contemplate a similar installation in an existing building. Though not originally intended to be collected, all condensate from all of the air conditioning systems in this particular building could have been collected and stored in the basement parking garage area. The lesson extends to other proposed installations. Just because it was not piped for convenient condensate collection does not mean that it can not be done. We have to be a bit more persistent and creative to make it possible.

RESULTS AND MODELS

This is an ongoing project and we will continue to collect condensate data through the Fall of 2008. After the problem with continuous power was corrected, data collection really started in July, 2008. The results presented here will span a four week period from the 8th to the 5th of August. The coincident outdoor dry bulb and dew point temperatures during this period ranged from 100°F db and 26°F dp to 102°F db and 89°F dp (37.8°C db and -3.3°C dp to 38.9°C db and 31.7°C dp). During this time, condensate collection varied from almost no accumulation to what appears to be a maximum for the 100% outdoor air unit (AHU #23) as well as for AHU #6. Figure 7 shows data for AHU #6 for the first two weeks of this time period. Note that the frequency of pump-out cycles increased during periods of increased dew point temperatures over the two week period. As the average dew point temperature increased, there was a corresponding increase in the amount of condensate collected. Figure 7 also contains horizontal dashed lines that correspond to average dew point temperatures of 49°F, 70°F, and 62°F that show this same relationship.

Over the four week period, 4,075 gallons (15,443 L) of condensate water were collected at AHU #6. This AHU serves offices and a small lecture hall in the building and could be considered a "normal" air conditioning unit. There are at least two other large units that supply 100% outside air for makeup in chemistry and biology classrooms. The nominal cooling capacity of AHU #6 is 216,000 Btu/hr (63,303 W). It is a two-fan unit with provisions for outside air and exhaust air streams as well as return and supply ductwork.

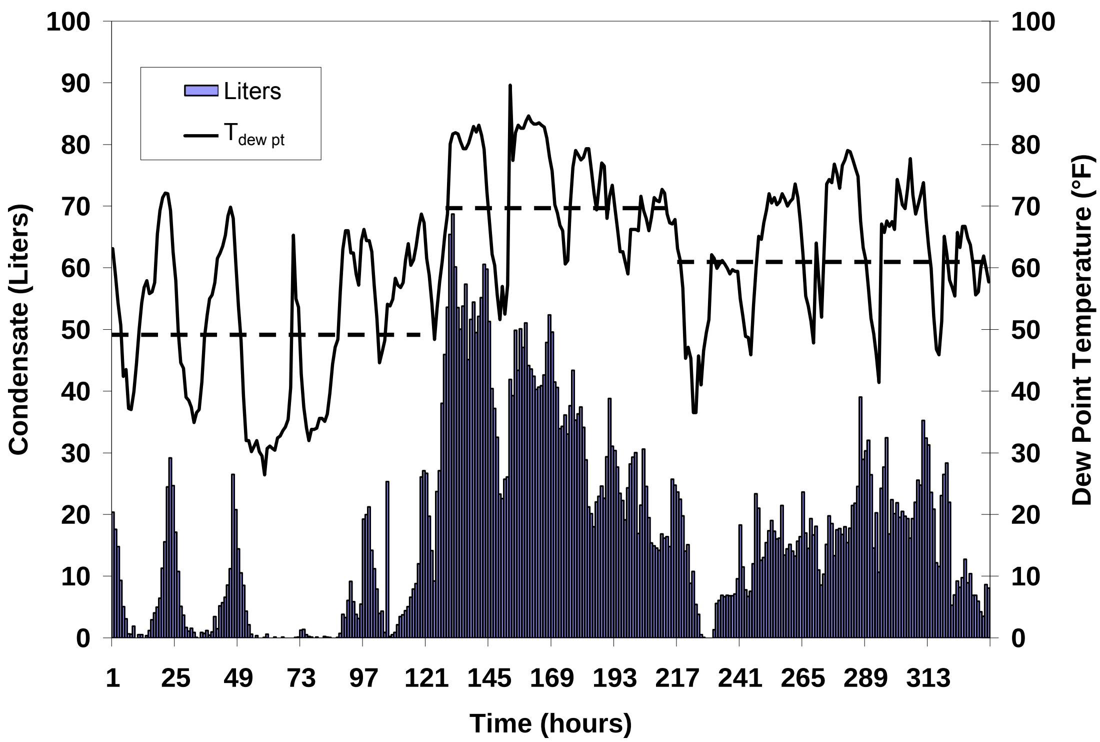


Figure 7. Average Hourly Condensate Collected for AHU #6 for the Period of July 8 – 22, 2008.

Data for the second two week period of July 22 – August 5th showed a similar pattern. However, for this period of time the average dew point temperatures were considerably higher. Correspondingly, the condensate production rate was greater during this period.

Condensate Water Quality

Samples of condensate were collected from the air handling units at the discharge pipe before entering the roof drain. These water samples were then tested for common water quality metrics. Results of the tests are given in Table 1.

Table 1: Water analysis results

Test	Value	Acceptable range
Conductivity	86 µS/cm	0-400 µS/cm
Dissolved oxygen	7.15 mg/L	5-11 mg/L
Turbidity	0.7 NTU	0-1 NTU
Nitrates	0.6 mg/L	0-45 mg/L
Chlorides	1.2 mg/L	0-250 mg/L
pH	6.5	6.5-8.5

The samples were not cultured so potential biological contamination was not identified. However, the water as tested was of very good quality and would be considered acceptable for human consumption with minimal treatment for biological contaminants.

DISCUSSION

A simple model is proposed that could be used to estimate the amount of condensate water that could be generated from a "normal" air conditioning system. This model could easily be applied to commercial buildings in hot and humid climates.

It was assumed that AHU #6 was operating normally and that approximately 20% of the volumetric airflow was made up of outside air with the remaining 80% return air from the conditioned space. Standard return air conditions of 70°F and 55% RH were assumed for the conditioned space and supply air after the chilled water heat exchanger was assumed to be at saturation conditions of 55°F and 95% RH. Air conditioning systems often are rated at their "design" capacity and thus, the nominal cooling rating for this AHU would be approximately 18 tons as given in equation 1.

$$Q = \frac{1.08\ CFM\,\Delta T}{12{,}000} \qquad (1)$$

Where:
CFM = volumetric air flow – 8,000 cfm
ΔT = Temperature difference across the chilled water cooling coil - 25°F

The average daily condensate production for the 28 day period of this study was about 145 gallons/day. This production is tied to the capacity of the particular air handling unit and thus a production per day as a function of cooling capacity is proposed as;

$$Condensate\,Generation = \frac{8gal}{day - ton} \tag{2}$$

This expression is not to be confused with a detailed engineering model for condensate production. It is the beginnings of a reliable empirical expression for the amount of condensate that could be generated from a "normal" commercial air conditioning system operating in a humid climate. Even this expression can only be applied if one knows the number of days that the dew point temperature would be above 60°F. As shown in Figure 7, condensate generation is tied to the potential (dew point temperature) for moisture to be condensed from atmospheric air. This potential is only realized at elevated dew point temperatures because of the way air conditioning systems operate. This is especially true for chilled water systems that supply chilled water at 45°F and experience a 10 - 15°F rise through the chilled water coil. This means the average heat exchanger temperature is approaching 60°F and explains the lack of condensate when dew point temperature is less than 60°F.

Now to carry the example forward, if we assume that a proposed large commercial building is to have 600 nominal tons of cooling installed, the designer would want to be able to estimate how much condensate water would be available from this system. For an installation in Doha, Qatar, there are approximately 3,300 hours a year that the dew point temperature is above 60°F. So, using this information and equation 2, we would have the following;

$$Potential\ Condensate\ Production = 8 \times 600 \times 137.5 = 660,000\,gallons\left(2,500,000\,Liters\right)$$

This is a significant amount of water that, in most commercial buildings, is sent to the sanitary or storm sewer. As shown in Table 1, the quality of this water is quite good and could easily find use in augmenting a grey-water system, primary makeup water in cooling towers, or for use in irrigation. If needed, the water could be processed through a single stage RO system and with either ozone or other bacteria treatment, be used as a source of potable water.

In a climate such as Doha, Qatar with very high per capita water use and little or no naturally occurring water sources, any additional water source should be welcomed. The data from this monitoring project show that there is large volume of water that is currently being discarded and only adds to the waste water treatment needs. Grey water or irrigation needs could very easily be augmented or even displaced with the collection and use of condensate water.

SUMMARY AND CONCLUSIONS

As a step towards water sustainability, collection of condensate water from air conditioning systems has tremendous potential. The current study is following the production from only two of 25 air conditioning units on an institutional building in Doha, Qatar. The data suggest a simple "factor" for estimating the amount of condensate production possible from such systems. A simple example shows that over 660,000 gallons of water could be captured from the condensate drains of the 600 installed tons of air conditioning on a large commercial building in a location with 140 days of dew point temperatures above 60°F. The key wording here is "captured from the condensate drains" in a building. It would be trivial to separate the condensate piping (or combine it with grey water piping) in the plumbing system if planned into the design phase of a project. Planning for storage and re-use of the collected water is also easier at the start of the design phase. Existing buildings are more challenging, but creative solutions can always be developed given the sustainable potential of reusing the condensate. Though not a complete replacement for potable water needs in a modern commercial building, water conservation efforts would make this water go quite a way towards meeting demand. Grey water use, irrigation of vegetation around the building, or as make up water in cooling towers are all proven uses of condensate water collection systems (Frechette et al., 2007). In hot and humid regions, the potential for generating significant amounts of water is available and should be pursued. T. Boone Pickens recently stated that "Water is going to be the next Oil." This is one technique that can help us do a better job of managing a very precious and necessary resource.

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