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Analysis and Exploitation of the Condensed Water of Chillers

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Abstract

Energy resources are going to be exhausted in the near future. It is essentially required to use the energy in an organized manner. Therefore, the chiller's condenser water has been focused to utilize the maximum of the input energy of the machine. This water can be categorized as distilled water if the contamination level is zero. The low-graded distilled water can be used in steam generators; acid-based Batteries, chemical dilution and even can be used in vehicle radiators to avoid blockades of pipes. Generally, the production of distilled water requires a lot of energy. In the present work condensed water of domestic chillers has been analyzed for contaminants to decide its future use. Five samples were collected from chillers installed in the city of Gurrah Mohallah Mandi Bahauddin, in the Punjab province of Pakistan. Using the ethylene diamine tetra acetic acid (EDTA) titrimetric method,a small amount of Ca, Mg, Pb, and SO_4 were detected that confirmed the conductivity of water around 81µS/cm. The magnitude of Total Dissolved Solids (TDS) was 54 mg/L, pH was 6.2 and total hardness was recorded about 0.576 mg/L.

Keywords: Condensed Water; Chiller; Acid Based Batteries

Introduction

The word chiller refers to the electrical device that alters the properties of air by ejecting heat along with humidity from certain space. In the dark ages, peoples were thinking to get the airy environment in the summer season but they failed until the 1800s. Chinese used hand fans approximately 3,000 years ago. Some of their inventors got the reward for making the first hand driven rotary fan. In traditional Middle Eastern ages building's towers were used to get the ambient breezes [1].

In the late 19th century the American engineers worked hard to get a proper space for relaxation. In 1881 the American President James Garfield used a device that blew air through cotton sheets doused in ice water [2].

It was not until the end of the 20th century when Americans had developed Primitive air-conditioning systems, but these were accessible to the rich community only due to its cost and efficiency [3].

In the 1900s, first electric fans appeared in the United States and the chilling units spread beyond America in the last couple of decades. The breakthrough was the electricity and Nikola Tesla's practical module of alternating current motors that made possible the invention of oscillating fans in the early 20th century[4,5].

Engineer Willis Carrier of New York invented the first modern air-chilling system in 1902. This machine was designed for printing plant, where the humidity was the main problem. It sent air through water-cooled coils. In 1922 Willis invented compact centrifugal chiller. In 1965 the Carrier Corporation obsoleted domestic air conditioning systems [6].

The United State of America developed the implanting technique to measure the efficiency of the residential chiller and heat pump in cooling mode.

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This technique was time taking and the laboratory tests were necessary to find a season-wise energy efficiency ratio. The American physicist used a cyclic test to examine cooling capacity by integrating temperature across the evaporator when the compressor is shut down[7].

A complete air conditioning system consists of refrigeration, heat transfer units, air filters, air distribution unit, piping system, and a controller to regularize function of its components.

Condensed Water of Chiller

The previous work has been cited for exploitation of condensed water of the chiller and its applications. Modeling and simulation techniques have been exercised to improve the performance of innovative and alternative Heating, Ventilating, and Air Conditioning (HVAC) systems. The arithmetic code was written for low-grade energy devices such as solar air onditioning and desiccant cooling systems. Siriwardhena and Ranathunga (2013) [8] worked on chiller's condensate recovery system and captured the condensed water. They advised planning for storage and re-use of the collected water. T. Boone Pickens stated that "Water is going to be the next Oil"[8].

El-Ghonemy (2012) [9] reported that freshwater collected from the ambient environment can be used for agriculture purpose. Due to the acute shortage of fresh water in some regions of Northern Africa, the Middle East, and Southern Asia poorly filtered water was used for drinking and planting purposes. Solar powered and open-air evaporating techniques had been used for producing fresh and pure water. It is still a common practice among the scientists of Europe to develop ideas of production of fresh water on an industrial level [9].

Scrivani and Bardi (2008) [10] used solar concentrating plants to extract atmospheric water vapor. They adopted both direct and indirect methods. Quantitative calculations were carried out by simulating different weather scenarios in three targeted Mediterranean partner countries (Jordan, Lebanon, and Morocco). The indirect method of cooling power provided by chillers to extract water from the air can be considered economically interesting in specific conditions [10].

Wahlgren (2001) [11] discussed the atmospheric water vapor processing designs for the potable water production system. Atmospheric water vapor processing (AWVP) technology was used to condense air molecules [11].

Khan and Al-Zubaidy (2013) [12] emphasized on the conservation of condensed water from air conditioning machines in a hot andhumid climate of United Arab Emirates. He ensured the availability of condensate water in the field of agriculture and municipalities. Khan added that the high floor building's HVAC systems for fresh air can produce 2600 liters of condensate water in 24 hours and 78000 liters in a month, which can be used to reduce the need of potable water and to save a significant amount of energy and to control CO2 emission up to 0.54284 kg per kWh energy[12].

Condensed water of chiller may be referred to as the byproduct. The surficial temperature of evaporator coils falls to 4oC–5oC when the chiller is turned on. Air being thrown on evaporators condenses on the surface; as shown in figure 1. The ingredients of condensed water depend on the space allocated for a chiller. The composition of water may contain many metallic, nonmetallic particles along with NOx and SOx. It is, therefore, a charming situation for environmentalists to go for deep analysis of condensed water. Allover the world and particularly n Pakistan, a little attention has been given to utilizing this water. Therefore, it is the need of time to analyze the water and suggest its appropriate use.

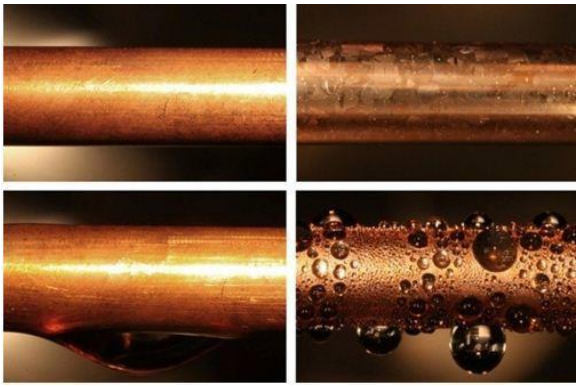

Fig 1. Condensed water on the surface of evaporator coils

Materials and Methods

Experimental setup

The experimental setup was executed for chillers already installed. Five samples were collected from Gurrah Mohallah (Mandi Bahauddin) Pakistan in plastic insulating bottles for analysis.

Analysis Techniques

Conductivity

The technique of electrical conductivity was opted to measure the concentration of ionizable solutes present in the sample. Therefore, conductivity may be considered a significant tool for monitoring and surveillance of the water spectrum including pure water, drinking water, natural water, processed water, condensed water, etc. It is also used to evaluate the concentrations of conductive chemicals in water[13].

TDS

Total dissolved solids (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in water. The conductivity meter can be used to obtain a good estimate of the TDS in water. For a neutral sample the temperature compensated conductivity reading can be converted to TDS in a unit of ppm through the conversion given as;

TDS= (conductivity in µS / cm) × 0.666 [14].

pH

Hardness is one of the variables that predict the quality of water. The quantity of calcium and magnesium contents (ppm) in water present the hardness of water. Water hardness can be instantly identified through titration using the chelating operator [16]. The reported values are given in table 1.

Table 1. Water Hardness [18]

TDS (ppm)	Conductivity µS/cm	Designation
0-70	0-140	Very soft
70-150	140-300	Soft
150-250	300-500	Slightly hard
250-320	500-640	Moderately hard
320-420	640-840	Hard
>420	>840	Very hard

Results and Discussion

Different parameters of condensed water of chiller were examined through different techniques. Demand for clean water is a common slogan. It is one of the appealing situations attracted our attention to the question in hand. The results are summarized in table 2.

The conductivity of the five samples reported recently is (42- 144) µS/cm. The recommended range for drinking purpose is (50-500) µS/cm [17].

Total Dissolved Solids (TDS) were found in the range of (28.0-95.9) mg/L.

The water can't be recommended for drinking and medical purposes. Its low-mineral contents and lack of Sanitizers (chloride) makes it excellent for other purposes such as irrigation, acid batteries, steam engines, and radiators etc.

The **pH** of condensed water falls in the range of (5.5-6.6). Generally, the pH of condensed water less than 7 is considered acidic. The pH of condensed water can be increased by adding soda ash[18].

Hardness of the five samples (1-5) are quantified as (0.39 mg/L), (0.53 mg/L), (0.54 mg/L), (0.61mg/L) and (0.81 mg/L) respectively. Some salts and sulfate like calcium, magnesium, SO_4, lead, and chloride are reported in recent study. The chemical analyses of the condensed water and compliance with the WHO are summarized in Table 3.

The recommended concentration level of **calcium** in drinking water is 75 mg/L and current study of five samples reports calcium contents as 10 mg/L, 21 mg/L, 13 mg/L, 02 and 10 mg/L respectively.

The recommended concentration level of **magnesium** in drinking water is 30 mg/L mg/L[15 . The concentration of magnesium in samples (1-5) are reported as 4.0 mg/L, 1.0 mg/L, 6.0 mg/L, 0.4 mg/L and 2.2 mg/L respectively.

Lead contents reported in five samples are 0.20 mg/L, 0.33 mg/L, 0.24 mg/L, 0.20 mg/L and 0.33 mg/L. The limit of lead in drinking water is 0.05 mg/L and no relaxation for the maximum permissible limit[18]. Lead is a cumulative general poison and associated with several health hazards like anemia and damage to kidneys.

Concentrations of **sulfate** in five samples are reported as 3.0 mg/L, 4.0 mg/L, 6.0 mg/L, 6.7 mg/L and 8.8 mg/L respectively. The contaminant sulfate level in drinking water is reported at 250 mg/L(Agar, 2010). The mean sulfate level in condensed water is 5.7 mg/L may be increased by treatment. Sulfate treatment is done by ion exchange, distillation, and reverse osmosis[19]. A small amount (0.01 mg/L and 0.02 mg/L) of **chloride** in sample 1 and 3 is reported. The contamination level for chloride in drinking water is 250 mg/L[20]. Chloride treatment is made by distillation, and reverse osmosis[15]. Chlorine disinfected drinking water concentration level has been reported as 0.2-1 mg/L[11].

Table 1. Results of different parameters of water samples under study (N/D=Not Detected)

Samples	Cond: µS/cm	pH	Total Hardness	Elements mg/L							
				TDS	Ca	Mg	Pb	Cr	Fe	SO_4	Chloride
1	48	6.3	0.39	32	10	4	0.2	N/D	N/D	3	0.01
2	42	6	0.53	28	21	1	0.33	N/D	N/D	4	N/D
3	62	5.5	0.54	41.3	13	6	0.24	N/D	N/D	6	N/D
4	109	6.6	0.61	72.6	2	0.4	0.2	N/D	N/D	6.7	0.02
5	144	6.6	0.81	95.9	10	2.2	0.33	N/D	N/D	8.8	N/D

Table 2. The chemical composition and WHO standards of water

Parameter	WHO-Guideline value	Upper and lower limits of condensed water of AC	Mean value of condensed water of AC in the study area
Conductivity µS/cm	0-400	42-144	81
T.D.S (mg/L)	1000	28.0-95.5	54
pH	7.0-8.0	5.5-6.6	6.2
Total hardness (mg/l) as $CaCO_3$	100	0.39-0.81	0.576
Ca (mg/l)	75	21-37	11.2
Mg (mg/l)	30	0.4-6.0	2.72
Pb (mg/l)	0.05	0.02-0.33	0.26
SO_4 (mg/l)	250	3.0-8.8	5.7
Chloride (mg/l)	0-250	0.01-0.02	0.006

Conclusion

Five samples of condensed water of air-conditioners have been analyzed for conductivity, TDS, PH, chloride, sulfate, calcium, magnesium, lead, chromium and iron. Three samples were collected from the residential area and two from air polluted region.

Electrical conductivity might be used to check water quality. Chromium and iron are not detected in these samples. Chloride, sulfate, and pH stay below the permissible value.

Increased values of conductivity, magnesium, and lead stay up in permissible value. The condensed water of the cooling system is recommended for cooling purposes like chiller attached with different equipment, and evaporative coolers. Laundry may be included for the same purpose. Acid-based UPS batteries can be maintained with the condensed water of air-conditioners. The water may be utilized to grow a few shrubs and flowers around the home. Some newest generation of air-conditioners actually uses the condensed water to cool the hot condenser coils of the chiller itself.

So-called condensed water is an environment-friendly and beneficial addition to our economy. The condensed water and environment linkage is the optional part of the research work, which might be used as a probe to investigate the pollutants of the environment in a novel way. The same investigation is in practice for a long time with some other techniques such as sample collection by the surfaces of polythen bags. leaves etc.

Since the condensed water has a negligible amount of Magnesium and calcium, that causes blockades of water lines, it is therefore recommended for heat and steam engines. The common issue with heat engines and steam generators is the blocking of water/steam guiding pipes due to different salts dissolved in tap water used.

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