Emerging An Approach to Recuperate Condensate Water From Air Conditioners In Karachi, Pakistan

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Abstract

Fresh water supply is a major problem in big cities likewise in Karachi - a metropolitan city of Pakistan. Some of the technologies can contribute to freshwater supply at a reasonable cost which is becoming significant, and the influence of these technologies can lead to reducing water scarcity. The research presented in this paper is related to water extraction from air, particularly with the intention of generating it for exceptional events, when the availability of drinking water is challengeable. The concept of the study shows the possible methods for the collection of condensate water from Air Conditioning (AC) units to relieve water scarcity in this metropolitan city. An AC of a commercial building was selected from the city as a reference sample of water. Comprehensive characterizations are being conducted that include physicochemical and microbiological analyses to determine the quality of studied water and to evaluate this water for prospective purposes. The condensate water quality is determined for essential parameters, and majorly conductivity and turbidity were found 18 µS/cm and 7 NTU respectively. It is significant to note that the examined condensate sample is showing resemblance to distilled water and it requires a low polishing cost for further treatments for physicochemical parameters which include ion exchange resins, electrochemical processes, UV treatments, and for microbiological parameters, it includes preferably membrane filtration technique due to its low cost.

Keywords: *Condensate water; Quality; Air conditioning; Scarcity.*

1. Introduction

Water is a tremendous resource for all living creatures, and it also performs a crucial role in the economic, environmental, and social development of the world. Inadequate water supply and distribution also contribute the water scarcity nowadays. Water suppliers face so many challenges in providing sustainable, equitable, and cost-effective water to living beings. Mainly the water crises in the globe are ascribed to water deficiency, in several parts of the world. The other considerable reason for water inadequacy is the lack of water administration [1]. Pakistan is one of the thirty-six republics of the world that are water-stressed countries. An increase in urbanization, industrialization, agricultural activities, uninterrupted water distribution and supply, and climatological disorders had led to water crises in Pakistan [2]. Thousands of people every year lost their lives due to the lack of unavailability of freshwater supplies. Pakistan's population of 207 million records that 21 million people extremely have no access to clean water [3] whereas the other factors include water scarcity in the form of incidental and operational conditions [4]. Pakistan ranks third on the list of water scare countries recently studied by the International Monetary Fund (IMF) [5]. Authorities of the South Asian countries have been alerted by the United Nations development program (UNDP) and Pakistan Council of Research in Water Resources (PCRWR) that water will no more available by the year 2025 for domestic purposes [6]. Water is more rigorous in Pakistan's economy than in other countries [7].

The water scarcity has affected the domestic use of water in Karachi (7th largest city in the world), due to poor infrastructure and inadequate facilities. The balance between the use of natural resources and their need to preserve is one of the biggest challenges in urban planning. Karachi has a population of 14.9 million people according to the latest census in 2017 that indicates it is the most densely inhabited city in the world. The search for livelihood opportunities has caused the migration of people from rural areas to Karachi and has resulted in urban sprawl [8]. According to Karachi Water and Sewerage Board (KWS&B) supplies, the provision of approximately 665 MGD water, against the

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requirement of 820 to 1,200 MGD causing a supply gap of 155 to 535MGD [9].
The above-mentioned facts emphasize the urgency of finding unconventional water sources. Condensate water which is produced from Air Conditioning (AC) units can be an alternative source of water with no cost as a by-product via condensation of air humidity during the cooling process, which is normally discarded all over the world. Treatment of condensate or its recycling can make it useful for drinking, flushing, irrigation, and industrial processes as a water conservation technique [10]. A substantial quantity of condensate water is predicted to be generated from AC in a humid environment like Karachi and can be used for different purposes. An increase in summer peak temperatures and continuous urbanization has increased AC sales in Pakistan up to 24% in a year, amid soaring demand in Karachi. The recent estimation shows markets sales is increased to approximately 725,000 units from August 2015 to 2016, from around 550,000 in the same period of the past year [11].
It is estimated that the AC generates 25 L/day, which can vary from 5 to 20 gallons per day for a house to millions of gallons per annum for large housing structures such as commercial and industrial buildings, residential apartments, and large educational institutes [12]. The use of condensate for gardening purposes can help in achieving the sustainability objective. Feasibility and utilization of condensate water is possible in different ways like boiler water, water used in batteries, industrial functions, irrigation, washing clothes, drinking purpose etc. [13]. Recovering AC condensate water has emerged as the latest technology of water resource management which has contributed to a great extent. According to a study, 2 ton air conditioner unit produces 25 L/day [14].
The main purpose of the research is to evaluate the quality of AC condensate water for different uses in Karachi city. This study targets to determine the quality of condensate water by performing physicochemical and microbial analysis. This paper also includes different applications of condensate water like gardening, battery filling, car washing, toilet flushing, floor washing, etc. to reuse the water which is usually not taken under consideration.
This paper is arranged in four sections. Methodology is being presented in Section 2 while results are being discussed in Section 3. All conclusions are summarized in Section 4.

2. Materials and Methods

The research presented in this paper is comprised of two types i.e., desk-based and field-based. A secondary source of data is being considered and reviewed in line with the field of interest from the published materials such as scholarly articles and books of literature studies. In reference to the condensate water quality and quantity, the primary source of information is collected through the collection of samples from Karachi in summer 2021. The condensate water from the AC is collected in clean and sterilized plastic bottle. Systematically the condensate water is evaluated to determine the level of contaminants in the sample by applying laboratory techniques linked with WHO and relevant water guidelines.
Condensate water quality analysis includes some crucial physicochemical parameters which are Turbidity, Copper concentration, Chloride concentration, Lead concentration, Hardness, TDS, pH, TSS, Conductivity etc. The analysis of these parameters are carried out by using Turbidity meter (HACH 2100Q), HACH DR 2800 UV Spectrophotometer, pH meter, TDS meter, DRB 2000 Reactor, and prime microbial analysis parameters include *Legionella*, *E. coli*, Coliforms, and Total Bacterial Count, performed by the membrane filtration technique from the standards of APHA and WHO in the accredited ISO 17025 Certified laboratory from PNAC, Karachi.
A quantity assessment process of the condensate water is conducted in Karachi to devise an outline of the condensate water revenue from the AC. The sample of condensate water from an AC is collected from an office building comprising of a new AC in one-litre capacity sterilized water bottle, as shown in Figure No. 01. The water sample is escorted by filling a form which includes sample location, date, time, type and the capacity of AC unit (2 tons).

Fig. 1: Photograph showing AC water sample

3. Results and Discussion

The results of sampled condensate water quality and quantity analysis, carried out in Karachi, is presented and discussed in this section.

3.1. Quality Evaluation of Condensate Water

Quality assessment of condensate water aims to recognize certain elements that can be present in water and can be risks for living creatures. The results of condensate water show a little variation in the chosen parameters. It must be noted that these quantities are being selected for water quality monitoring program, on the basis of chance of occurrence. Tested parameters result in the generation of condensate water from AC and are correlated with the standards of World Health Organization (WHO) and Sindh Environmental Quality Standard (SEQS), 2016 for drinking water. The methods adopted for analyses are shown in Table 1.

Table 1: Physicochemical and Microbial Quality Analysis for the Condensate Water Samples

S.NO	PARAMETER	UNIT	WHO	SEQS	RESULT
1	**Color**	PtCo	≤ 15 TCU	≤ 15 TCU	ND
2	**Odor**	.....	Non-Objectionable/ Acceptable	Non-Objectionable/ Acceptable	N/O
3	**Turbidity**	NTU	< 5 NTU	< 5 NTU	7
4	**pH Value**	.....	6.5 – 8.5	6.5 – 8.5	7.32
5	**Total Dissolved Solids**	mg/L	< 1000	< 1000	120
6	**Total Hardness**	mg/L	…..	< 500	7.77
7	**Conductivity**	µS/cm	…..	……	18
8	**Chloride**	mg/L	250	< 250	6.34
9	**Lead**	mg/L	< 0.01	≤ 0.05	ND
10	**Copper**	mg/L	2	2	0.005
11	**Chromium**	mg/L	0.05	≤ 0.05	ND
12	**Mercury**	mg/L	0.001	≤ 0.001	ND
13	**Zinc**	mg/L	3	5	0.004
14	**Total Plate Count**	CFU/ml	< 500/ml	<500/ml	558
15	**Total Coliform**	CFU/ml	0/100ml	0/100ml	78
16	**Fecal Coliform**	CFU/ml	0/100ml	0/100ml	0
17	**E.coli**	CFU/ml	0/100ml	0/100ml	18
18	**Legionella**	CFU/ml	<10/ml	-	0

WHO = World Health Organization
SEQS = Sindh Environmental Quality Standard

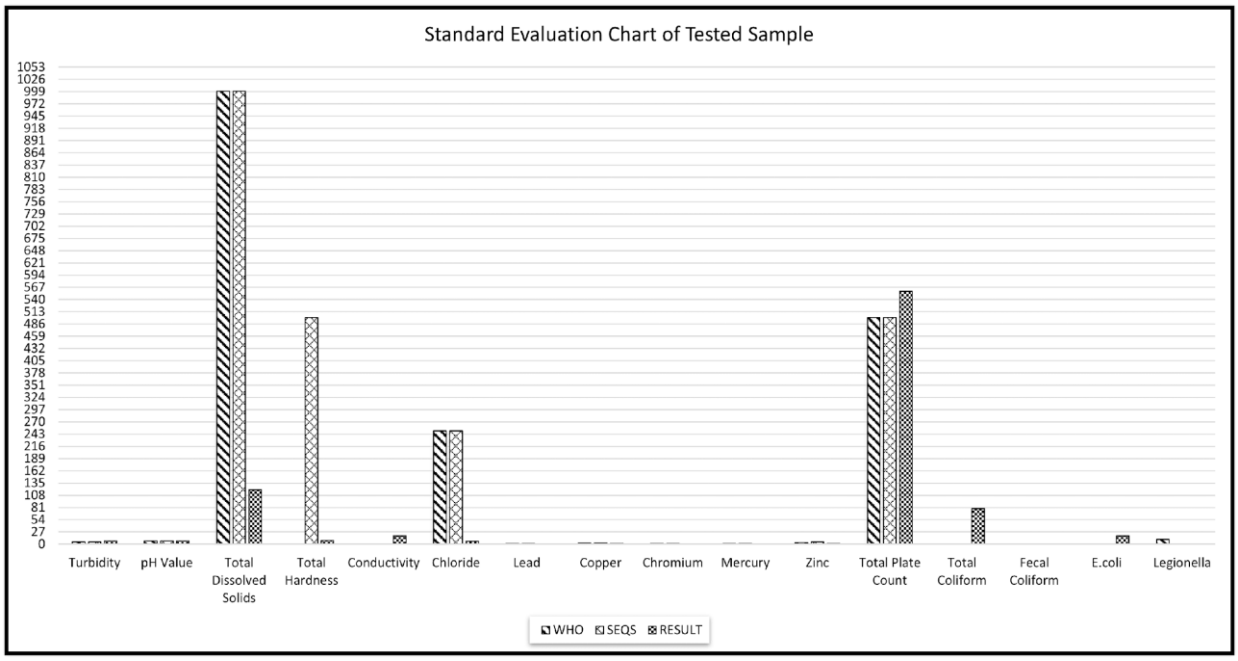

Fig. 2: Standard evaluation chart of tested sample

Condensate water sample concentrations are 0.005mg/L, 0 mg/L, 0.18µs/cm, 7 NTU, 6.34 mg/L, 7.32, 7.77mg/L, and 120mg/L of Copper, Lead, Conductivity, Turbidity, chloride, pH, Hardness and TDS respectively while the microbial parameters are 558cfu/ml, 78 CFU/100ml, 0 CFU/100ml, 18 CFU/100ml, and 0 cfu/10ml of total plate count, total coliform, Faecal coliform, *E. coli* and *Legionella* respectively. In collected condensate water the absence of heavy metals indicates no hazard for irrigation and domestic purposes except for drinking. The quality of condensate water is found unfit for human consumption while this investigation discovered that the quality is close to distilled water, and it can be further recommended for domestic usages such as for washing and other household purposes, fisheries purposes, and irrigation.

3.2. Quantification of Condensate water

Variations with respect to different parameters in one type of AC in terms of discharge rate and volume are prescribed below in Table 2. In Karachi, one of the targeted locations is visited for quantification assessment with reference to time. The commonly used AC is of the capacity of 2 tons.

Table 2: Volume and discharge rate of condensate water with collection time for one type of AC

S. No.	Key Features	Unit	Specification
1	**Sample ID**	EA	ACW
2	**AC Capacity**	Tons	2.0
3	**Collection Time**	hr.	1
4	**Volume of Water**	Litre	1.08
5	**Discharge Rate**	l/hr.	1.08

The above discharge rate per ton determines by applying the arithmetic mean formula "Σ (discharge rate) / Σ cooling capacity" and shows the result is 1.08 L/hr. Using empirical approach, it can be said that the discharge rate has directly proportional relation with the cooling capacity.

4. Conclusions

Karachi city has extremely hot and humid weather, so the requirement of AC peaks in every residential and commercial buildings as well as in industries. This AC produces a large amount of freshwater and this water is discarded without taking into account its importance and availability. In view of water shortage in metropolitan city Karachi, being an alternative source of condensate water, it can be utilized for many domestic and industrial purposes. The analysis of physicochemical and microbial parameters indicates that the quality of the studied water has close resemblance to distilled water. Comparison with WHO and SEQS standards, the analyses readings of sample are fulfilling the requirements of most of the standards. This study presents that condensate water would be beneficial for different purposes including washing, irrigation and sanitation etc. Condensate recycled water can also be beneficial for drinking purposes in low-budget treatment. Hence it is suggested that increasing sampling size will produce better picture of its exact utilization.

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