Water condensate management of atmosphere humidity in Bandar Abbas, Iran

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Abstract:- Earth's atmosphere contains billion cubic meters of fresh water, which is considerable as a reliable water resource, especially insultry areas. Water is produced from air conditioners, with no cost, as a by-product.

This cross - sectional study was conducted to evaluate the quantity and chemical quality of water obtained from Bandar Abbas air conditioners; at intervals beginning of March to early December period. Sixty six samples were taken in cluster random plan. To collect samples, Bandar Abbas was divided into four clusters; based on distance from the shore and their population densities.

Water analysis was based on chemical tests as: turbidity, alkalinity, total hardness, dissolved solids and electrical conductivity. Meanwhile sample quantity measurements were performed. Obtained water had slightly acidic pH, near to neutral range. Total dissolved solids, electrical conductivity, total hardness and alkalinity of extracted water were in very low ranges. In average, each air conditioner produced 36 liter of water per day. Split type air conditioner produced more water than window air conditioners. With regard to some assumptions, approximately 4680 to 9360 cubic meter of water per day can be obtained by this method in this city which is suitable for many municipal and industrial water applications.

Key-Words: - Atmospheric moisture, Air conditioner, Water extraction, condensation, Bandar Abbas

1 Introduction

Hard water is one of the most abundant natural resources, only about 3% of the earth’s water is fresh and less than 1% of total water in earth is available. The rest are out of access at present and it is in the form of vapor in the atmosphere, soil moisture and etc [1]. In recent years, the problem of fresh drinking water supply concerns in many communities, especially in arid and semi-arid areas [2]. So, it is over 50 years that different ways of supplying water such as desalination by distillation, reverse osmosis and electrodialysis, has been used in order to obtain fresh water. However, studies still need to search for new technologies to find better ways of utilization and performance which have not been resolved.

International organizations warn that serious water crisis will affect Iran in 2025 (UNEP, 2004). Of course, sources such as intake of enormous resources in the North and South of Iran and even atmosphere vapor are other alternatives for the water crisis combat. Earth's atmosphere contains 12900 cubic kilometers of fresh water; which 98% of that amounts as vapor and the rest 2% are in the form of clouds. So, the important context is how to extract the water, and in another word: the economic exploitation of this water is more considerable [4]. Atmospheric Water Vapor Processing (AWVP) is a developing technology based on the condensation of the moisture in the atmosphere and then collecting the water [5]. There are many places on the planet due to climate conditions (topography and parameters weather), which can be used for condensation moisture in the air as a source for water supply [6].

A method for the condensation of atmospheric water vapor is the use of equipment with condensation mechanism, worth to mention that water obtained by this method requires high cost [7].

Significant areas of Iran are located in arid and semi-arid, so the country has been faced with problems related to water shortage. While one percent of the world's population lives in Iran, Iran's share of renewable water resources is only 0.36 percent. In Iran, there exist a very high humidity in coastal areas, so in summer season, the air humidity even reaches as high as one hundred percent. For example, in the southern areas of Iran, condensate atmospheric moisture can be used for various consumptions. In southern Iran, especially in coastal cities, due to warm and humid climate in a long period of year, air conditioner is used as cooling systems. Air conditioners have two models; window and split type.

Window air conditioners are often located on a tray behind a window and there is an outlet for discharging the condensed water at the end of the tray. In split type air conditioners also there is a pipe for condensation water discharge. In the past studies, water production as a byproduct of air conditioners has been considered as an idea for the water supply system in warm and humid climates. Thus, no charge for this water is necessary; hence the use of this water can be very efficient [8].

Based on a study about extraction of water from atmospheric moisture in dry areas; millions liters of water can be obtained from atmospheric water vapor [9]. Several studies have been done about the use of atmospheric moisture as a reliable source of water.

Many studies in the field of water harvesting from atmospheric moisture has been performed that in all studies atmosphere moisture has been introduced as a reliable source of water supply [2, 10–13].

In a study leading to the patent, Bar developed a new technology for extracting water from atmospheric moisture that in this method, water was collected in three stages [14]. Studies in the field of water extraction from atmospheric moisture using a metal collecting plates has been carried out in different parts of the world: Sweden and Tanzania [15], Tunisia and France [16, 17] and Bahrain [18] are good examples of this subject.

The purpose of this study was to achieve the quality and quantity of water samples extracted from Bandar Abbas air conditioners in order to develop management programs for optimal use of this permanent source of water, based on qualitative and quantitative specifications.

2 Material and methods

Study was conducted to evaluate the quantity and chemical quality of water obtained from Bandar Abbas (BA) air conditioners. BA is located in Hormozgan province, South of Iran (Fig. 1).

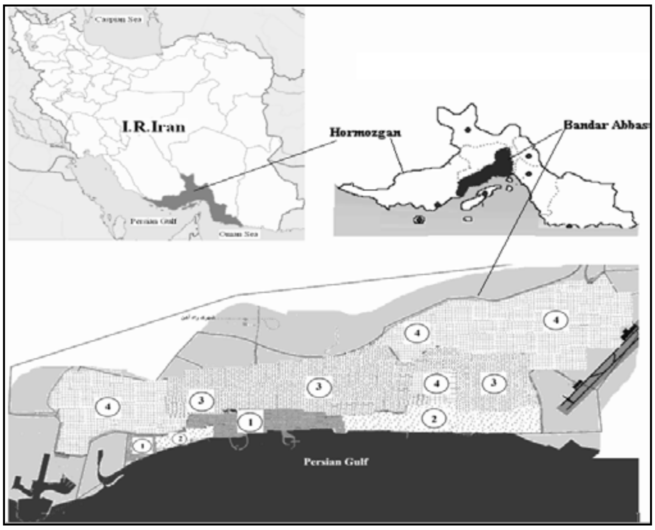

Fig. 1.Geographical location of Bandar Abbas, south of Iran & Classification of Bandar Abbas on the four areas

Total Sample numbers in this study were sixty six. Sampling plan was cluster random; each cluster was one of the BA regions. In this

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division BA was divided into four clusters, based on distance from the shore and the population densities. Cluster 1 includes the coastal areas with high population density with vehicle traffic. Cluster 2 includes the coastal areas with low population density and vehicle traffic. Cluster 3 includes offshore areas with high population density and traffic vehicles and finally Cluster 4 includes offshore areas with low population density (Fig. 1).

To calculate the sample size a water production rate of 30 to 55 liters per day was assumed for each home air conditioner. Thus, with respect to the standard deviation of 6 σ, sigma was determines as 4.16. After that 1 liter was assumed for measurement error and using sample number formula ($n=\frac{z_{\alpha/2}^{2}\times\sigma^{2}}{d^{2}}$) sample volume was calculated. Based on the area covered by each clusters, sample number for each region was determined, thus 14, 16, 17 and 19 samples were taken from cluster 1 to 4, respectively. In order to consider the seasonal conditions in the study, the samples were taken in 9 month period; at intervals beginning of March to early December of 2011.

In order to sampling for chemical parameter tests, plastic bottles with a capacity of 1.5 liter which previously were washed with distilled water were used. The bottles located on the desired locations and then transported to the laboratory in determined time period. Plastic containers with a capacity of 20 liters were used for quantitative measurement. The collected water samples were measured using a calibrated gauge two times per day. After sampling, samples were sent to the laboratory for chemical analysis which included: turbidity, alkalinity, total hardness, dissolved solids (TDS) and electrical conductivity (EC).

Hardness and Alkalinity measurements using titration methods and reagents made by *Merck* company, expire date by end of 2012, based on standard No c 2340 of the standard reference method were performed [19]. Measurement of pH using pH meter *Elmetron* Model CP-501 was conducted by using the method specified in the catalog system. For EC and TDS analysis, TDS meter model Aqualytic CD24 and for turbidity, turbidity meter Hach Model 2130B was used. For alkalinity measurements, titration methods and reagents made by Merck Company, expire date by the end of year 2012, based on standard No B 2320 of the standard reference method were performed [19]. Data were analyzed using (mean, standard deviation, Max, Min), Student test and ANOVA (P<0.05 for significant) with Statistical Package for the Social Sciences (SPSS) 16.0 for Windows.

3 Results

In this study, generally two categories of quantitative and qualitative data obtained from the cooler waters of Bandar Abbas in the gathering.

Qualitative results about the parameters contained in the study are presented in figures 2 to 4. Quantitative results about water production rate of each home air conditioner are presented in table 1.

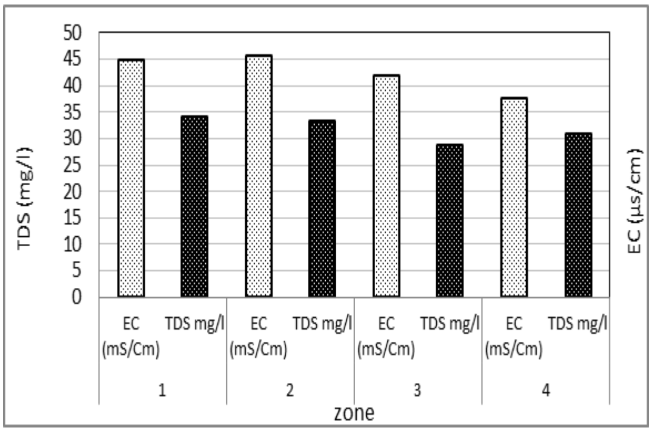

Fig. 2.Average values for TDS and EC of air conditioner water condensate in BA

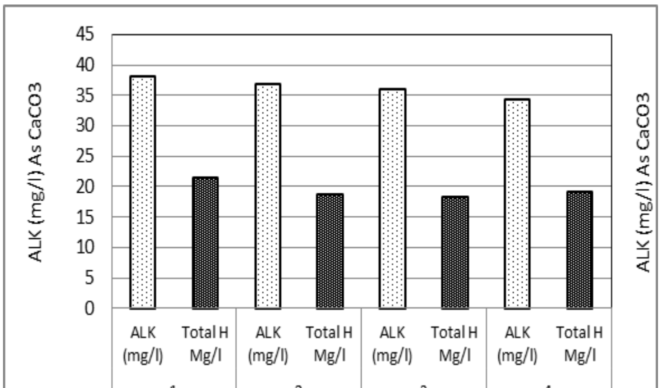

Fig. 3.Average values for Total hardness and Alkalinity of air conditioner water condensate in BA

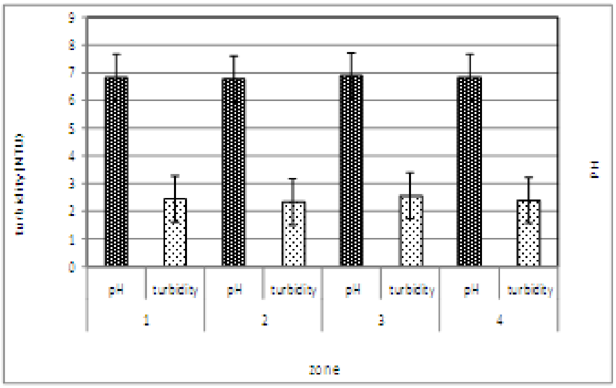

Fig.4.Average values for turbidity and pH of air conditioner water condensate in BA

Table 1: quantity of produced water by each home air conditioner in Quarter periods (l/d)

zone	Zone 1			Zone2		
Sampling duration	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 1**	**Quarter 2**	**Quarter 3**
Number	14.0	14.0	14.0	15.0	15.0	15.0
Mean	33.4	47.1	29.1	33.8	47.6	21.3
Std Dev	3.7	4.3	3.0	3.8	5.0	2.5
Min	27.9	40.3	24.7	28.0	40.3	24.7
Max	37.9	52.7	33.8	39.7	55.3	32.5
zone	Zone 3			Zone 4		
Sampling duration	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 1**	**Quarter 2**	**Quarter 3**
Number	17.0	17.0	17.0	19.0	19.0	19.0
Mean	30.4	44.9	30.1	31.0	45.1	28.7
Std Dev	3.3	5.1	2.2	3.6	4.2	3.0
Min	24.7	37.1	24.9	26.0	36.4	23.4
Max	35.1	52.7	34.5	37.1	51.4	33.8

4 Conclusion

According to the results, pH of extracted water is slightly acidic; close to neutral range, it would be related to the presence of gases, and especially carbon dioxide is in the air. The t-test showed no significant difference between the mean pH in the four regions (P-value > 0.05).

The average turbidity measurements showed that the minimum and maximum average of turbidity is 2.35 and 2.55 NTU, respectively. Minimum measurements for turbidity were related tolow population density region close to the beach and the maximum measured in the high density away from the beach. Test t-test significant differences between mean turbidity was observed (P-value <0.05). We supposed turbidity of extracted water is close to zero, same aspure water, while results showed a significant value for turbidity. It would be because of suspended particles of dust presence in BA air and the second factor can also be related to the particle emissions from vehicles. As, it was stated previously, considering the low and high traffic locations in the study made significant differences in the results.

As presented in Figure 2, there is a significant differences between both electrical conductivity and total dissolved solids in regions close to the beach and in regions away from the beach with P-value <0.05. The average electrical conductivity and the total dissolved solids are higher in the water samples in the areas close to the beach than in the areas away from the beach. This could be due to dissolution of salts from the sea which presents in water droplets in the atmosphere above the sea.

Figure 4 represents that the alkalinity of water samples are in the range of 17-22 mg/l as $CaCO_3$ which classifies the water samples into low alkalinity waters category. Minimum and maximum hardness values were measured 36 and 41 mg/l as $CaCO_3$, respectively. Based on these values, the water classified into very soft category and water can cause corrosion of metal in contact, so, it is necessary to consider this for any consumption.

Bandar Abbas has more than half million population and the average family size of 5 people. Supposing 1 or 2 air conditioners per each household, about 100,000 to 200,000 air conditioners are exist in BA. The average of extracted water per unit in the four regions is about 36 liters per day. With these assumptions, it can be estimated that about 4680 to 9360 cubic meters of water can be extracted from BA air conditioners per day. table 1, shows that the production rate of water in split air conditioners is more than of the window types and the difference between them were also significant (P-value <0.05).

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This difference in the quantity of extracted water between two air conditioner types would be related to appropriate collection system in a variety of split air conditioners, while in the window types, the water initially collected in a tray and then be transferred by a pipe or hose. Thus evaporation of water in trays or leak from the tray or pores is a good reason for lesser water production in the window types. Perhaps the major reason for the difference in the amount of water production in the two types of air conditioners is related to higher efficiency in split air conditioners. Due to public interest increment in the split air conditioners, it is predicted to increase the extraction of water from the air conditioners, therefore the planning for this significant amount of water, it would be economically justified. As mentioned earlier, no excess fee or energy is necessary for water production in this method which is a significant advantage of this method.

Considering that the coastal cities of southern Iran are often located in scarce water areas, this water can be considered as a significant and important source for many types of urban and industrial consumptions, exclusion of drinking needs. According to tests carried out, the water quality is suitable to many municipal uses such as irrigation, landscaping, swimming pools, fountains in the parks, building construction, firefighting, and car washes and so on. Also with matching quality chemical extracted water to the values listed in Table 2 which is related to the standards of industrial water in Iran [21], it can be find; excluding very sensitive group, extracted water has good quality for all needs of water industries. In order to ensure the microbial safety of the condensate water, recommended amount of 5 grams per cubic meter of per chlorine powder to be added to the water.

Basically for judgments about any source of water, some principles such as the impact on health, quality of products, cost of treatment, type and surface treatment technology and its effects on biodiversity have to be considered. The chemical quality of the collected samples, and the bacteriological quality of water samples, after a simple disinfection, should have no adverse effect on consumer's health. Of course, the collected water without treatment is not recommended for drinking purposes. As mentioned later, the condensate water has suitable quality for many of industrial uses while this water source is freely accessible, for a few applications with no cost for treatment, no adverse effects on environment, no harmful effects for equipment and no health risks. At this time, the mentioned water not only is useful for any use, but also by dripping on the floor crates aesthetical and cognitive health problems for residents of these areas. Therefore, it requires a comprehensive plan for collection, storage and for its best applications.

Table 2

Range of water quality indices for different groups (mg / l)

Parameter	low sensitive	relatively sensitive	sensitive	very sensitive
Fe	0-1	0-0.3	0-0.1	0-0.05
Mn	0-1	0-0.3	0-0.05	0-0.01
pH	5-10	5-10	6-10	7-9
Hardness	0-500	0-250	0-10	0-5
Alkalinity	0-500	0-150	0-100	0-50
Sulphate	0-500	0-250	0-75	0-20
Silica	0-50	0-250	0-100	0-5
TSS	0-100	0-10	0-5	0-1
TDS	---	0-500	0-100	0-50

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