# Feasibility studies for water harvesting from fog and atmospheric moisture in Hormozgan coastal zone (south of Iran)

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## Abstract

The level of precipitation in the coastal towns & islands of the Hormozgan province is very low, but the relative humidity so high that wets the soil at below dew point temperatures and could therefore be utilized for relieving the water shortage, to some extents by employing water harvesting systems from fog & air moisture. The inhabitants of Qeshm Island have made efforts from the ancient times to collect air moisture along rainwater gathering. The reminders of these efforts are 366 small wells drilled in stone, which are now a tourist attraction. This method is also applied today in a less elaborate manner.

This research has been carried out to study the feasibility of water harvesting from fog and air moisture in the coastal towns and islands of the Hormozgan province of Iran on the northern shores of the Persian Gulf.

To examine the potential water in the atmosphere, the data from Bandar Abbass synoptic station with a statistical period of 1961-2005 was reviewed and the humidity values of over 70% and wind speed less than 5m/s were analyzed. The average water content of each cubic meter of air in Bandar Abbas in its most dry condition is 16.2g which amounts to 19.5g in its most humid state. The maximum water yield by applying this method could be harvested from 22 June until 22 September. The recorded data show that highest rate of moisture in each cubic meter of air occurred in 1961 while the highest extractable water potential was in 1995. Mentioning these facts, somehow indicate the importance of parameters effecting water harvesting such as wind speed and direction and the amount of moisture in the air.

Field observations and archaeological artefacts approve the results obtained by the conducted estimations showing the feasibility of water harvesting from fog & air moisture in this region and its rates in the different seasons.

## 1. Introduction

In the coasts and islands of southern Iran, the relative air moisture is high so that its value during summer reaches over 98 percent; but rainfall is very low in this region. Also, in this region, areas like Kish Island have over 150 foggy days in year, and Bandar Abbas, Jask, and Lenge Port have over 100 foggy days during each year. Among other important issues in this region is that in contrast to northern coastal areas in Iran where most fog occurs during winter, most fog occurs during warm months and summer in the southern coasts [1].

The residents of the coastal cities and islands of Hormozgan Province experience the contact of air moisture to solid material, e. g. metal objects like the structure of an ongoing construction, parked cars, stones and concrete blocks, etc., and their concentration into water drops making them wet during summer nights and early mornings. At times even water turns to small streams in the streets.

The use of the outlet water from air conditioning devices and coolers for watering plants in small gardens, the little streams of water and dews from putting plastic covers on plants, and the creating of small ponds for gathering the waters are common practice.

Dr. Kardovany, one of the scientists working in the field of dedesertification, proposed a project for harvesting water from air humidity for watering gardens and farms in this area in 2001. He believes that by burying metal plates in the fields, the plants can live with no need for rainfall and by only using the dew created by high air humidity[2].

Thus, if the water resources in this area do not suffice for drinking, air humidity can be used, especially during summer. This research studies the feasibility of harvesting water from air humidity and fog in the coastal regions and islands of Hormozgan using meteorological statistics and information from Bandar Abbas and Gheshm.

## 2. Area Under Study

relatively high during the year and its value increases from west to east. The location of Hormozgan with a sultry period of over 6 months is shown in Figure 1 [3].
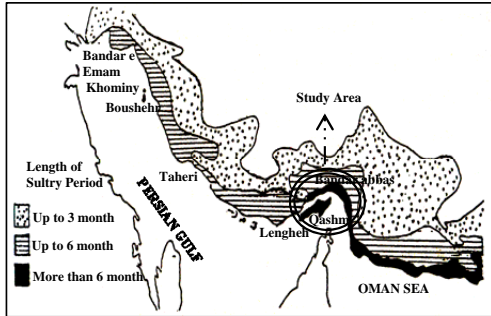


Figure 1: Sultry period in the southern coasts of the Persian Gulf

According to the results from Bandar Abbas synoptic station with a statistic period of 1961-2005 and Gheshm synoptic station with a statistic period of 1996-2005, the maximum annual relative air humidity in Bandar Abbas is 100% which includes 33 years of the 45 years of statistics. The average maximum annual relative air humidity is 99.4% and the average annual relative air humidity in the 45 years of statistics is 65.3%.

In Gheshm, the maximum annual relative air humidity has been reported as 100% which includes 7 years of the 10 years of statistics. The average maximum annual relative air humidity in Bandar Abbas is 99.4% and the average relative air humidity in the 10 years of statistics is 69.0%.

Also, according to Figure 2, which shows the occurrence diagram and probability curve of relative humidity in Bandar Abbas area, in approximately 8 to 10 percent of the year, the humidity has been reported as over 90% and the maximum occurrence rate in Bandar Abbas is recorded as 60 to 70%, which is 70 to 80% in Gheshm.

During 80% of the year in Bandar Abbas and 85% of the year in Gheshm, the relative air humidity has been reported to be over 50%. During about 55% of the year, the relative air humidity has been recorded as over 70% in Gheshm (approximately 50% of the year in Bandar Abbas).
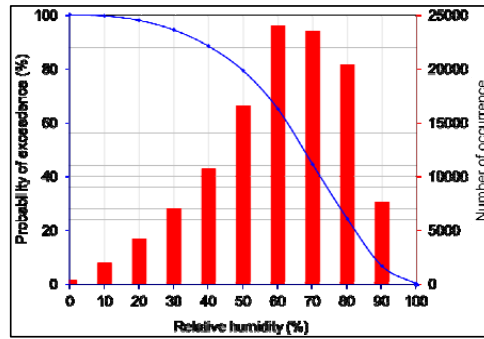


Figure 2: Frequency of occurrence and probability curve of relative humidity in Bandar Abbas s. station

## 3.Feasibility Study Criteria & Bases

Based on the thermodynamic parameters of the air mass, including the relative humidity and air temperature, the amount of water in the air and its conditions for saturation by the dew point can be calculated. This means that the conditions in which the ratio of humid air mixture $r(p,t)$ should get close to the ratio of saturation mixture $r_w(p,t_d)$ are that the dew point temperature should be less than air temperature $(t_d < t)$, for the $r = r_w$ condition to occur.

Concentration occurs after the following processes.

- First, processes in which water vapor in the air is kept constant, and by decreasing the temperature, becomes lower. This can be shown as below:

| Initial Condition | Temperature Decrease | Final Condition |
|---|---|---|
| $r_w > r$ | $\rightarrow$ | $r_w = r$ |
| Humid Air | | Saturated Air |

- Second, processes in which the maximum water vapor which a particle can absorb, i. e. $r_w$, is kept constant, and the water vapor in the particle is increased [4].

| Initial Condition | Water Vapor Increase | Final Condition |
|---|---|---|
| $r_w > r$ | $\rightarrow$ | $r_w = r$ |
| Humid Air | | Saturated Air |

Generally, a process in which the $r_w$ of an air mass can be decreased to $r$ or less (first process), is the basis for water harvesting from fog and air humidity.

In the relations above, p stands for air pressure, t for air temperature, and r the ratio of humid air mixture.

Also, td is the dew point temperature and $r_w$ is the ratio of saturated air mixture.

In the feasibility studies based on the smallest dew point temperature to reach saturation, values of 70% to approximately 92% of relative humidity have been used for conditions to harvest water from air humidity and relative humidity between 92% to 98% in additions to concentration cores for fog production with a wind speed of less than 6m/s have been used for feasibility studies. Thus, all other values for air humidity and wind have been omitted.

As to the elaborate statistics during the 45 years in Bandar Abbas, the years 1961 and 1992 were determined for maximum and minimum potential water in air humidity and the year 1995 was chosen as the 45-year average and studied. The data from Gheshm station was only used for control purposes due to similar results. The average air humidity of the area in the year 1995 is shown in Figure 3.
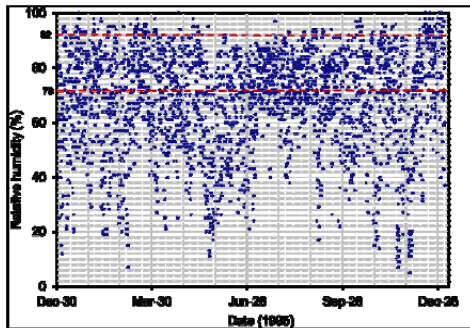


Figure 3: Relative humidity and fog average time-series diagram in Bandar Abbas synoptic station

The time-series diagram of wind in Bandar Abbas in the year 1995 is shown in Figure 4. As it is known, minimum wind speeds open the way for maximum water harvesting.
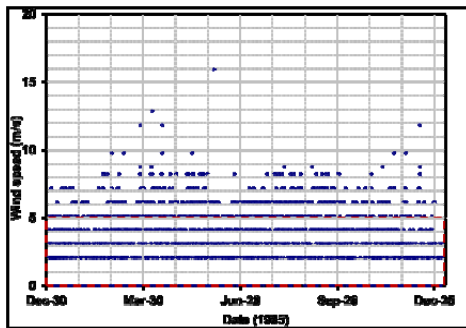


Figure 4: Wind time-series in Bandar Abbas station

## 3.1. Water Value in Air

To calculate the water value in the air, humidity indicators were considered for the whole year and as it can be seen in Table 1, the sum of the existing water or the annual net humidity has been divided by number of occurrences.

Table 1: Calculation of Water Value Indicator

| Year | Water Value (Yearly) | Number of Occurrences per Year | Water Value Indicator (gr/m3) |
|------|------|------|------|
| 1961 | 28450 | 1460 | 19.5 |
| 1992 | 47540 | 2928 | 16.2 |
| 1995 | 50936 | 2917 | 17.5 |

Thus, the average water value in 1m3 of air in Bandar Abbas in its driest conditions is 16.2gr, 19.5gr in its most humid conditions, and 17.5gr in average conditions. In Figure 5, the harvestable water is shown in contrast with the non-harvestable water.
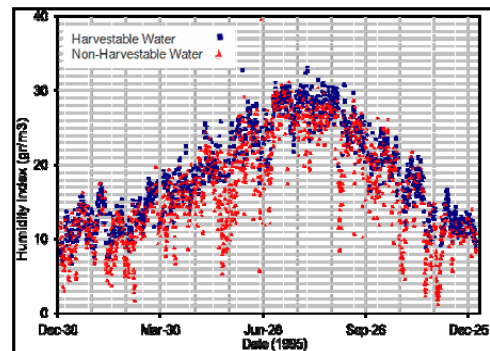


Figure 5: Harvestable water time-series diagram in Bandar Abbas synoptic station

Since the meteorology data is recorded with a time period of 3 hours, the considered harvestable water volume should be calculated with the wind speed value for 3 times. For example, in one specific 3 hours, for 2gr/m3 water and a wind speed of 1m/s, the maximum harvestable water volume would be:

2 (humidity indicator) × 1 (wind speed) × 3600 (one hour) × 3 (time indicator) × 100% (harvesting indicator) = harvestable water volume

= 21.6 (lit/m3 per 3 hours)

In Table 2, the maximum harvestable water in different years, the monthly, daily, and hourly average have been shown.

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Table 2: Calculation of Maximum Harvestable Water (lit/m3)

| Year | Yearly Sum | Monthly Average | Daily Average | Hourly Average |
|---|---|---|---|---|
| 1961 | 113935 | 9495 | 312 | 13.01 |
| 1992 | 84294 | 7025 | 231 | 9.62 |
| 1995 | 221392 | 18449 | 607 | 25.27 |

Since the water cannot be completely harvested and the harvested volumes depends on both the continuity of harvesting conditions during the 3 hours and the performance of the device. Thus, for calculating the harvestable water, even if an indicator of 10% is used, according to the results obtained by different experiments by researchers around the world from the fog network device, the results can be suitable (Table 3) [5].

Table 3: Calculation of harvestable water (lit/m3) according to harvesting indicators

| Harvesting Indicator | Year | Yearly Sum | Monthly Average | Daily Average | Hourly Average |
|---|---|---|---|---|---|
| 10% | 1961 | 11394 | 949 | 31 | 1.30 |
| | 1992 | 8429 | 702 | 23 | 0.96 |
| | 1995 | 22139 | 1845 | 61 | 2.53 |

The actual harvested water will be determined according to different tests in each point of the area under study.

The design which has been considered for water harvesting is shown in Figure 6 which will be tested in 3 areas for 6 months.



Figure 6: Proposed design for the water harvesting from air humidity system

## 3.2. Time Distribution

In Table 4, the maximum harvestable water volumes are presented by month. The maximum harvestable water is obtainable in the three months of July, August and September. In sum, in these three months in the year 1961, it has included in 55% of the year, in 1992, in 62% and in 1995, in approximately 50%. Also, the minimum harvestable water is expected in the cold months of the year.

The important point is that according to the fact that the maximum water in 1m3 of air occurred in the year 1961, thus the year 1995 has the highest potential harvestable water. This, in a way, verifies the performance of the parameters effecting the harvest, including wind and humidity.

Table 4: Calculation of Maximum Monthly Harvestable Water (lit/m3)

| Month | Maximum Harvestable Water (lit/m3) | | |
|---|---|---|---|
| | 1961 | 1992 | 1995 |
| January | 3989 | 5106 | 7563 |
| February | 2465 | 3958 | 8353 |
| March | 10739 | 3751 | 14313 |
| April | 9475 | 6052 | 16028 |
| May | 7170 | 1272 | 11942 |
| June | 5972 | 4508 | 19622 |
| July | 26090 | 17797 | 39614 |
| August | 14754 | 20734 | 42393 |
| September | 20996 | 13147 | 26551 |
| October | 5250 | 3002 | 11878 |
| November | 3074 | 1252 | 10716 |
| December | 3962 | 3716 | 12418 |
| Total | 113935 | 84294 | 221392 |

## 4. Analysis of Resuts

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The average water value in 1m3 of air in Bandar Abbas in its driest conditions is 16.2gr, 19.5gr in its most humid conditions, and 17.5gr in average conditions.

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The actual harvested water will be determined according to different tests in each point of the area under study. The design which has been considered for water harvesting is shown in Figure 6 which will be tested in 3 areas for 6 months.

According to the high potential of Hormozgan for water harvesting, it seems that air humidity and fog are suitable sources for supplying water shortages for houses and even farms.

It is obvious that in the mentioned area, due to shortage of superficial water and saltiness of the underground sources, the harvested water from fog and air humidity can be of important sources for water suppliance for the residents of the area due to their cost-efficiency.

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