Dew yield from passive Condensers in a coastal arid Area - Kutch

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Abstract

Dewfall occurs over a season of nine months in coastal arid district of Kutch. Quantity too is appreciable. A research program has been started to develop efficient passive condensers to harvest dew and use it as a supplementary source of drinking water which is scarce in the area. A passive condenser is a device that cools itself at night by radiative exchange with clear sky. Under favorable conditions condenser may become colder than the dew point of surrounding humid air and attract condensation.

Condensers need to be inexpensive, compact and high yielding. We report in this paper, comparative dew yield of condensers made from six different materials including, aluminum sheet, galvanized iron sheet and polyethylene mixed with titanium oxide and barium sulfate, polyethylene, fiber reinforced plastic plain and corrugated. A test condenser is a panel 1 X 1 m in size and 25 mm thick. Top surface is made of the material being tested for condensation. Its underside is insulated by 25 mm thick styrene foam sheet. Panel is mounted on a metal frame at an angle of 30° from horizontal. Higher end of the panel is 2 m above the ground. Condensate flows down the sloping surface into a collection bottle via a channel and tube. Yield is measured daily in the morning.

Ambient conditions are continuously recorded by a ten channel data logger. In this paper results of the first three months are presented. Dew yields are correlated with ambient conditions and material properties.

Key words: dewfall , moisture from air , arid coastal areas, passive condensers

Introduction

Plastic clad greenhouses tend to cool in-phase with the ambient at night, some times becoming even colder than the surrounding air if not heated or covered with night curtain. It was observed (Sharan and Prakash 2003) that dew condensed frequently on the roof of an experimental greenhouse located at Kothara (23^o 15'N, 69^o 48'E). Dew is the atmospheric water vapor condensing on a surface that has been cooled by radiative cooling at night (Raman et a1 1973).

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Sharan and Prakash reported that condensation occurred in varying quantity over a season of nine months from September to May. Total collection from the roof area of 124 m^2 was 1191 liters over 103 dew–nights in the season. It worked out to 11.5 liters per night when averaged over only the dew-nights; or 4.5 liters per night over the entire nine-month season. Samples of dew water were tested and found chemically potable. Kothara lies in a hot, arid coastal region of Kutch where shortage of drinking water is acute, widespread and chronic. Frequent occurrence, appreciable quantity and good quality suggested it would be useful to harvest dew and use it for drinking.

To make this practical it would be necessary to develop passive condensers that would be inexpensive, compact and high yielding. Accordingly, a research program has been launched to develop such condensers for families living in this area.

The results reported here are from an ongoing investigation to identify the materials suitable for construction of dew condensers. First a review of literature is presented. It is followed by description of the experimental set-up. Finally the empirical results are reported.

Literature Review

The possibility of harvesting dew for human consumption was recognized early. A careful review of the construction and functioning of the ancient devices can be seen in Nikolayev et al (1996). Their investigation suggests that the early devices were most likely not as effective as is made out in the legends. Nevertheless, their study has contributed to a better understanding of how to build more successful devices. Several groups are now engaged in developing devices that can harvest large quantities of dew to ameliorate the drinking water problem in special situations such as in arid coastal areas and deserts (Nilsson et al 1994, Nilsson 1996; Parker and Lawrence 2001); remote islands (Beysens et al 2003; Muselli et al 2002; Milimouk et al), and even in semi arid urban areas (Berkowicz et al). Valuable insights about design, choice of materials and installation have emerged from the work of these groups and individuals.

Nikolayev et al (op cit) elaborated on what a good condenser needs to be and how should it be installed: "the 'ideal' condenser should be 'grass-like', i.e. a light sheet thermally isolated from the massive parts and the ground. It is important that the surfaces should be open to let them irradiate the energy into space. It means that nothing that can reflect the irradiation of the condenser should be placed near its surface and vice versa. The condenser itself should be placed far enough from such surfaces, e.g. the ground to avoid the ‘greenhouse’ effect. The material of the sheet should be well wetted by water to reduce the nucleation barrier. The place of condenser should be chosen on an open area but where the winds are not strong and dew is frequent (i.e. where humidity is high enough).”

Nilsson (1994, 1996) studied the possibility of using pigmented polymer foils with high solar reflectance and high thermal emittance, specially in the so called atmospheric window i.e. 8 to 13 μ m wavelength range, to condense atmospheric moisture. He reported that suitable pigments can be a mixture of titanium oxide (TiO_2) and barium sulfate ($BaSO_4$) and a composite of TiO_2 and SiO_2. Nilsson tested condenser made out of Tio2 and BaSo4 pigments. The foil surface was 1.44 m^2, backed by 5 cm styrene foam insulation. The panel was tilted 20 degrees from horizontal and mounted with its centre 0.7 m above ground. They tested the device at Dodona (Tanzania). Beysens et al (op cit) built a bigger a bigger condenser of the same material and tested it at Grenoble (France). The condensers gave higher yields and attracted condensation frequently.

The test condensers fabricated for tests at Kothara are similar in construction to those developed and described by Beysens et al and Nilsson. One of the several materials being tested at Kothara site is a film made of polyethylene mixed with 5% TiO_2 and 2% BaSo4 by volume. This is similar to the one described and used by Nilsson and Beysens et al. It was manufactured to specification at Ahmedabad. It is 400 micron thick. It was tested for emmittance at the facilities of Indian Space Application Centre, Ahmedabad. Emmittance in the infrared range was 0.83. The one used by Nilsson had emmittance of 0.89.

Experimental Details

Six materials have been selected for trial - plain galvanized iron sheet (GI plain) of 20 gage , plain aluminium sheet of 20 gage , polyethylene mixed with titanium oxide (TiO_2) and barium sulfate ($BaSO_4$) referred to hereafter as PETB of 400 micron thickness, polyethylene (PE) 200 micron thickness, fiber reinforced plastic (FRP) plain , and corrugated, one mm thickness. The GI and almunium were selected because these are already used as covering for fodder godowns and industrial sheds found in the area. If significant yield can be obtained from these roofs, it would be necessary to only install the collection and filter mechanisms and start using them as roof top dew harvesters. The PE and FRP, although more expensive than the GI sheet, were selected because these are also used as external coverings.

Test condensers

Figure 1 shows a schematic diagram of test condensers. A condenser has three components, panel, mounting frame and collection accessories. Panel is composite of two sheets bonded together with adhesive. The sheet on top is made of material being tested for its suitability to construct condensers. This sheet is insulated with styrene foam sheet of 25 mm thickness on the underside. Panels are squares of 1x1 m. Panel is mounted on metal frame made of welded angles. The collection accessories (channel and tube) are also supported on the frame. The panel is mounted on the frame with a 30 angle with the horizontal. Flow is channeled via a flexible rubber tube into a plastic bottle securely placed on the ground.

Twenty four condensers were made - four each of six different materials - GI sheet, aluminium sheet, PETB , FRP plain, FRP corrugated and polyethylene. Four condensers of each material are installed facing north, south, east and west. Figure 2 shows the test site at Kothara.

Dew collected overnight is measured at 8 am each day. Measurements will be recorded over a full season (September '04 – June '05). The aim is to determine which material attracts more condensation and which directional orientation is more beneficial. The aim is also to correlate the dew yield with ambient conditions.

Instrumentation

An eight channel data logger is installed at the site. Ambient temperature, relative humidity, wind velocity and the surface temperature of a condenser are continuously recorded.

Results (October- December)

Presently data is available for ninety day period October-December 2004. North-oriented and east-oriented condensers of three materials - GI, aluminium and PETB - were installed first by the end of September 2004. Their dew yield recording began from October 1. In this analysis results of only these six condensers will be used. Tables 1-3 show the daily data of dew yield of October, November and December.

Frequency

In the period of 90 days the PETB condenser extracted moisture on 21 nights, GI on 16 and aluminium on 14. The difference between north-and-east oriented condensers is of only one day. PETB condensers extracted moisture significantly more frequently than the two metal condensers.

Quantity

In the period of 90 days the north- oriented PETB condenser extracted 3.795 liters of dew water, GI 1.75 liters and aluminium 1.65 liters (Table 4). The east-oriented condensers yielded nearly similar amounts - 3.82, 1.815, 1.72 liters respectively for PETB, GI and aluminium.

The yield from PETB condenser works out to - 0.042 liters per m^2 per night of the 90 day period. In other words a 100 m^2 PETB condenser would have yielded an average of four liters of water during this period. The yield from the metal surfaces would be nearly half as much.

Condensation and ambient conditions

We will examine the ambient conditions on select days to gain insights into the phenomena of condensation.

Table 5 shows the ambient conditions - air temperature, relative humidity, wind speed and the temperature of the PETB condenser surface - on the night of October 28. There was no yield on this day. Table -6 shows the conditions on the following day , October 29. There was good yield on this day as indicated at the bottom of the table. Examination of the conditions shows that the relative humidity was upwards of 90% in the later half of the night on October 29. It was much less – not exceeding 84.6% on October 28. Most other conditions - air temperature, wind speed, condenser surface temperature – were otherwise comparable on both nights. Highly humid air is required for large condensation.

Table 7 shows the ambient conditions of November 12. On this night condensation on the PTEB condenser was nearly ten times greater than any of the two metals condensers. The humidity levels did not exceed 87.9% during the night. This suggests that the PETB is able to extract moisture from air of lower humidity levels than the metal condensers. This is the likely explanation for more frequent condensation on the PETB discussed earlier. There were more days with similar pattern.

Raman et al (op cit) stated that dew occurs when (1) there is plenty of moisture-laden relatively warm air , (2) clear skies leading to good nocturnal cooling and (3) calm or very week wind at low level. Zangvil (1996) expressed similar view after studying dewfall in Negev desert (Israel) for six years.

Preliminary conclusions

Shortage of drinking water in coastal arid regions like Kutch is acute , widespread and chronic. Dewfall as a potential supplementary source has been overlooked so far. Closeness to sea, clear night sky make for conditions conducive to frequent dewfall. Passive dew condensers need to be developed to harvest dew.

Condensers made of six different materials are under investigation at Kothara (Kutch). These materials include – galvanized iron sheet, aluminium sheet, polyethylene mixed with TiO_2,and $BaSO_4$, polyethylene and fiber reinforced plastic. Based on the first three month observations the following conclusions can be drawn.

1. Passive condensers can extract significant amount of moisture from the air at night in arid coastal area of Kutch.
2. Condenser made of polyethylene mixed with titanium oxide and barium sulfate (PETB) gives much higher yield – nearly 2.5 times- than the galvanized iron and aluminium surfaces under similar ambient conditions.
3. PETB condenser can extract moisture from air with lower humidity levels (as low as 87%) than the metal condensers which appear to require upwards of 90% levels of humidity.
4. High humidity, calm winds, clear sky and relatively warm ambient appear to result in high dew condensation.

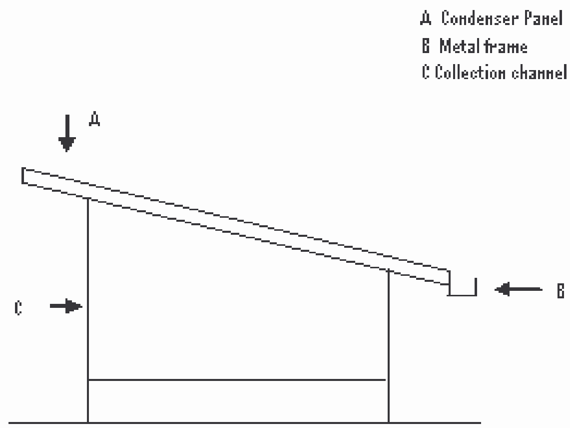

Figure 1. Schematic diagram of test condenser

Figure 2. Condensers Test site at Kothara

Table 1. Daily dew yield from Trial condensers (Kothara, Oct. 04)

Date	GI condenser Orientation		Aluminium condenser Orientation		PETB condenser Orientation	
	North (ml)	East (ml)	North (ml)	East (ml)	North (ml)	East (ml)
7	0	0	0	0	0	50
9	20	0	0	0	240	170
10	0	0	0	0	140	150
11	0	0	0	0	0	0
12	20	50	75	75	150	140
13	0	0	0	0	85	100
14	0	0	0	0	20	50
15	210	220	230	240	350	320
16	145	165	175	160	285	270
17	130	160	150	165	290	280
18	140	160	165	170	290	310
19	0	0	0	0	0	0
20	140	100	120	140	250	250
21	165	190	110	150	290	300
28	0	0	0	0	0	0
29	90	130	120	120	230	220
30	0	0	0	0	0	0
31	0	0	0	0	0	0
Average	118	147	143	153	218	201
Total	1060	1175	1145	1220	2620	2610
Dew nights	9	8	8	8	12	13
There was no condensation on the dates not shown.						

Table 2. Daily dew yield from Trial condensers (Kothara, Nov. 04)

Date	GI condenser Orientation		Aluminium condenser Orientation		PETB condenser Orientation	
	North (ml)	East (ml)	North (ml)	East (ml)	North (ml)	East (ml)
12	0	15	0	10	110	150
19	150	200	170	200	270	250
20	80	60	50	40	150	140
21	70	60	40	30	150	170
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	20	0	0	0	150	140
Average	80	84	87	70	166	170
Total	320	335	260	280	830	850
Dew nights	4	4	3	4	5	5
There was no condensation on the dates not shown.						

Table 3. Daily dew yield from Trial condensers (Kothara, Dec. 04)

Date	GI condenser		Aluminium condenser		PETB condenser	
	Orientation		Orientation		Orientation	
	North (ml)	East (ml)	North (ml)	East (ml)	North (ml)	East (ml)
1	205	190	160	140	240	220
19	25	10	0	0	25	45
20	140	105	85	80	80	95
31	0	0	0	0	0	0
Average	123	102	82	73	115	120
Total	370	305	245	220	345	360
Dew nights	3	3	2	2	3	3
There was no condensation on the dates not shown.						

Table. 4 Total Dew collection over a ninety day period (October to December Kothara 2004)

Orientation	GI-condenser (ml)	Aluminium-condenser (ml)	PETB-Condenser (ml)
North	1750	1650	3795
East	1815	1720	3820
Total	3565	3370	7615

Table 5. Ambient conditions on a no dew night (Oct 28 '04 Kothara)

Hour of day	Amb. Temperature (^{o}C)	Wind speed (m/s)	Relative Humidity (%)	PETB-condenser Temperature (^{o}C)
1600	37.8	6.7	35.7	40.7
1700	36.7	7.0	39.4	40.3
1800	34.6	5.4	38.5	36.5
1900	32.7	4.7	50.2	32.7
2000	29.7	1.9	60.0	29.4
2100	27.2	1.6	67.9	26.5
2200	25.4	1.9	77.3	24.7
2300	24.3	2.0	84.6	23.6
0	25.7	4.4	75.7	25.2
100	24.1	1.9	78.4	23.7
200	23.1	0.9	81.2	22.4
300	21.8	1.6	71.3	22.2
400	21.6	1.7	70.1	21.9
500	21.2	2.7	70.5	21.2
600	21.2	2.4	66.1	20.9
Dew yield North GI (0 ml) Al (0 ml) PETB (0 ml) East GI (0 ml) Al (0 ml) PETB (0 ml)				

Table 6. Yield and ambient conditions on a dew night (Oct 29 '04 Kothara)

Hour of day	Amb. Temperature (^oC)	Wind speed (m/s)	Relative Humidity (%)	PETB-condenser Temperature (^oC)
1600	38.1	7.7	14.9	42.7
1700	36.6	7.9	15.8	41.0
1800	34.9	6.7	22.5	36.9
1900	32.0	4.6	34.8	32.0
2000	29.7	5.0	42.6	29.6
2100	27.9	4.8	44.8	27.6
2200	26.6	4.7	48.6	26.3
2300	25.3	3.8	50.1	24.8
0	23.8	9.5	86.1	23.5
100	23.0	1.8	87.9	22.3
200	21.8	16.7	93.9	21.3
300	22.5	3.6	95.9	22.2
400	22.5	3.7	93.1	22.1
500	21.6	2.4	97.1	20.6
600	21.5	3.2	97.3	20.9
Dew yield	North GI (90 ml)	Al (120 ml)	PETB (230 ml)	
	East GI (30 ml)	Al (12 0 ml)	PETB (220 ml)	

Table 7. Yield and ambient conditions on a dew night (12 Nov'04 Kothara)

Hour of day	**Ambient temperature (^oC)**	**Wind speed (m/s)**	**RH (%)**	**PETB-condenser temperature (^oC)**
1600	37.2	4.1	15.5	38.6
1700	36.9	4.4	15.5	33.7
1800	35.9	4.5	25.4	31.6
1900	32.0	3.0	36.9	27.8
2000	27.6	2.6	45.1	19.0
2100	23.6	1.7	51.0	17.3
2200	22.3	1.7	49.3	15.5
2300	21.6	3.4	39.0	15.8
0	21.5	2.6	86.6	16.6
100	20.0	1.6	87.9	15.0
200	18.2	1.4	84.4	12.9
300	17.5	1.6	75.9	11.4
400	16.3	1.7	77.4	10.6
500	15.9	1.8	79.2	10.4
600	15.9	1.8	82.2	10.5
Dew yield	North GI (0 ml)	Al (0 ml)	PETB (110 ml)	
	East GI (15 ml)	Al (1 0 ml)	PETB (150 ml)	

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