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W.P. No.2007-08-05
August 2007

INDIAN INSTITUTE OF MANAGEMENT
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Harvesting dew to supplement drinking water supply in arid coastal villages of Gujarat

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Abstract

Shortage of drinking water is chronic, sever and widespread in Kutch - a hot and very arid region. It is specially acute in coastal villages where surface sources dry up rapidly and groundwater is not potable. Many of these are listed as "no source" villages and are supplied water on tanker-trucks daily from long distances. The conventional efforts to conserve and augment water resources are all in place. But one potential resource - dew - had remained unnoticed. The possibility that it may also be a supplementary resource was first noticed in the summer of 2001 when it was observed that dew condensed frequently on a plastic- clad greenhouse in Kothara, a village 15 km from the coast. That led us first, to carry out systematic measurement, and then to develop practical ways to harvest dew for human use.

Measurement at Kothara was followed by measurements at two other locations along the coast - Panandhro and Mithapur. Data showed that dew occurred over an eight-month season (October- May) spanning the entire dry part of the year. Quantity was more in summer months than in winter. Dew water was found potable and safe. In the next three years development of dew harvest systems was carried out, prototypes were made and tested. After successful field trial three models were launched.

The key component of the systems is the condenser, made of thin plastic film which can harvest 15 – 20 mm of dew water in the season. Condenser cools itself by radiative exchange with sky, without the use of any external energy. Working installations have been made on large roofs and on open ground. While the devices are specifically engineered to condense dew, these routinely harvest rain as well. These are being promoted as "dewrain" harvest systems that deliver useful but varying amount of water through all the months of the year.

Keywords: dew condenser, radiative cooling, drinking water, coastal arid areas

Drinking water shortage in arid coastal areas of Gujarat

Kutch is an extremely arid and hot region (Figure 1). Rainfall is low (300 mm annual) and very erratic (C.V. 75%). Evaporation far exceeds the precipitation - annual pan evaporation at Bhuj 2000 mm. Accordingly, the village ponds, tanks rarely get filled-up. Even when full, water depletes rapidly by evaporation and seepage. Groundwater is saline in most parts, particularly near the coast. Our Development and Research Station is in village Kothara (Talk: Abdasa, Kutch). This village has piped supply, but water is suitable for only cleaning and washing, not for drinking. Drinking water is available in just one open bore-well. People, mostly women and children go to this well in the morning and evening and carry water home. Even so, Kothara is fortunate to have at least a small source of drinking water in the village. There are 152 villages around Kothara that have no local source of drinking water and have to be supplied with tankers on a regular basis. These are termed “no source “villages. Shortage of drinking water which also affects cattle is chronic, widespread and sever.

Dew - A hitherto unnoticed resource

Efforts are on to augment potable water resources of this area in various ways. But one potential resource -- dew -- has remained unnoticed. It was discovered in the year 2001, in the course of greenhouse work in village Kothara. Its roof (124 m^2 plastic) surface attracted condensation frequently, more in summer. Year long daily measurements showed that condensation occurred over a continuous eight-month season (October - May). Dew occurred for 103 nights in the season. The collection from the roof was an equivalent of 10 mm over this season. The peak collection in a night in April was 39 liters [Sharan and Prakash 2003]. Measurement at Kothara was followed by measurements at two other locations along the coast - Panandhro and Mithapur (Figure 1). Condensers used for measurement were specially constructed for the purpose, whose details can be seen elsewhere [Sharan 2006]. Table 1 shows the comparative aspects of rain and dew in coastal areas of Kutch. It is seen that dew is smaller than the rains in magnitude. But, it occurs over a longer season and over many more days than the rain. In view of the fact that it is more uniformly distributed through the months, it can be a more reliable source of moisture.

Figure 1: Coastal Arid Region of Gujarat

Arrows indicate sites where dew measurement was made (Panandhro , Kothara , Mithapur)

Table 1: Rains and Dew in Coastal Areas of Kutch

Aspects	**Rains in coastal Areas of Kutch**	**Dew in coastal areas of Kutch**
Annual mean	300 mm	20 mm
Number of days Normal occurrence	10	95 - 105
Span of season	June – September 4 months	October – May 8 months
Water quality	Potable	Potable
Values for rains are obtained from the Met Department (Bhuj); values for dew were taken from our own Development and Outreach Station -Kothara**.**		

Development of dew harvest systems

Above findings led to a three-year R&D initiative to develop practical and affordable systems of dew harvest. Detailed account of the development can be seen elsewhere [Sharan 2006, Sharan 2007 a]. A dew harvest system must first make water by condensing moisture present in the air in vapor form. In this respect it differs from rain and fog harvesting, both of which intercept water in fluid form. The working principle of dew condensers is illustrated schematically in Figure 2. A 25 mm thick, rectangular panel (A) is mounted on a light frame (C). The panel is made of 25 mm thick styrene foam board with 0.2 mm thick polyethylene film laminated on its top face. It is mounted on a meter high frame at an angle of 30 degrees from horizontal. A collection channel (B) is attached to the frame along the lower edge of the panel board. The entire assembly is a small dew condenser. Top surface (film side) faces the sky. The insulated underside faces the ground.

At night, under a clear sky, the film looses heat by radiation to sky, and gains by conduction and convection from the surrounding air. The layer of insulation underneath prevents heat gain from the ground surface. As evening sets-in, the film will begin to cool. By early morning it becomes cooler than the surrounding air since the emmissivity of plastic is higher than that of air. When the film surface reaches the dew point temperature of the air, conditions for condensation are created. If at that time the air is also very humid (RH upwards of 85 %) and the wind calm , large amount of dew condensation will occur. Efficient dew condenser should be thin and light , made of material with high emmissivity, well insulated underneath and erected against the wind with sufficient slope for rapid draining by gravity [Sharan 2006].

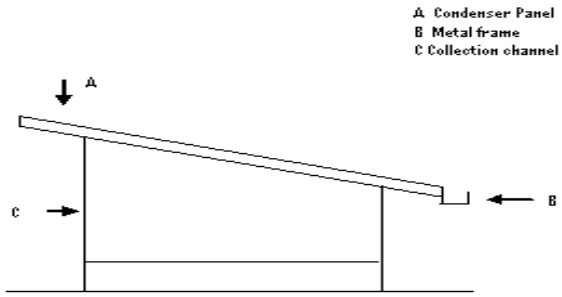

Figure 2: Schematic Diagram of Dew Condenser

Practical Dew harvest systems

Following models are now being promoted.

1. Condenser-on-Roof (CoR)
   These are installed over the existing roofs which would normally not attract Condensation such as RCC slabs, cement sheets;
2. Condenser-on-Ground (CoG)
   These are installed over the waste lands
3. Roof-as-Condenser (RaC)
   Large sheds that have corrugated iron roofs can be used directly with only the installation of gutters. The yields are lower than those from the plastic condensers but so also are the investments
4. Condenser-on-Frames (CoF)
   These are meant for measurement of dewfall at new locations,
   Have 1 m^2 surface and are mounted on simple angle-iron frames.

The CoRs and CoGs are constructed on site. Some Examples of working installations are given below. Detailed descriptions of the system at Sayara can be seen in Sharan et.al [2007 b] , of Suthari in Sharan et.al [2007 c] and Panandhro in Clus et.al [2007] .

Condenser-on-Roof at Sayara (Kutch)

This system is installed at a school in village Sayara about 10 km from the coast of Arabian Sea. Three adjacent, gable-roofed buildings (**Figure 3)** were retrofitted with Condenser-on-Roof. All roofs were identical in pitch (15 degrees), orientation – one half facing north, other south-and made with reinforced cement concrete (RCC), with top covered with mortar. Roof area of three buildings combined is 360 m^2. Condenser panels of the type described above were overlaid on the roof surface covering it completely. Dew water condensing on the surface at night flowed to the gutters and into the collection tanks on the floor. The yield from all three buildings in the season, October '05 to May '06, was 10.1 mm, and dew events numbered 101 (Table 2). The system continues to function with very little maintenance. During the rainy season it also harvests rain water for which there is a large covered storage.

Dew water samples were chemically analyzed in the laboratory of Gujarat.

Institute of Civil Engineers and Architects, Ahmedabad and found to be potable.

EC	:	0.24 dS / m
PH	:	7.70
TDS	:	154 ppm
$Ca^{+2} + Mg^{+2}$	:	1.50 me / lit
Na^{+}	:	1.00 me / lit
CO_3^{-2}	:	Trace
HCO_3^{-}	:	1.25 me / lit
Cl^{-}	:	1.50 me / lit

Roof-as-Condenser – Suthari (Kutch)

The system was installed over the roof of a fodder warehouse at village Suthari, just three km from the shore. The roof has surface area of 343 m^2 and is made of corrugated galvanized iron sheets. Unlike Sayara, here no external condenser was used. Being made of metal and being capable of attracting condensation , the roof itself was used to harvest dew with installation only of collection gear (Figure 4). The dew yield for is given in Table 3. The dew-nights numbered 95 and the collection was 4 mm (1372 liter). Collection is low but so was the investment.

Condenser-on-Ground - Panandhro (Kutch) and Satapar (Jamnagar)

Two large CoGs are now in operation , one at Panandhro and the other at Satapar (Figures 5a, 5b) . These systems are installed directly over the ground. The Panandhro system consists of ten modules of the special ridge-and-trough condensers formed at the site. Ridges, each 35 m long, are built over gently sloping ground. Ridge is trapezoidal (top 50 cm, base 200 cm, two sides sloping 30 degree from horizontal, height 100 cm) and lined with the condensers described above. Each module has 85 m^2 surface, the ten together 850 m^2. Each module is connected to a common collection pipe at the lower end. The main storage is located in the middle. Partial Season Dew Collection from CoG Panandhro is shown in Table 4.

The Satapar system is similar. It consists of eleven trapezoidal ridge condensers as shown. The system is built over a 30 X 20 m ground. The ridges, each 20 m long, are built over gently sloping ground. Ridge are trapezoidal (top 50 cm, base 200 cm, two sides sloping 30 degree from horizontal, height 100 cm) and lined with the condenser panels of the type described above. Each module has 50 m^2 surface, the eleven together 550 m^2. All the modules drain into a common pipe at the lower and leading to a covered storage below ground. Water for use is withdrawn by a hand pump (Figure 6). The system was commissioned in early April ’07. Total cost of the installation was Rs 117,000.

The dew water collection in the month of April was 861 litres over 17 nights; in May 34 litres over 8 nights. Dew season ended by the middle of May to resume in October. The interim is the season of rains. First rain occurred on June 22. Till the end of July, there ware eight rainy days. Storage tank (20,000 litres) became full soon after the rains started and remained so through July. Also there were occasions when the excess water was moved over to the well of the neighbouring farm.

Figure 3: Dew Harvest System at Sayara (CoR)

Table 2: Dew yield - Sayara (CoR)

Month	**Dew yield – all three buildings (liter)**	**Dew nights (no.)**
October '05	4.30	1
November	176.30	15
December	150.80	6
January '06	220.40	9
February	750.70	13
March	1076.30	20
April	782.40	24
May	465.10	13
Total season	3626 (10.1 mm)	101
Total cost of installation Rs 36,000		

Figure 4: Dew Harvest System at Suthari (RaC)

Table 3: Dew yield - Suthari (RaC)

Month	**Dew yield (liter)**	**Dew nights (no.)**
October '05	45	17
November	80	18
December	74	08
January '06	68	03
February	480	14
March	478	23
April	132	09
May '06	9	03
Season total	**1372 (4 mm)**	**95**
Cost of collection gear was Rs 12,000		

Figure 5 a: Dew Harvest System at Panandhro (CoG)

Table 4: Part - season dew yield - Panandhro (CoG)

Season of 2006-07	**Dew yield (liter)**	**Dew nights (nos)**
October '06	Occurred but not recorded	Occurred but not recorded
November '06	do	do
December '06	do	do
January '07	221	3
February '07	1860	17
March '07	1597	18
April '07	1620	21
May '07	262	9
Panandhro system has 10 ridge condensers each of 85 m^2 surface. Cost of the system Rs. 85,000.		

Figure 5 b: Dew Harvest System at Satapar (CoG)

Figure 6: School Children Drawing Dew Water – Satapar

Conclusion & Recommendations

1. The prevailing view among the scientists in India (hydrologists , engineers , meteorologists) is that the dew is not of any utility to humans because of low quantity and infrequent occurrence. This view may not be as true for areas near coasts as for the hinterland. Our measurements at three locations along the Gujarat coast - Panandhro , Kothara and Mithapur - have shown that (a) dew occurs over a season of eight months - October to May , the quantity and frequency of occurrence are higher in summer than in winter months (b) number of dew nights are large , varying from 95 to 105 (c) the amount of dew water collected by specially made plastic condensers was equivalent of 20 mm , not a negligible amount in arid areas.
2. Dew is smaller in quantity than the rainfall but it is more uniformly distributed over the season which is twice as long as the rainy season in Kutch. If suitable devices are deployed, as has been demonstrated in Kutch, dew water can become a significant supplementary source for human use.
3. Given that many coastal areas in the country are short of drinking water, it is recommended that measurement of dew resources be made and the possibility of dew harvest examined. The data should be published.
4. While the systems described here, were engineered specifically for dew harvest, these also harvest rain. Since the dew and rainy season in Kutch are complementary, the systems provide varying amount of water through all the months of the year. Accordingly these are promoted as the dewrain harvest devices. The systems promoted in Gujarat are of two types - those installed over the roofs called Condenser-on-Roof or CoR - and those installed over open ground – called Condenser-on-Ground or CoG. In addition people who own buildings with large metal roofs are advised to use these to produce water simply by installing gutters. No external condenser is required. These are termed - Roof-as-Condenser or RaC.
5. The CoRs and CoGs cost approximately Rs 200/ m^2. The RaCs are much cheaper but also yield less. The CoR yield 10 mm water over the season, the CoGs 10 – 15 mm and the RaC 4-5 mm. All systems are affordable, easily fabricated and maintained.

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