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Rainwater unable to quench the thirst,

now hopes from dew drops

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In arid region of Kachchh, moistened air prevails in most of the months in a year due to its coastal vicinity over a large land tract. Thus, dew drops can be proved as a supplemental source of drinking water in arid region of Kachchh by making serious and proper efforts. It is experienced that the moisture present in the air can be extracted in form of dew drops through condensation process by establishing a suitably designed dew condenser at an appropriate place. Amount of dew water is less than collected from the rainwater; however, reliability of getting assured quantities of dew water is more than of rainwater, as the rainfall in some of the years completely fails and duration of getting dew water is almost doubled to that of rainwater. System of dew water harvesting including its design dimensions, types, materials, and scope in arid regions, is discussed this article. Besides, it describes the criteria for selecting optimum sites for dew water harvesting, compares dew water with rainwater, and estimates surface areas required for dew water harvesting system to fulfill drinking water requirements depending upon the family size.

Key words: Dew drops, Rainwater

IN India, water management is being practised from historical times including several methods where rainwater is harvested and stored for subsequent utilization and for recharging of groundwater. Technique of rainwater harvesting and storage is proved to be successful for adequate management of scarce water resources. However, the rainwater harvesting methods are prevailing in the country from ancient times, stored rainwater could not be made available throughout the year in the western parts of where the rainwater is mainly received from India south-west monsoon of four months, i.e. June-September. It is also observed that most of the water conservation and storage structures in the western arid region of the country could not be filled up to their maximum storage level due to relatively low, uncertain and uneven distribution of the rainfall. As a result, these structures usually fail in supplying the expected drinking and irrigation water needs especially, for those years receiving below average rainfall.

Kachchh (Gujarat) experiences arid climate. The average annual rainfall of this region was 390 mm between 1988 and 2014. The occurrence of short-duration and high-intensity rainfall storms is a usual phenomenon in Kachchh and receive greater amount of rainfall in a short duration. A major portion of this rainwater gets escaped out of the area as a waste without any utilization. Due to irregular and uneven distribution of the rainfall, this arid region always remains prone to drought. The annual rainfall of Kachchh has seen large variability over the last 10 to 15 years with coefficient of variation as 75%. About 90% of the agricultural lands are rainfed while facility of irrigation is available for 10% area. Surface water resources are meager in the region due to low rainfall. Under these circumstances, groundwater resources are being extracted through shallow dugwells and deep tube-wells for providing irrigation from long times. The increased dependency on the groundwater resources for irrigation, domestic and other uses has resulted in over exploitation of groundwater and consequently helped to ingress of saline seawater under the ground surface. The seawater intrusion has entered into the groundwater aquifers of the area due to its coastal location and has increased salinity levels of the inherent groundwater resources. Looking at scanty quantities of rainwater and degraded quality of groundwater, it is necessary to find alternatives for freshwater supplies in the arid region. Therefore, this study attempts to evaluate potential of dew water harvesting that extracts the water present in the atmosphere. Dew drops are formed from the humidity of the atmospheric air, which is cooled at a surface of a condenser where the moisture

available in the air is converted to liquid water through the condensation process. Dew water harvesting is generally suitable for coastal arid regions having high relative humidity and a large deficit of freshwater supplies for drinking water, and hence, this study aims at finding its suitability in Kachchh, Gujarat.

Early efforts of dew condensation through airwells

In India, efforts for collection and utilization of dew water are as discussed here. The first ever method of collecting dew water from the atmospheric air by augmenting condensation process was accomplished through airwell. Internal layer of the airwell adequately lowers the air temperature up to that level at which dew formation starts. There is little difference between dew and fog; fog consists of water droplets which condense around the particles present in the atmosphere whereas dew is formed by water drops that comes from the condensation of moisture present in the air on some surface. An airwell requires moisture from the air for dew formation. A certain amount of water always remains present in the atmosphere over the entire earth even in a desert. It is estimated that atmosphere contains about $12{,}900 \times 10^9$ m^3 of water, of which 98% part is available in the form of water vapour and rest 2% as condensed water. The amount of water vapour present in the air is called as relative humidity (RH) which depends upon the temperature. When the air is cooled up to the dew point, this water vapour comes in saturation stage and the moisture condenses on a suitable surface.

System of acquiring water from dew drops by condenser

The most suitable method among the available methods to get the amount of harvested dew water is using a radiated dew condenser. An 'International Organization for Dew Utilization' is constituted to enhance and standardize activities of dew collection all over the world. This organization suggests use of a standard substance which consists of white colour and low density polyethylene foil with inbuilt structure of microspheres of 5% volume of titanium oxide and 2% volume of barium sulphate. This standard substance helps in minimizing atomic resistance and maximizing reflectance of more radiations in near-infrared field. An inclination angle of 30° from the horizontal is found optimum to collect dew drops from a flat condensed structure. A dew condenser is called as a passive device (Fig. 1) because it extracts moisture from the air without using any external energy.

The surface of the condenser easily exchanges radiations and becomes cool under the open sky in the night. In this way, surface of condenser becomes cooler than dew point temperature of surrounding moist air. In this condition, amount of some vapour present in the air condenses on the surface of the condenser. Condenser's surface makes an angle from the horizontal such that the dew water can be drained through gravitational force. Under suitable circumstances in long duration of the night, a large quantity of water is collected through condensation process. The recommended properties of the dew condensers are presented in Table 1.

Table 1. Recommended properties of dew condenser for better efficiency

Property	Description
Thickness and size	Condenser should be of less thickness, short in size and light weight.
Radiation reflectance	It should be capable enough to radiate more.
angle from horizontal	Condenser surface should be at an angle of 30° from the horizontal to enable draining of dew water automatically towards storage tank through gravity.
Resistance	Lower layer of the condenser should be well-resistant.
strength	It should be of good strength to bear pressure exerted by the air.

Types of dew condensers

Dew condensers can be commonly classified into following four categories:

(*i*) *Condenser on roof*: This condenser is established on the existing roofs which are not capable at their own for executing condensation process, for example, RCC and cement-layered roofs. In this method, surface of the roof is covered and laminated by a styrene foam board of 25 mm thickness and a layer of 0.2 mm thick polyethylene film. Polyethylene layer is placed at an angle of 30° from the horizontal such that the water harvested from dew drops easily comes to storage tank flowing through the pipes. Cost of this type of dew condenser is about ₹ 200/m^2 area. It requires less maintenance and minimum floor area.

(*ii*) *Condenser on ground:* This type of condenser is established directly on the ground surface particularly on the wastelands. This condenser contains several parallel drains which drains the dew water to the lower end where a common collection pipe carries the dew water collected from all the drains

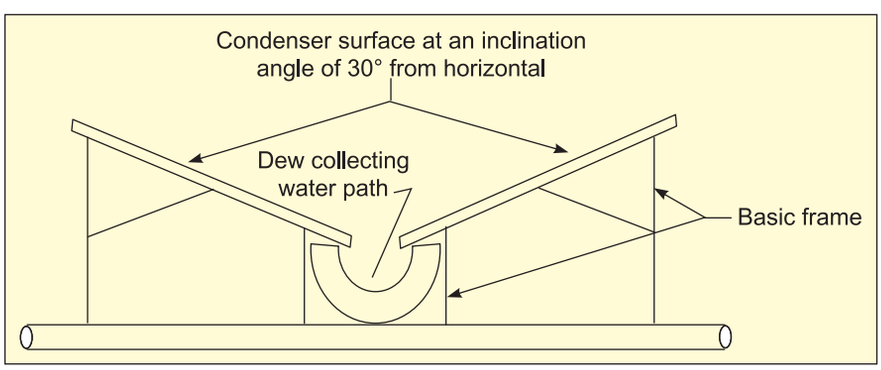


Fig. 1. System of dew water harvesting using condenser

to a main storage tank. This type of dew condenser can be feasibly adopted in Kachchh region where large tracts of the land are available as a waste due to presence of inherent soil salinity. The lands nearby the Rann of Kachchh may be the potential areas for their installation. The cost of this condenser would be same as that of dew condenser on roof.

(iii) Roof used as condenser: In case, material of the roof permits easy condensation of atmospheric water, it can directly be used as a condenser. Cost of this type of condenser is relatively less as money is needed only for installation of pipes required to convey dew water from roof surface to collection tank. In Kachchh region, many new sheds with their surface consisting of galvanized iron are increasingly constructed due to rising areas under industrial units. Iron itself can execute condensation process. Thus, roofs of the iron sheds can be easily transformed in low-cost dew condensers. If materialized, several dew condensers are possible to construct in the arid region of Kachchh.

(iv) Condenser on frame: This type of condenser is established on a frame made of iron rods and usually it is used in research studies for successful installation of dew condensers at new places and to measure amount of water collected from dew. Generally, size of surface of this condenser is kept as 1 m^2. Presently, attempts are being made to establish the condenser on frames of iron rods at professional level with increased surface area in Kothara of Kachchh region.

Table 2. Environmental factors affecting amount of received dew water and their favourable criteria for dew formation

Factors	Criteria
Sky covered by clouds	Sky should be clear without clouds in the night.
Temperature	Difference between air temperature and dew point temperature should be less. In Kachchh, amount of dew water increases if this difference is less than 2°C.
Relative humidity	It depends upon the difference between air temperature and dew point temperature. Value of relative humidity should be more than 85% to harvest dew water.
Wind velocity	Wind velocity at a height of 5 m from ground surface should be less than 1 m s^{-1}. If wind velocity is more than 4 m s^{-1} then dew does not form at all.
Wind direction	Wind should blow from southwest to northeast.

Scope of dew water harvesting in Kachchh

In the coastal region of Kachchh, initiatives were taken by the Indian Institute of Management, Ahmedabad, for the collection of dew water and utilizing it as drinking water since 2004. Process of establishing dew condenser on ground is illustrated in Fig. 2. It has been experienced that if a water harvesting structure is constructed with arrangements of collecting both dew water and rainwater, this system works in more effective way and may be useful to supply a certain amount of drinking water round the year. Laboratory testing revealed that the dew water meets the water quality standards prescribed by the World Health Organization and is suitable for drinking purpose. In arid lands of Kachchh, dew formation in large quantities occurs between 8 and 9 months (from end of September to start of May). In rest of the months, rainy season covers the sky with clouds and dew does not occur. A little rain occurs during rainy season, however, number of rainy days in some years is only five or less.



Fig. 2. Step-by-step process of establishing dew condenser on the ground surface in Kothara, Kachchh by the Indian Institute of Management, Ahmedabad.

Selection of suitable sites to establish dew condensers

The most important point to consider while selecting site to establish a dew condenser is that the dew water should be available at the preferred place in adequate amounts over a long-duration with high frequency of dew formation. The area under industrial field has extended manifold during last few years in Kachchh district, and hence, large numbers of factories, mills, and godowns are constructed. Presently, the roof of those industrial units and buildings mostly consists of corrugated galvanized iron or other suitable material, which is capable of condensing the moisture present in the air. On these roofs, the dew condenser can be easily constructed with low cost. In coastal areas of Kachchh, large amount of the dew water can be collected due to high relative humidity in the atmosphere. Favourable climatic parameters for dew formation are listed in Table 2. For a suitable dew harvesting site,

relative humidity should be more than 85% and wind velocity at a height of 5 m from ground surface should be less than 1 m/s. In Kachchh district, freshwater scarcity is severe in two coastal blocks, i.e. Abdasa and Lakhpat, where large areas are available to install condensers for harvesting dew water. The other coastal blocks such as Mandvi and Mundra seem to be doubtful for locating the potential sites to acquire large amount of water from dew water harvesting due to wind blowing at high speed there. Other potential areas having easy feasibility of installing dew condensers are the Little and Great Ranns of Kachchh where large saline wastelands are available. However, there is no or little information available about the factors affecting amount of dew water, e.g. air temperature, relative humidity, wind velocity etc.

Dew water harvesting from greenhouse roof

Greenhouse is very useful and widely-known technique for improving quality and yield of vegetables in arid climatic regions. Roof of these greenhouses can be a good alternative for harvesting ample quantities of the dew water. A schematic of dew harvesting through greenhouse roof is shown in Fig. 3. In Kothara of Kachchh region, during 2002-2003, personal efforts were made by Indian Institute of Management, Ahmedabad, to capture about 1,191 litres of dew water from 124 m^2 greenhouse roof area (Table 3). Thus, the plastic-made roof of greenhouse yielded about 9.6 litres of dew water from 1 m^2 area in 365 days. The dew formation in Kachchh usually starts in last week of September and it continues up to first week of May falling year. In this manner, the dew water can be collected for about eight months. It is observed that large amount of dew is formed between October and March-April. Looking at arid climate and possibility of dew water harvesting in Kachchh, a water harvesting system storing both dew water and rainwater from the roofs of greenhouses can play a vital role in irrigating high-value cash crops. The Krishi Vigyan Kendra, Central Arid Zone Research Institute, Kukma is working on awareness generation among the local people, especially farmers, about this new and untraditional source of water.

Table 3. Quantity of harvested dew water from greenhouse roof in Kothara, Kachchh (2002-2003)

Months	Number of dew forming nights	Amount of harvested dew water (litres)
June	0	0
July	0	0
August	0	0
September	5	31
October	23	159
November	6	61
December	7	145
January	8	113
February	5	69
March	19	307
April	24	214
May	6	92
Total	103	1191

Source: Sharan, G. (2006). *Dew harvesting – to supplement drinking water sources in coastal belt of Kachchh.* Foundation Books, New Delhi.

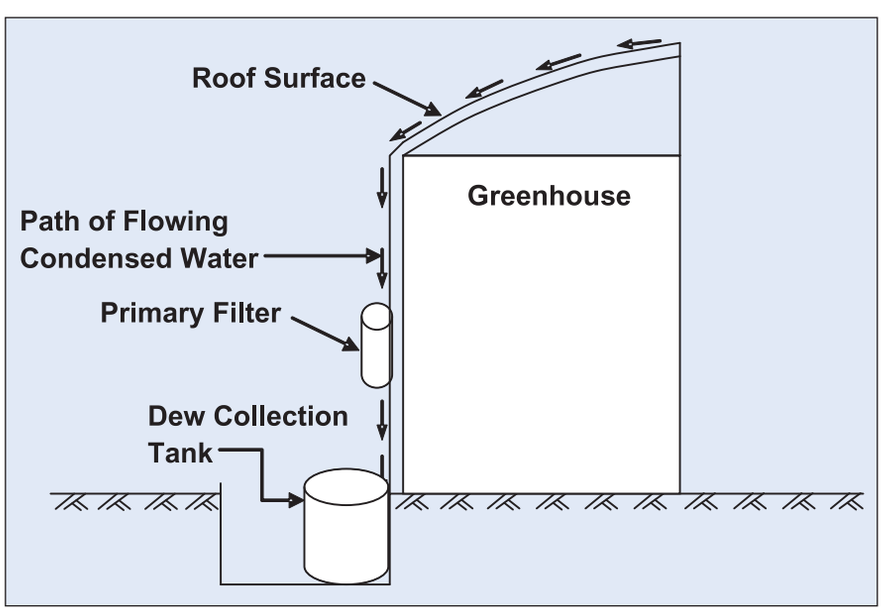


Fig. 3. S-System of dew water harvesting from greenhouse roof.

Both rainwater and dew water harvesting through dew condensers

In general, rainy season extends over a four months, i.e. June to September; however, dew formation occurs during eight months, i.e. October to May. Thus, it is evidence that the water collection and storage system can be made more effective by combining the harvesting system of dew water with rainwater. Research studies showed that the rainwater falling over the surface of the dew condenser can be easily collected and stored. Hence, the condenser can be made more efficient by using it throughout the year for getting dew water from October to May and for receiving rainwater from June to September.

Quality of dew water

A general perception of the people about dew water is that there would be deficiency of minerals, which may not be always correct. The mineral elements are usually present in the atmospheric gases and dew water comes in contact of these gases when moisture of the air gets transformed into dew drops. Thus, the minerals get dissolved into the dew water. To confirm presence of minerals and/ other salts in dew water, regular and periodic testing of dew water is needed. In comparison to rainwater, dew water has less opportunity to come in contact with atmospheric gases, and hence, the concentration of chemical parameters remains low in dew water. Quality of dew water can be improved to make it suitable for drinking purpose by adding/ removing different elements through filtration process depending upon deficit/excess of a particular element. Presently, adequate types of filters are available in market that are capable of

Table 4. Water quality analysis of dew water

Water quality parameter	Measured concentration in dew water	Drinking water quality standards
Electrical conductivity	240 µS/m	<250 µS m^{-1}
pH	7.7	7-8.5
Total dissolved solids	154 ppm	<1000 ppm
Calcium and magnesium	1.5 meq/litre	-
Sodium	23 ppm	<200 ppm
Carbonate	Negligible	-
Bicarbonate	76 ppm	<300 ppm
Chloride	53 ppm	<200 ppm

Source: Sharan, G. (2007). *Dew harvesting as supplemental source of drinking water supply in coastal villages of arid Gujarat*. Working Paper No. 2007-08-05. Indian Institute of Management, Ahmedabad

Table 5. Comparative analysis of rainwater and dew water in coastal areas of Kachchh

Aspect	Rainwater[1]	Dew Water[2]
Annual average amount	390 mm (years 1988-2014)	20 mm
Number of days	13	95-105
Duration and Period	4 months (June to September)	8 months (October to May)
Water Quality	Drinkable	Drinkable

Source: [1]Based on rainfall data collected from ICAR-Central Arid Zone Research Institute, Regional Research Station situated at Kukma, Bhuj.
[2]Sharan, G. (2007). Dew harvesting as supplemental source of drinking water supply in coastal villages of arid Gujarat. Working Paper No. 2007-08-05. Indian Institute of Management, Ahmedabad.

Table 6. Surface area computation to meet annual drinking water requirement of a family in Kachchh region

Family size	Required surface area (m^2)			
Person	Supplying only dew water	Both rain and dew water use	Dew water and 75% rainwater use	Dew water and 50% rainwater use
1	55-100	3-5	4-6	5-9
2	110-200	5-10	7-13	10-19
3	164-300	8-15	11-19	15-28
4	219-400	11-19	14-26	20-37
5	274-500	13-24	18-32	25-46

Note: Drinking water requirement/caput/day, 3-5 litres

maintaining concentration of a given parameter within the limits specified for drinking purpose by the World Health Organization. Results of water quality analysis for dew harvested in Kachchh are discussed in Table 4.

Utilizing dew water to meet basic drinking water requirements for human use

The basic drinking water requirement for human range from 3 to 5 litres/caput/day. If computed for the mean annual rainfall of 390 mm and 20 mm of dew in Kachchh (Table 5), the annual drinking water requirement for a family of 5 persons can be completely met from a surface area ranging from 274 to 500 m^2 (only dew water) or from 13 to 24 m^2 (dew water and rainwater), Table 6. Practically, it is difficult to get surface area within a residential house required to meet annual drinking water supplies of 5 persons family from dew water alone. Therefore, both dew water and rainwater are needed to be collected from the condenser to meet out the basic drinking water requirements of human in the region like Kachchh.

SUMMARY

Quantities of dew water are definitely negligible in comparison to that collected through rainfall, and perhaps, this is the major cause that many people in India still guess that dew has no importance for human use. However, in the western part of the country, where rainwater quantities are incapable to meet the drinking water needs entirely, hopes are now from the dew drops.

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Jai Kisan, Jai Vigyan

- A total of ₹ 788.33 crores have been sanctioned for opening six new agricultural colleges for eastern India under Central Agricultural University, Imphal, and a new Central Agricultural University in Meghalaya.
- For the establishment of two new agricultural research institutes in Asom and Jharkhand, a sum ₹ 100 crores is allocated.
- First academic session of the Rani Lakshmibai Central Agricultural University has been allocated for four new agricultural colleges in Datiya and Jhansi.
- An Memorandum of Understanding was signed for transforming the Rajendra Central Agricultural University, Pusa, Samstipur, Bihar. A proposal of ₹ 400 crores is submitted in EFC.
- Post-Graduate Institute of Horticulture is being established in Amritsar, Punjab.
- Foundation stone of the Indian Institute of Agricultural Biotechnology is laid at Ranchi for promoting agricultural biotechnology.