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RESEARCH ARTICLE

QUALITATIVE EVALUATION OF HARVESTED RAINWATER SAMPLES FROM THE RESIDENTS OF DHARWAD AND HUBBALLI CITIES, DHARWAD, KARNATAKA

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ABSTRACT

Background: Rain water harvesting (RWH) is a technology that can be used for collecting and storing rainwater from rooftops, open land surfaces using simple storage utensils such as tanks, pits and cistern. Harvested rainwater is a renewable source of clean water that is ideal for multiple uses. **Objectives:** The present research was conducted with the objective of exploring the purpose for adoption of rain water harvesting system, to assess the physical and chemical characteristics of harvested rainwater samples and assess the impact of usage of harvested rainwater for drinking and cooking purpose. **Methods:** The study was conducted in urban areas of Dharwad and Hubballi cities, in Dharwad district of Karnataka state. Purposive Random Sampling technique was adopted to choose 60 adopters of rainwater harvesting system, 30 each from Dharwad and Hubballi cities. The harvested rainwater samples were collected during the January month of 2017 so that all seasonal and non-seasonal rains of the year 2016.The rainwater samples were subjected to analysis and checked against drinking water standards prescribed by Bureau of Indian Standards (BIS 10500/1991). **Results:** The results of the study revealed that majority of the rain water harvesting systems were constructed during 2010-12, costed less than Rs. 20,000/- for construction. It was found that only 5 residents adopted rooftop rainwater harvesting system and use harvested rainwater for domestic purposes. Majority of the residents had borewell recharge system. The adopter cleaned the rain water harvesting system whenever it was dirty and had no filtration system. **Conclusion:** The physical and chemical parameters of harvested rainwater qualified to the BIS drinking water criterions. The regular maintenance of rain water harvesting system was found to be necessary for ensuring quality of harvested rainwater and life span of the system.

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INTRODUCTION

Rain water harvesting (RWH) is a technology that can be used for collecting and storing rainwater from rooftops, open land surfaces using simple storage utensils such as tanks, pits and cistern. Harvested rainwater is a renewable source of clean water that is ideal for multiple uses. The greater attractions of a Rain Water Harvesting system (RWHS) are its accessibility, low cost and easy maintenance features at the household level. Rain water harvesting enhances water supply by mitigating the temporal and spatial variability of rainfall and provide water for basic human needs and other small-scale productive activities. RWH and storage have proved to be an affordable and sustainable intervention in areas with dispersed populations or where the costs of developing surface or groundwater resources are high (Mati *et al*., 2005).

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Thus Rainwater promotes savings of potable water in the residential as well as in commercial buildings. According to Karim *et al.* (2004) study on 'Perception and acceptance of rainwater harvesting in a coastal area in Bangladesh'. They revealed that the knowledge and awareness regarding RWH was a key issue, about 41.67 per cent of them preferred to use rainwater for domestic purposes over other water source. Interestingly 70.00 per cent of them preferred rainwater for drinking over other water sources and the reason was because visual quality of harvested rainwater is very high and satisfactory when compared to other water sources. From the study of Umamani and Manasi (2011) it can be concluded that among households that have adopter RRWH 43.3 per cent a majority were found to use it for recharging groundwater followed by 18.3 per cent used for cleaning of house and 1.6 per cent were found to use it for cooking and drinking because they had directed rooftop water directly to their overhead tanks. However, they have installed filters/purifiers in their kitchen for filtering water.

Lekwot *et al.* (2012) explored from their study that about 55 and 44 per cent of the respondents had Dug well and rainwater as a source of water supply respectively. They found that harvested rain water was majorly used for personal hygiene (44.00 %), cooking (22.00 %). Drinking (17.00 %) followed by washing utensils (11.00 %). Tobin *et al.* (2013) studied household use of harvested rain water. Most common use for stored water was for personal hygiene (92.70 %) Others were domestic chores (92.20 %), cooking (92.20 %), irrigation or animal husbandry (72 %). Least common use was for drinking by 76.20 per cent. Using harvested rain water which has not undergone purification process for drinking and cooking will result in affecting its users with certain water borne diseases such as cough, cold, Sore throat, dysentery and diarrhea. Sohel (2005) discovered similar results in the Paikgacha Thana of Khulna district. People collected rain water without any due consideration on design hence potentiality of collecting rain water to the fullest was not possible.

Maximum people used rain water without any purification hence are affected by many water borne diseases. The study conducted by Gakungu (2013) on assessing quality of harvested rainwater in Embakasi area of Nairobi county revealed that the quality of first rainfall were within the guidelines for both chemical and microbiological parameters established by the World Health Organization (WHO). On the contrary turbidity levels were higher. All the samples required some level of treatment such as chlorination in order to ensure they meet WHO regulatory standards. Rain water harvesting is a perfect alternative for surface and ground water as later is concerned with the rising cost as well as ecological problems. Rain water harvesting is a non-complex and financially efficient way of managing limited water resource ensuring sustained and long-term supply of water to the community. Based on the above rationale, the study on 'Qualitative evaluation of harvested rainwater from residential buildings of Dharwad and Hubballi cities' was undertaken with the following objectives:

- To explore the purpose for adoption of rain water harvesting system in Dharwad and Hubballi cities.
- To assess the physical and chemical characteristics of harvested rainwater samples.
- To explore the impact of usage of harvested rainwater for drinking and cooking purpose.

MATERIALS AND METHODS

The present investigation was carried out in the department of Family Resource Management, College of Rural Home Science, University of Agricultural Sciences, Dharwad during the period of 2016-17. The methodological steps and procedures followed to conduct the present investigation are explained under the following headings.

Research Design: The present research was aimed to explore the adoption and non-adoption level of rain water harvesting systems, their conditions, potential and knowledge about the rain water harvesting system. The focus was also on imparting capacity building program for the non-adopters and influences them to adopt rain water harvesting systems. Furthermore, among the selected families the potential of rain water harvesting system to satisfy the demand for water were scrutinized.

Quality of harvested rainwater: It implies the physical and chemical characteristic of the harvested rooftop rainwater. It is influenced by the physical and chemical properties of roofing materials. Physical analysis includes testing of Colour, odour, taste, turbidity, total dissolved solids and total hardness of harvested rainwater. Chemical analysis includes testing for pH, minerals (such as iron, zinc, copper, fluoride, aluminum, lead, magnesium, sodium, potassium) and alkalinity in the harvested rainwater.

Locale of the study: The study was conducted in the Dharwad district of Karnataka state. The average annual rainfall is around 780 mm. Years ago, Dharwad was known for its lakes, which are gradually drying out, the surface water sources are failing to meet the demand and underground water sources are being exploited. Hence people are adopting rain water harvesting systems at their residential buildings to harvest rainwater falling on their roofs in various urban areas of Dharwad and Hubballi taluka.

Sampling technique: Keeping in view the objectives of the study purposive random sampling technique was adopted for selecting 60 residential buildings from both Dharwad and Hubballi cities. For comparative analysis the selected residential units were divided into 30 adopters each from both Dharwad and Hubballi cities.

Research tools: The research tools used to collect the required information from the selected adopters and non-adopters of rain water harvesting system under the present study were pre-structured interview schedule, checklist. The tools were formulated by reviewing the relevant literature. The pre-structured interview schedules were prepared in English for better understanding.

Water quality analysis: The harvested rainwater from the rooftop was collected in the rain tanks. The rainwater was collected from the 2 households of Hubballi and 3 households of Dharwad city during the January month of 2017 so that all seasonal and non-seasonal rains of the year 2016 are covered. It was collected in sterilized plastic drooping bottles at room temperature. The bottles were placed in the Dry ice container and were carried to laboratory within 24 hours of its collection. The rainwater samples were subjected to analysis and checked against standards prescribed by Bureau of Indian Standards IS 10500/1991 (Annexure I).

Statistical analysis: The data collected was tabulated by keeping in view the objectives of the study. The data was analyzed employing Frequency and percentage.

RESULTS

Technical aspects of RWHS of selected adopters

Year of construction of RWHS: The year of construction of the adopted rain water harvesting system was classified into three categories through class-intervals. According to the Table 1 about 43.33 per cent of the adopters residing from Dharwad city got constructed their RWHS between the years 2010 to 2012 followed by the same per cent of the adopter got constructed during the year 2013 to 2015. During the years 2004 to 2009 about 13.33 per cent of the adopters got constructed their rain water harvesting system.

Further in case of the adopters residing from Hubballi city majority i.e., 43.33 per cent of them got constructed their RWHS between the years 2010 to 2012 this was followed 33.33 and 23.33 per cent of the adopters got constructed their RWHS between the years 2004 to 2009 and 2013 to 2015 respectively. The trend of majority follows among the total adopters irrespective of the study area about 43.33 per cent of them got constructed their RWHS between the years 2010 to 2012 this was followed 33.33 and 23.33 per cent of the adopters got constructed their RWHS between the years 2013 to 2015 and 2004 to 2009 respectively.

Cost of construction of RWHS: From the Table 1 we can note that in case of Dharwad city majority (60.00 %) of the adopters spent less than Rs. 20,000/- as cost of construction of RWHS this was followed by 33.33 per cent of the adopters spent Rs. 20,000/- to Rs. 40,000/- as cost of construction of RWHS and just 6.67 per cent of the adopters spent more than Rs. 60,000/- as cost of construction of RWHS. In case of Hubballi city majority (63.33 %) of the adopters spent less than Rs. 20,000/- as cost of construction of RWHS this was followed by 30.00 per cent of the adopters spent Rs. 20,000/- to Rs. 40,000/- as cost of construction of RWHS and just 6.67 per cent of the adopters spent more than Rs. 40,000/- to Rs. 60,000/- as cost of construction of RWHS.

Overall irrespective of the locale of the study majority (61.67 %) of the adopters spent less than Rs. 20,000/- as cost of construction of RWHS and 31.67 per cent of them spent Rs. 20,000/- to Rs. 40,000/- as cost of construction of RWHS. This was followed by 3.33 per cent of the adopters spent Rs. 40,000/- to Rs. 60,000/- as cost of construction of RWHS and equal per cent of the adopters spent more than Rs. 60,000/- as cost of construction of RWHS.

Method of RWH adopted: The Table 1 depicts various methods of rain water harvesting system installed by the selected adopters of rain water harvesting in both Dharwad and Hubballi city. It was found that three methods of rain water harvesting such as Bore well recharge (BWR), Ground water recharge (GWR) and Roof-top Rain Water Harvesting (RRWH) were adopted by the selected respondents. In the Dharwad city majority i.e., 90.00 per cent of the selected residential buildings had adopted bore well recharge method of rain water harvesting, this was followed by just 10.00 per cent of the selected residential buildings had adopted rooftop rain water harvesting method and none of the adopters from Dharwad city adopted ground water recharge method of rain water harvesting.

Furthermore, in Hubballi city a majority of the residential buildings i.e., 70.00 per cent of them had adopted bore well recharge method of rain water harvesting. This was followed by 23.33 per cent of the selected residential buildings possessed ground water recharge method and rest 6.67 per cent of the selected residential buildings possessed roof-top rain water harvesting respectively. From the Table 12 and Fig. 6 it is revealed that among the overall adopters of rain water harvesting irrespective of the study area about majority i.e., 80.00 per cent of selected residential buildings possessed bore well recharge method of rain water harvesting. This was followed by 11.67 per cent of the selected residential buildings possessed ground water recharge method and rest 8.33 per cent of the selected residential buildings possessed roof-top rain water harvesting respectively.

Cleaning practices of RWHS followed by the selected adopters

Roof cleaning practice: It is evident from the Table 2 that cent per cent of the selected adopters from both Dharwad and Hubballi cities respectively followed practice of cleaning their roof. Amon them equal per cent of the selected adopters (93.33 %) of both Dharwad and Hubballi cities opined that they cleaned of the roof whenever dust and dirt accumulates. About 83.33 and 56.67 per cent of the selected adopters from Dharwad and Hubballi cities respectively cleaned their roof once before first rain every year. A small percentage (3.33 %) of the adopters did not clean their roof at all as they did not use harvested rain water for domestic purposes. Irrespective of the study area most of the adopters (93.33 %) opined of cleaning roof whenever dust and dirt accumulated. However nearly three fourth of the adopters (70.00 %) opined of cleaning roof once before first rain every year. This is followed by small percentage (1.67 %) of the adopters opining of not cleaning their roof at all as they did not use harvested rain water for domestic purposes.

Gutters cleaning practice: It is evident from the Table 2 that adopters of Dharwad city 63.33 per cent opined of cleaning gutters weekly whereas rest 36.67 per cent of them opined of cleaning gutters monthly. The trend was contrary in case of adopters of Hubballi city majority *i.e*., 53.33 per cent of the adopters agreed that they cleaned gutters monthly however 46.67 per cent of the adopters agreed that they cleaned gutters weekly. Overall a majority (55.00 %) of the adopters irrespective of the locale of the study opined of cleaning gutters weekly and remaining 45.00 per cent of the adopters opined of cleaning gutters monthly.

Filter cleaning practice: It is evident from the Table 2 that among adopters of Dharwad city 90.00 per cent opined of not cleaning filters whereas rest 10.00 per cent of them opined of cleaning filters. The trend was similar in case of adopters of Hubballi city where majority *i.e*., 93.33 per cent of the adopters agreed that they did not clean filters however 6.67 per cent of the adopters agreed that they cleaned filters. Overall a majority (91.67 %) of the adopters irrespective of the study area opined that they did not clean filters and remaining 8.33 per cent of the adopters opined that they cleaned filters.

Cleaning practice of storage tank: It is evident from the Table 2 that among adopters of Dharwad city 90.00 per cent opined that they cleaned the storage tank twice a year however rest 10.00 per cent of them opined that they cleaned the storage tank monthly. The trend was similar in case of adopters of Hubballi city where majority (93.33 %) of the adopters agreed that they cleaned the storage tank twice a year however 6.67 per cent of the adopters agreed that they cleaned the storage tank monthly. Overall a majority (91.67 %) of the adopters irrespective of the locale of the study opined that they cleaned the storage tank twice a year and remaining 8.33 per cent of the adopters opined that they cleaned the storage tank monthly.

Quality testing of harvested rainwater from Dharwad and Hubballi cities: The rainwater samples were collected by Rooftop Rain Water Harvesting Syatems (RRWHS) from 3 residential units of Dharwad cities and 2 residential units of Hubballi cities. Water quality analysis was conducted according to the standard methods for examination of drinking water by the Bureau of Indian Standards (BIS): IS10500/1991.

The physical and chemical parameters are shown in the Table 3 and Table 4.

Physical parameters

Colour, Odour and Taste: It is measured in terms of Hazen units. From the Table 3 we can note that according to the BIS standards prescribed, desired limits are 5 hazen units and permissible limits are 25 hazen units. But in all the five rainwater samples of RWH the colour was nill. As seen from the table all the rainwater samples have odour in desired limits. According to the BIS standards the taste of the rainwater must be agreeable and as prescribed all the 5 samples had agreeable taste.

Turbidity: Turbidity is a measure of the ability of light to pass through water, it is a measure of the waters murkiness. It gives estimate of suspended solids in the water. According to the BIS desired limits are 5 NTU and permissible limits are 25 NTU. But the turbidity in all the five rainwater samples was nill.

Total dissolved solids (TDS): According to the BIS standards for drinking water the desired limits for TDS is 500 mg/l and permissible limits is 2000 mg/l. But results are very low as compared to the desired limits recommended by the BIS standards. Among all the five rainwater samples, highest amount (60.09 mg/l) of TDS was present in rainwater sample 2, followed by 60.07 mg/l of TDS was present in rainwater sample 4 and 60.01 mg/l of TDS was present in rainwater sample 1 as well as 5 whereas least amount (60.00 mg/l) of TDS was present in rainwater sample 3.

Total hardness: The total hardness of the water is measured in terms of quantity of CaCO3 in the water sample. According to the BIS standards desired limits are 300 mg/l and permissible limits are 600 mg/l. From the Table 3 we can note that in rainwater sample 1, 2, 4 and 5 the total hardness was 35.00 mg/l whereas in rainwater sample 3 it was slightly higher *i.e.*, 35.07 mg/l. But outcomes are very low as compared to the desired limits recommended by the BIS standards. Chemical parameters pH. The pH is the measure of the acidity or alkalinity of water. It is usually measured by using colorimetric test – litmus paper changes colour with increased acidity or alkalinity. According to the BIS standards pH was 7.5 in rainwater sample 3 followed by 7.2 in rainwater sample 1 and 5, whereas it was 7.0 in rainwater sample 2 and 4 respectively. The results of the chemical analysis are within the desired limits recommended by the BIS standards (Plate 1).

Chemical parameters

pH: pH is the measure of the acidity or alkalinity of water. It is usually measured by using colorimetric test – litmus paper changes colour with increased acidity or alkalinity. According to the BIS standards pH was 7.5 in rainwater sample 3 followed by 7.2 in rainwater sample 1 and 5, whereas it was 7.0 in rainwater sample 2 and 4 respectively. The results of the chemical analysis are within the desired limits recommended by the BIS standards (Plate 1).

Minerals: The total calcium content of the rainwater samples was measured according to the BIS standards, the desired limits are 75.00 mg/l and permissible limits are 200 mg/l.

From the Table. 4 we can note that the calcium content in rainwater sample five is highest (2.70 mg/l) followed by 2.23 mg/l in rainwater sample 3, 1.78 mg/l in rainwater sample 2, 1.72 mg/l in 1 and 1.59 mg/l in rainwater sample 4. But results are very low as compared to the desired limits recommended by the BIS standards. Moreover, the iron, chloride, residual free chlorine, calcium, copper, manganese, sulphates, nitrates, fluoride, phenolic compounds, mercury, cadmium, selenium, arsenic, cyanide, lead, zinc, chromium, mineral oil, aluminum and boron content were nil in all the five rainwater samples.

Alkalinity: The desired limits for alkalinity are 200 mg/l and permissible limits are 600 mg/l whereas, in the water sample 3 the alkalinity is 50.00 mg/l followed by in water sample 4 it is 49.07 mg/l, in the water sample 2 it is 48.02 mg/l, in the water sample 1 it is 48.00 mg/l and in water sample 5 it is 43.67 mg/l. But results are very low as compared to the desired limits recommended by the BIS standards (Table 4).

Benefits of RWH expressed by the adopters: Table 4 revealed the benefits of rain water harvesting persuaded that among the selected adopters of Dharwad city majority (73.33 %) of them persuaded that there was reduction in the hardness of ground water followed by 63.33 per cent of the adopters persuaded that there was reduction in dependency on municipal water supply system as benefits of installing rain water harvesting system. About 26.67 per cent of the adopters observed increases ground water level and only least *i.e.*, 10.00 per cent of the adopters observed reduction in water bill. In case of the Hubballi city majority *i.e.*, 70.00 per cent of the adopters persuaded reduction in dependency on municipal water supply system due to installation of rain water harvesting system followed by more than half them opining about reduction in the hardness of ground water.

About 26.67 per cent felt increase in ground water level as the benefit of installing of rain water harvesting system and 16.67 per cent of the adopters observed reduction in water bill. Irrespective of the study area from the Table 4 it is revealed that majority (66.67 %) of the adopters perceived reduction in dependency on municipal water supply system followed by 65.00 per cent of them perceived reduction in the hardness of ground water as benefits of installing rain water harvesting system. Increase in ground water level was perceived as benefit of installing rain water harvesting system by 26.67 per cent while reduction in water bill is perceived as benefit by 13.33 per cent of the adopters of rain water harvesting system respectively.

Maintenance cost of the RWHS spent by the adopters: From the Table 5 we can note that in Dharwad city majority (53.33 %) of the adopters spent Rs. 1,000/- per year for maintenance of rain water harvesting system followed by Rs. 1,200/- per year spent by 46.67 per cent of adopters for maintenance of their rain water harvesting system. Likewise in case of Hubballi city majority of the adopters (50.00 %) of them spent Rs. 1,000/- per year for maintenance of their rain water harvesting system followed by Rs. 1,200/- per year by 36.67 per cent and Rs. 600/- per year by 13.33 per cent of the adopters for maintenance of rain water harvesting system. From the Table 5 it is revealed that irrespective of the study area majority (51.67 %) of the adopters spent Rs. 1,000/- per year as maintenance cost for their rain water harvesting system. This was followed 41.67 per cent of the adopters spent Rs. 1,200/- and rest 6.67 per cent of the adopters spent Rs. 600/- per year for maintenance of rain water harvesting system.

Table 1. Technical aspects of RWHS of selected adopters

(n_1=60)

Sl. No.	Components of RWHS	Adopters		
		Dharwad (n=30)	**Hubballi (n=30)**	**Total (n_1=60)**
1.	**Year of construction of RWHS**			
	2004 to 2009	4 (13.33)	10 (33.33)	14 (23.33)
	2010 to 2012	13 (43.33)	13 (43.33)	26 (43.33)
	2013 to 2015	13 (43.33)	7 (23.33)	20 (3.33)
2.	**Cost of construction of RWHS (rupees)**			
	< 20,000/-	18 (60.00)	19 (63.33)	37 (61.67)
	20,000/- to Rs. 40,000/-	10 (33.33)	9 (30.00)	19 (31.67)
	40,000/- to Rs. 60,000/-	-	2 (6.67)	2 (3.33)
	> 60,000/-	2 (6.67)	-	2 (3.33)
5.	**Method of RWH adopted**			
	Bore well Recharge	27 (90.00)	21 (70.00)	48 (80.00)
	Underground Water Recharge	-	7 (23.33)	7 (11.67)
	Rooftop Rain Water Harvesting	3 (10.00)	2 (6.67)	5 (8.33)

Table 2. Cleaning practices of RWHS followed by the selected adopters

Sl. No.	Components	Adopters		
		Dharwad (n=30)	**Hubli(n=30)**	**Total(n_1=60)**
1*	**Roof cleaning practice**	30 (100.00)	30 (100.00)	60 (100.00)
	Whenever dust and dirt accumulates	28 (93.33)	28 (93.33)	56 (93.33)
	Once before first rain every year	25 (83.33)	17 (56.67)	42 (70.00)
	Not cleaned as rainwater is not used for domestic purpose	---	1 (3.33)	1 (1.67)
2.	**Gutters cleaning practice**			
	Weekly	19 (63.33)	14 (46.67)	33 (55.00)
	Monthly	11 (36.67)	16 (53.33)	27 (45.00)
3.	**Filter cleaning practice**			
	Clean filters (RRWHS)	3 (10.00)	2 (6.67)	5 (8.33)
	Do not posses filters (BWR)	27 (90.00)	28 (93.33)	55 (91.67)
4.	**Cleaning practice of storage tank**			
	Cleaned monthly	3 (10.00)	2 (6.67)	5 (8.33)
	Cleaned half yearly	27 (90.00)	28 (93.33)	55 (91.67)

Note: Figure in the parenthesis indicates percentage.
* Multiple responses are possible

Table 4. Chemical parameters of harvested rainwater samples

Sl. No.	Variables	BIS (IS10500/1991)		Hubli		Dharwad		
		Desirable limit (Requirement)	Permissible limit	Rainwater sample 1	Rainwater sample 2	Rainwater sample 3	Rainwater sample 4	Rainwater sample 5
8.	Calcium (as Ca), mg/l, max.	75	200	1.72	1.78	2.23	1.59	2.70
9.	Copper (as Cu), mg/l max.	0.05	1.50	Nil	Nil	Nil	Nil	Nil
10.	Manganese (as Mn), mg/l, max.	0.1	0.3	Nil	Nil	Nil	Nil	Nil
11.	Sulphate (as SO4), mg/l max.	200	400	Nil	Nil	Nil	Nil	Nil
12.	Nitrate (as NO3), mg/l	45	100	Nil	Nil	Nil	Nil	Nil
13.	Fluoride (as F), mg/l, max.	1.0	1.5	Nil	Nil	Nil	Nil	Nil
14.	Phenolic Compounds (asC6H5OH), mg/l, max.	0.001	0.002	Nil	Nil	Nil	Nil	Nil
15.	Mercury (as Hg), mg/l, max.	0.001	No relaxation	Nil	Nil	Nil	Nil	Nil
16.	Cadmium (as Cd), mg/l, max	0.01	No relaxation	Nil	Nil	Nil	Nil	Nil
17.	Selenium (as Se), mg/l, max	0.01	No relaxation	Nil	Nil	Nil	Nil	Nil
18.	Arsenic (as As), mg/l, max.	0.05	No relaxation	Nil	Nil	Nil	Nil	Nil
19.	Cyanide (as Cn), mg/l, max.	0.05	No relaxation	Nil	Nil	Nil	Nil	Nil
20.	Lead (as Pb), mg/l, max	0.05	No relaxation	Nil	Nil	Nil	Nil	Nil
21.	Zinc (as Zn), mg/l, max	5	15	Nil	Nil	Nil	Nil	Nil
22.	Chromium (as Cr6+), mg/l, max.	0.05	No relaxation	Nil	Nil	Nil	Nil	Nil
23.	Mineral Oil, mg/l, max.	0.01	0.03	Nil	Nil	Nil	Nil	Nil
24.	Alkalinity, mg/l, max.	200	600	48.00	48.02	50	49.07	43.67
25.	Aluminium (as Al), mg/l, max.	0.03	0.2	Nil	Nil	Nil	Nil	Nil
26.	Boron (as B), mg/l, max.	1	5	Nil	Nil	Nil	Nil	Nil

Table 5. Harvested rain water for drinking purpose

(n1=60)

Sl. No.	Variables	Adopters		
		Dharwad (n=30)	**Hubballi (n=30)**	**Total (n_1=60)**
1.	**Reasons for drinking harvested rainwater**			
	Easy access of water	2 (6.67)	1 (3.33)	3 (5.00)
	Cleanliness of water	1 (3.33)	1 (3.33)	2 (3.33)
	Quality assurance of water	2 (6.67)	2 (6.67)	4 (6.67)
	Water is non polluted	1 (3.33)	1 (3.33)	2 (3.33)
	Not used for drinking	27 (90.00)	28 (93.33)	55 (91.67)
2.	**Precautionary measures before drinking rainwater**			
	Use electrolyte formula	1 (33.33)	1 (50.00)	2 (40.00)
	Coat inner walls of storage tank with limestone	2 (66.67)	1 (50.00)	3 (60.00)
	Use same tank for storing municipality and rainwater	3 (100.00)	2 (100.00)	5 (100.00)
3.	**Health impact of using rainwater**			
	Cold and cough	1 (33.33)	---	1 (20.00)
	Throat infection	---	1 (50.00)	1 (20.00)
	None	2 (66.67)	1 (50.00)	3 (60.00)

Table 6. Maintenance cost of the RWHS spent by the adopters

Sl. No.	Maintenance cost (rupees/year)	Adopters		
		Dharwad (n=30)	**Hubballi (n=30)**	**Total (n_2=60)**
1	600	---	4 (13.33)	4 (6.67)
2	1000	16 (53..33)	15 (50.00)	31 (51.67)
3	1200	14 (46.67)	11 (36.67)	25 (41.67)

Note: Figure in the parenthesis indicates percentage

DISCUSSION

Rain Water Harvesting (RWH), in its broadest sense, is a technology used for collecting and storing rainwater for human use from rooftops, land surfaces or rock catchments using simple techniques such as jars and pots as well as engineered techniques. As per the study adoption of RWHS during 2004-2009 though was not mandatory, nearly one fourth of the houses had already built and were using it. In view of reduction in annual average rainfall and scarcity of water for domestic supply Hubli-Dharwad Municipal Corporation (HDMC) made RWH mandatory for all newly constructed houses in Dharwad and Hubballi cities with a site dimension of 40 ft. x 60 ft. from 2010. Hence there has been a swift increase in the number of installations of RWHS. But during 2013-2015 due to availability of both ground water and pipeline water supply the adoption rate RWHS drastically dropped. RWHS is a low-cost water conservation technique, because majority of the respondents incurred less than Rs. 20,000/- for its construction.

The results are on par with the findings of Umamani and Manasi (2011), wherein majority of respondents (46.00 %) were found to have spent less than Rs.15000/- for installation of RWHS. It can be noticed that there is a change in the cost of installation (from the year 2011 to 2017). This is due to the hike in the price of building materials such as sand, cement etc. Majority of the houses adopter BWR for the reason that it softens the groundwater and can be pumped whenever necessary. Regular maintenance of the RWHS is necessary since it avoids contamination of harvested rainwater and prevents residents from cold, cough, throat infection and water borne diseases. The physical and chemical parameters of collected harvested rainwater samples though lacked certain minerals necessary to be present in drinking water, yet were overall in balance with the drinking water standards prescribed by BIS. Rainwater can be recommended for drinking with minimal mineral treatment such as Oral Rehydration Salts (ORS) can be dissolved prior consumption or can be mixed with borewell water. Mixing of harvested rainwater softens the bore well water, reducing the concentration fluorides, chlorides, sulphates and phosphates etc. Hence RWH has proven to be a low-cost/maintenance and viable technique for bridging the gap between water demand-supply. It aids in securing present and future generations towards “Water sustainability”.

Conclusion

Dharwad city was popular for its natural water resources like – lakes, ponds, open well etc. Due to Global warming there has been drastic change in the climate with increased temperature decreased humidity and scanty rainfall. The growing population, migration of people to cities, increasing number of bore wells and reduced source of water resource, both the cities are still facing difficulty in meeting demand and supply limits. The HDMC took a virtuous step and made RWHS a mandatory.

In order to obtain completion certificate for their houses, all the newly built houses from the year 2010 had to install RWHS. Hence Dharwad and Hubballi cities are on the path of making major paradigm shift – from focus on the extraction and distribution of ground water to conservation of purest form of water i.e., Rainwater and rejuvenation of the other water resources such as Ground water, lakes, ponds etc. This means has to get popularized and adoption level has to be increased as urbanization and concretization of both cities had increased run-off and gets collected in low-lying areas. It can be diverted to storage facilities so that the run-off during rainy season can be an alternative water resource during dry seasons. Community participation should be encouraged as it can lead to a fruitful water supply scheme. The authority can encourage adoption level by providing concession on water bill for adopters or subsidy for installation of RWHS. As an additional recharge facility, footpaths, bus-stops, railway station, parks, can be efficiently utilized for recharging underground water resource. Other benefits include low cost flow irrigation, reduction in concentration of silt and minerals to fertilize the soil in the command area, and reduction in soil erosion. A superior key, rain water harvesting diminishes non-point source pollution. Having lower hardness than groundwater, rainwater extends their use for drinking and cooking. RWH from can help combat the chronic national water shortage scenario.

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APPENDIX I Bureau of Indian Standards for drinking water

Sl. No.	Variables	BIS (IS10500/1991)	
		Desirable limit (Requirement)	Permissible limit
1.	Colour, Hazen units, max	5	25
2.	Odour	Unobjectionable	---
3.	Taste	Agreeable	---
	Turbidity NTU,MAX	5	10
4.	pH	6.5-8.5	No relaxation
	Total hardness (CaCO3), mg/l max	300	600
	Iron (as Fe) mg/l, max.	0.30	1.0
5.	Chlorides (as Cl), mg/l, max	250	1000
6.	Residual free chlorine, mg/l, min.	0.20	---
7.	Total dissolved solids, mg/l max	500	2000
8.	Calcium (as Ca), mg/l, max.	75	200
9.	Copper (as Cu), mg/l max.	0.05	1.50
10.	Manganese (as Mn), mg/l, max.	0.1	0.3
11.	Sulphate (as SO4), mg/l max.	200	400
12.	Nitrate (as NO3), mg/l	45	100
13.	Fluoride (as F), mg/l, max.	1.0	1.5
14.	Phenolic Compounds (asC6H5OH), mg/l, max.	0.001	0.002
15.	Mercury (as Hg), mg/l, max.	0.001	No relaxation
16.	Cadmium (as Cd), mg/l, max	0.01	No relaxation
17.	Selenium (as Se), mg/l, max	0.01	No relaxation
18.	Arsenic (as As), mg/l, max.	0.05	No relaxation
19.	Cyanide (as Cn), mg/l, max.	0.05	No relaxation
20.	Lead (as Pb), mg/l, max	0.05	No relaxation
21.	Zinc (as Zn), mg/l, max	5	15
22.	Chromium (as Cr6+), mg/l, max.	0.05	No relaxation
23.	Mineral Oil, mg/l, max.	0.01	0.03
24.	Alkalinity, mg/l, max.	200	600
25.	Aluminium (as Al), mg/l, max.	0.03	0.2
26.	Boron (as B), mg/l, max.	1	5

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