RAINWATER HARVESTING IN HOUSES OF UDAIPUR CITY: A MEASURE TO CONSERVE NATURAL RESOURCE

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Thesis

Doctor of Philosophy in Home Science

(Family Resource Management)

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TOPIC: Rain water harvesting in houses of Udaipur city: A measure of conserve natural resource

ABSTRACT

Water is the most precious gift of nature. The increasing number of human population is posing a serious threat to its availability and sustainability for the future generations. The quality and quantity of under ground water are also decreasing. Thus, the study on rain water harvesting was undertaken with the objectives: 1) To find out the existing status of water resources in household and various water management practices adopted by homemakers. 2) To popularize and commission rain water harvesting system in households. 3) To assess the quality and quantity of existing and harvested rain water in households. 4) To find out the rooftop rainwater harvesting potential of selected houses. In order to find out various water management practices adopted by home makers and popularizing the rainwater harvesting technique, 100 households were selected. Out of 100 samples, 30 houses were selected purposively for commissioning of the rooftop rainwater harvesting system and estimation of rooftop rainwater harvesting potential.

To achieve the planned objectives the present study was divided into three phases: Phase I: Household survey Phase II: Laboratory and Household experiments Phase III: Estimation of rooftop rainwater harvesting potential. During the first phase household survey was conducted to collect the required information regarding the existing status of water resources and various water management practices adopted by homemakers. Second phase included laboratory and household experiments to assess the chemical and microbiological status and quantity of water available in borewell before and after commissioning of rainwater harvesting system. Experiments were conducted to identify the presence of pH, electrical conductivity, total dissolved solids, chloride, hardness, total coliform and faecal coliform bacteria in existing and harvesting rainwater available in borewells for the purpose of potable and non-potable uses. Samples of water were collected in sterilized bottles from thirty purposively selected houses. The data were analyzed using frequency and percentage distribution and the quality of harvesting rainwater was compared with the standards as suggested by World Health Organization (WHO, 1991) and Bureau of Indian Standards (BIS, 1997).

The results of the study indicated that majority of the respondents faced the problems related to the hardness and color of water and they were partially satisfied from the source of water with regards to quality and quantity of water available to them. This was due to the municipal supply of water with low pressure, resulting into scarcity of water and during summers the water table goes down to a great extent and quantity of water available in borewell for household activities is scarce. Rainwater harvesting technique was popularized among 100 homemakers and rainwater harvesting system was commissioned in 30 selected houses. It also revealed from the results that harvested water was within the permissible limits as suggested by WHO and BIS for the chemical quality. The results of total coliform bacteria was much higher with the value 102.4 MPN/100 ml as compared to permissible limits 10 MPN/100 ml prescribed by WHO and BIS. The sources of the contamination were mainly the method of water withdrawal. The water table of borewells increased and the availability of water per day per family was found to be higher due to higher rain water harvesting potential. Hence, on the bases of results it is advised that each family should commission rainwater harvesting system in their houses.

Key words: Rainwater harvesting, quality, natural resource

Major Advisor **Research Scholar**

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Introduction

Water is a major natural resource on which the social and economic condition of the country depends. Man can survive without food for about 50 to 55 days but without water one cannot survive beyond 4 to 5 days. A human adult body contains about 25 to 30 liters of water. A minimum of 2 to 2.5 liters of water is necessary per day for drinking and to sustain life. A reduction of more than 10% of water in the body fluid can be fatal.

Water is a major vehicle for moving nutrients within the body and removing salts and other wastes from it. It is not only essential for the sustenance of life, but is also necessary in myriads of human activities. The World Health Organization has recommended that it is ideal to supply 150 liters water per person per day, for the domestic requirements like drinking, washing, cooking etc. The government of India in its water policy has suggested a norm of 180 liters per capita for all domestic needs. But it has not been possible to supply even 100 liters per day, even in urban areas. The rapid development of productive forces, the rise of living standards, higher culture and welfare requirements have resulted in greatly increased demand of water. Land, water and energy are the three basic needs for any form of life. Out of these three, water is the most vital resource for the existence of life on earth, it is required for survival of human. Water is life because, it is required from birth to death for human being and for survival. Water is also an important part of the environment and is home for many forms of life on which human well being depends. The importance of water for every major aspect of development is fully recognized but the right quality and quantity of water is difficult to obtain whenever required and wherever needed.

Water is an inorganic component, which covers about $3/4^{th}$ of the earth's surface, but only 3 percent of it is available to man for use. The remaining 97 percent

of water found in oceans is full of soluble salts, being unfit for human use and consumption (Gurjar, 1994). Fresh water is an indispensable need of man. Today the problem of fresh water supply is increasing tremendously due to fast growing population, progressive industrialization, rise in standard of living of people, increase in demand for food, rehabilitation of arid areas etc. They also cause the contamination of water Consequently, this resource is becoming scarce with each passing day.

Out of the available surface and ground water for human use, the surface water rapidly gets polluted and is subjected to evaporation losses, the ground water has an advantage over surface water in that it is widely available in quantities sufficient to cater to the needs of scattered communities. Another advantage of ground water is its natural filtration brought about by movements through intergranular flow over sand. After a passage of about 15 meter over such beds, all pathogenic bacteria in the ground water get removed.

Just as surface water gets polluted by industrial effluents, agricultural run-off, human waste water disposal and land drainage, the ground water also becomes vulnerable to pollution when the same has its flow through the rock fissures, over gravel. In such a situation, no filtration takes place and pathogenic bacteria get transported to over large distances making the water unsafe for drinking. The unclean surrounding have also known to contribute to the high bacterial contamination of under ground waters.

It is considered by many, that the water, in some way is instrumental in disease out-break and was known even in ancient days. Hippocrates in 400 B.C. has written" Whosoever wished to investigate medicine properly, should consider water in relation to health and disease." Even in ancient Hindi literature, the importance of clean water to maintain good health is emphasized. It is now established that almost 80% of all sickness and disease are caused by polluted water, non availability of water and inadequate sanitation. In the developing world three out of five people have no access to safe drinking water and only one in four has any sanitary facilities. Population living in rural areas are less served with water than those in urban areas.

The most vulnerable age group to water borne diseases are children under five years old. Around 25 million children under five years, die each year from water associated diseases. One third of these die from diarrhea alone. The debilitating effects of diseases like elephantiasis and dracunculosis spreading through the medium of water make a large portion of our population idle.

In areas such as Rajasthan where, the availability of water itself is scarce, its degradation through unhygienic habits of the people causes innumerable health problems ranging from diarrhea, dysentery to dreadful diseases like dracunculosis, typhoid, cholera etc. It is therefore, necessary to investigate the status of our water sources in order to understand their usability for drinking and domestic purposes. In several countries of the world, the regular monitoring of the quality of source water is practiced so as to keep track of deterioration, if any. This procedure makes it possible for the administrators to classify the water sources for a specific human use such as water supply. While such a situation is unlikely to arrive in India in near future, we can certainly monitor our water resources for their upkeep and cleanliness. The wells and borewells are not likely to disappear from Indian scene in many more years to come, or may not go at all as the surface waters are over pressurized for their use. The present researches reported in the thesis is a step towards this direction as a sample study.

The available water on earth is in a finite quantity that has not changed over millennia. This has to be juxtaposed against increasing demands form a growing population. The population of the world, currently around 6 billion, is expected to exceed 8 billion by the year 2050. Apart from sheer numbers, the processes of urbanization and development are also expected to vastly increase the demand for fresh water. This situation of finite supply and growing demand leads to the projections of water scarcity which could be severe in some parts of the world.

In India, a consciousness of the importance of the subject of water resources and water harvesting led to the establishment of a National Commission on Integration Water Resource Development Plan three years ago and the first National Commission on water finalized its work plan and submitted its report to the

government of India in September 1999. In the mentioned scenario, augmentation of water sources is the prime need of the hour.

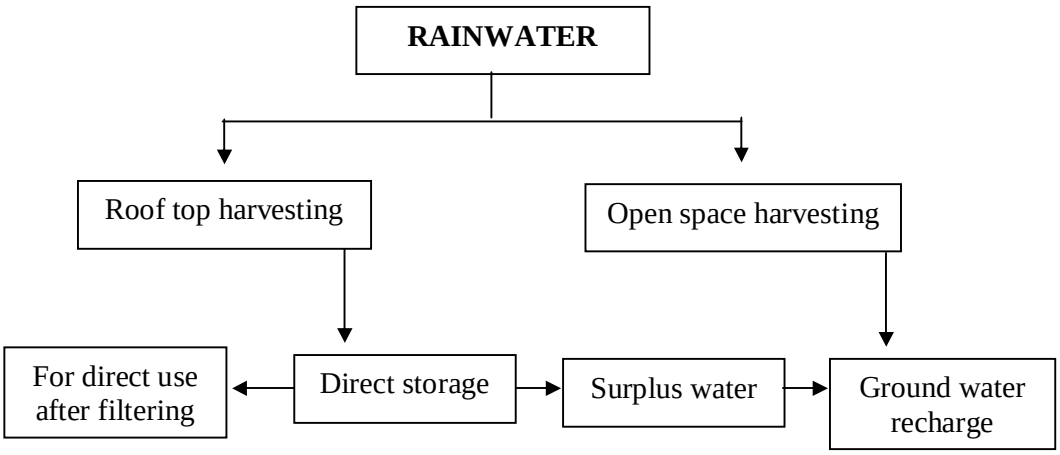
Rainwater is a free source of nearly pure water. It can be used to supply potable (drinking) water and non- potable water. For non-potable uses, like watering landscapes, it is ready for use as it falls from sky. For potable uses, rain water must be treated to remove or kill disease organisms that may be present. Rain water is one of the purest sources of water available. It's quality almost exceeds that of ground or surface water. It is the first forms of water that we know in the hydrological cycle, hence, it is a primary source of water for us. Rivers, lakes and ground water are all secondary sources of water. In present times, we depend mainly on such secondary sources of water. In the process, it is forgotten that rain is the ultimate source that feeds all these secondary sources and remain ignorant of its value. Water crisis situation occurs only because, effective collection and storage of rain water has been ignored. The potential of rain to meet water demand is tremendous. Unless people are involved in conserving rain water from individual households to big industries/institutions, it would be very difficult to meet the looming water crisis.

The concept of rainwater harvesting lies in **tapping the rainwater.** A major portion of rainwater that falls on the earth's on the surface, runs-off from streams to rivers and finally to the sea. An average of 8% of the total rainfall recharge the ground water aquifers. Therefore, most of the rainfall goes waste in the forms of surface run-off. The technique of rainwater harvesting involves tapping the rain from localized catchment surfaces such as roof of a house, plain and sloping ground surface etc. The rainwater that falls on these catchment is diverted into dugout ponds, vessels or underground tanks to store for long periods. Construction of small barriers across small streams to check and store the running water is also an example of small catchment water harvesting.

Water harvesting means to understand the value of rain and to make optimum use of rain water at the place where it falls. In scientific terms, water harvesting (broadly) refers to collection and storage of rain water and also other activities such as harvesting surface water, extracting ground water, prevention of losses through evaporation and seepage.

In general, water harvesting is the activity of direct collection of rain water. The rain water collected can be stored for direct use or can be recharged into the ground water.

Fig:1.1 Rainwater Harvesting



As indicated above, rain water falling on the terrace of building can be collected through pipelines/drains and stored in a storage tank for direct use or diverted into a open well/borewell for ground water recharge. Rain fall over the open spaces around the building may also be diverted for recharge purpose.

Justification of the study:

Water resource development is essential for the progress of mankind. Rapid population growth and even increasing living standard have resulted in a sharp rise in human requirement of water, necessitating expeditious development of the available water resources and its proper management. There is a continual need to manage our domestic water supply, its storage, use and specially to prevent it from contamination and pollution.

The rapid development of cities and population explosions in urban areas have led to depletion of surface sources. Whatever sources available now are at long distances forcing the corporation to spend higher capital expenditure and need lot of time for planning and execution apart from strain on finances. This is the reason that

Cherapunji in Assam receives highest rain fall in India to the tune of 11,000 mm per year also suffer from acute shortage of drinking water as rain water is not consumed but allowed to be drained away (Srivastava,2005). This has also resulted into over exploitation of surface sources like wells for drinking and industrial use, resulting to dropping water levels and drying up of bore wells or sea water intrusion because of imbalance of inflow and outflow equation for sub-surface water. The rapid urbanization has also introduced reduction in original permeable ground surface because of pavements, roads and construction of storm water drains for aiming to drain the rain water as quickly as possible to nearby natural stream, river or sea to avoid flooding of grounds and disruption in traffic. These surface and quick disposal gives no time for rain water to percolate into natural ground to replenish the water sub-surface aquifer causing the dropping of water levels or drying up of wells.

The results of man-made crisis can be seen as global warming and change in climatic conditions. The rains have become more irregular because of disturbance in natural cycle, and therefore do not reach when one wants them. Also, the quantity of rainfall is erratic, reduced and uncertain. Hence, now the need for conservation of rainwater has been felt much more than over before. It is therefore, necessary to conserve and augment the renewable natural ground water resources as last chance for survival, realizing that natural resources are not unlimited, if they are exploited beyond certain limit. The people can meet their own water demands by capturing, conserving and recycling the rain water falling on their land, which is available in plenty.

Udaipur city in Rajasthan is surrounded by Aravali hills and five lakes- Pichola, Fatehsagar, Rangsagar, Swaroopsagar and Dudhtalai. Deforestation in the hills surrounding Udaipur and in the adjoining forests of Mewar region has meant that each year's monsoon washes down tonnes of silt into lakes. It has been estimated that the capacity of Pichola is reducing every year by 0.93% and that of Fatehsagar by 1.16%. Both the lakes were major sources of water in the city and were almost dry by the end of august 2005. "UDAIPUR IS A CITY OF LAKES BUT DRY WAS A COMMON PHRASE TILL NOW" Though the data of rainfall in last three years shows that there were increase in average rainfall every year i.e. 504.88 mm in 2003, 601 mm in 2004 and 882.4 mm in 2005 (Soni, 2005), but this was not enough to replenish the water source and meet the water demand of the city with the growth of

population and industries in the city. The per capita available of water is decreasing day by day. Similarly, the water table has also gone down tremendously and will continue to fall further if rain water is not harvested in true sense and allowed to flow into surface drainage. There is no restriction from the municipal corporation on having access of borewell and tubewells by the pubic. This situation has further lead to drying of under ground water resource. In most of the households borewell is the common water resource to meet the domestic water requirement. The per capita consumption of water has increased but the average annual availability of water per capita has declined from 5,236 cubic meters in 1951 to only 2,227 cubic meters in 1991 and it is estimated that this will decline further to 1,555 cubic meters by the year 2013 (Chary and Vyasula,2000). So, to fill up the gap between limited availability and increased consumption of water by each family, the rainwater harvesting system is one of the most effective techniques at present and years to come.

In the past ten years, some extraordinary efforts made by the community in India to harvest rainwater has already shown that it not only improves the local ecology but also improves economy. Water is a necessary resource, that is used in almost all the household activities, its quality and quantity affects the well being and growth of human beings, their daily routine activities and living environment. So, the present study is a serious effort to have a first hand knowledge of the existing source of water in households and various water management practices adopted by the homemakers through out the year. This study was planned to popularize and commission rain water harvesting system in the houses and assess the availability and quality of harvested rain water.

Keeping all the above, in view it was felt rational to take up a study entitled, "Rain water harvesting systems in houses of Udaipur city: A measure to conserve natural resource."

The added purpose of the study is to conserve the abundant water during monsoon, so that it is available during the lean season and bring consciousness among people towards conservation and management of water for better quality of life through improving our environmental natural resource.

Hence, the present study was undertaken to judge the efficiency of rainwater harvesting system (in terms of quantity and quality) with the following objectives:

1. To find out the existing status of water resource in households and various water management practices adopted by home makers.
2. To popularize and commission rain water harvesting system in households.
3. To assess the quality and quantity of existing and harvested rain water in household.
4. To find out the rooftop rain water harvesting potential in selected households.

Operational Definitions:

Rainwater Harvesting: Rain water harvesting is a simple technique to collect rainwater that falls in your premises and utilize it for various purposes.

Water Harvesting Potential: The total amount of water that is received in the form of rainfall over an area is called the rainwater endowment of that area. Out of this, the amount that can be effectively harvested is called the water harvesting potential.

DELIMITIONS OF THE STUDY:

- The study was delimited within Udaipur City.
- Samples were delimited in respect of the houses where rain water harvesting system was installed.
- Only roof top rainwater harvesting system was commissioned in the houses.
- Only those houses were selected where rain water harvesting system was connected to borewell for recharging the under ground aquifers.
- Multistory buildings and apartments were not selected for the purpose of this study.

Abbreviations used in the Research

CL	=	Chloride
EC	=	Electrical Conductivity
TDS	=	Total Dissolved Solids
TCB	=	Total Coliform Bacteria
FC	=	Faecal Coliform

MPN	=	Most Probable Number
APHA	=	American Public Health Association
WHO	=	Would Health Organization
BIS	=	Bureau of Indian Standards
RWHS	=	Rainwater harvesting system

Review of Literature

A comprehensive review of literature is a must for all research endeavor. This chapter attempts to give an overview of the literature reviewed by the investigator to tie the theoretical and empirical aspects of the study. Knowledge of the related literature helps the investigator to define the frontiers of the field and helps in avoiding unintentional replication of previous work done. Further, it helps to interpret the significant of results.

In this chapter, relevant literature having direct or indirect bearing with the present investigation has been reviewed and presented under the following heads:

2.1 Water : An essential requirement for human existence

2.2 Depletion of water resources

2.3 Rain water collection and harvesting

2.4 Rain water harvesting from rooftop of houses

2.1 WATER: AN ESSENTIAL REQUIREMENT FOR HUMAN EXISTENCE

Water is vital to every human community and is essential resource for economic development, agricultural productivity, industrial growth, and human well-being. The availability of a clean, safe & secure water source has been, and will always be, a major concern for human populations (Kierche, 2000).

Water is an essential commodity for survival of mankind and other living organisms of earth. It is one among the fabulous gifts of nature for supporting its creations. Indian mythological evidences prominently indicate the great efforts of Bhagiratha in bringing water to the mother earth. Water is also described as one of the panchabhutas is our ancient vedas. But today, by ignoring these facts, man is indiscriminately polluting water in unknowingly provoking the nature for complex situations (Rao, 2001).

It is regretted by Ganesan (2002) that water is an essential basic resource for sustenance of life and development of economy. When the monsoon fails the scarcity

of water looms large in most parts and the economy is thrown out of gear and life becomes miserable. It has been observed in recent times, that scarcity of water has become a major irritant on the relationship between the states that depend upon common source for water. Hence, a prudent approach is to harvest the rain waters, store them in reservoirs and tanks and innovative use of water resources become essential for sustainable development of the economy.

According to Sathe & Lokhande (2002) water is a vitally important substance with properties that are unique, interesting and wide ranging in potential impact. Several of those characteristics play mayor roles in determining water quality and causing changes in it, either through natural phenomena or impacts brought about by man-made activities. Water also plays important roles in microbiological life processes. It provides the basic environment within which organisms live and contains the elements and chemical components that make their survival and growth possible.

Satya Priyaa explained in 2002 that 'No Water' Means 'No Life'. Everything will become dry and dead without water, hence water must be considered precious than gold or platinum. Wasting water is like wasting everything since it serves like a ‘nucleus’ for this universal cell. Cautiousness in the usage of water and the conservation of the same should be practiced by every single person and should avoid taking it for granted.

When water is constantly lost from the body it would lead to “dehydration” and when this becomes severe it leads to death. So

- Save Water
- Save Your Life
- Save The Universe

Titus & Pereira (2003) stated that water is the critical element for survival of human being. In fact, water is the basis of all life. Life began in the water and continues to be the essence of all living beings. All biological elements are made up of water to the extent of 70 to 80% body weight. Water also plays a pivotal role in the weathering & soil formation. Nothing on earth can live without freshwater. A human being will die within three days without it. It is simply because water is life and life is water.

Water is the most vital resource for the existence of life on earth. It is indispensable for the existence of plant and animal eco-system and forms an essential element in the development of economic activities as stated by Chinnan (2004).

Sahoo reported in 2004, that water is all sources of life and without this life is unthinkable in our mother earth and that's why it is aptly known as life. Despite of its preciousness water has remained as a neglected issue till today. Water as supply freely by nature is taken for granted in India. This is the reason why in a less than half a century of independent existence, India a water rich country has been reduced to a water insecure nation. The acuteness is such that during 2025 there may be an water emergency era where less than 1000 cu.m. of precipitation is considered critical for human survival. This will be clear from the following statistics. Annual per capital availability of renewable fresh water:

1955 – 5277 cu.m.

1990 – 2464 cu.m.

2025 – 1000 cu.m.

India witnessed severe water related problems during the year 2003 and became the no-1 problem.

Earth is an unique planet in this universe because life is possible here. It is again because of the presence of land, air, water and light. Among all resources water is the most important one in making life possible.

Bhuvaneswari (2005) reported that water is a precious resource available in nature. It is an essential constituent of all living organisms and forms about 75% of the matter of earth's crust. Water is distributed in different forms, such as rain water, river water, spring water, mineral water and ground water.

It is stated by Chelladurai (2005) that water is essential for survival of all living beings and also for socio-economic development of households, communities and nations all over the world. It is also necessary to maintain and enhance biodiversity and quality of environment. It is estimated that it accounts for 4 percent of the world's fresh water resources. This when India's share of 2.5 percent in the total land area of the world, seems more than adequate. According to the National

water policy, water is a prime natural resource for humans and hence, a precious national asset. Now a days, it is hard to find fresh water due to growth of population agricultural and industrial activities and contamination of water resources. The country receives about 4000 Km^3 of precipitation patterns and mismanagement of it often leads to wastage. Therefore, water the most important natural resource, should be preserved for future generations.

Mittal (2005) explained that water is the most precious gift of nature and vital for human survival. The increasing number of human population is posing a serious threat to its availability and sustainability for the future generations. The human body consists of almost 80 percent water, so it is impossible for them to survive without water. Thousands of other species of creatures are also dependent on water for their survival. The entire biosphere is dependent n water. In this context, the ever depleting water resources and their protection as well as sustainable consumption and supply of clean and potable water to humans and other creatures is the biggest challenge of the 21st century. The central & state government has been making sincere attempts to meet this challenge.

According to Narasimhan (2005) Water is an extraordinary natural phenomenon. Its attributes, its role in the functioning of the earth, and its importance in society excite interest in all branches of knowledge. Because no life can sustain without it, water constitutes a source of economic and political power. The future of modern technological society in a world of burgeoning population may depend as much on judicious water management as on available of cheap energy. In contemporary society, water is a major theme of scientific, economic, political, and social and human debate. There is widespread concern that the future of peace and prosperity in a finite. Earth will depend on our civilized ability to share the limited water resources of the world.

Water is the one of the most precious gifts of nature. No life in any form human, animal or plant is possible without this priceless asset of the living system. Water is also a primary requirement for sustainable agricultural and industrial development. History is witness to the fact that great civilizations anywhere in the world flourished adjacent to rivers, streams and assured water bodies. But they continued growing till water resources could be managed well. With poor

management of these resources began their downfall and eventually they disappeared. (Singh and Padaria, 2005).

It is reported by Somasundaram in 2005 that water is pivotal natural resource, which fulfills number of significant functions. Unlike most other natural resources, water does not have any substitute in this main uses. It can be used lavishly or effectively but cannot be replaced. The source of water is unevenly distributed both spatially as well as temporally. India is one of the few countries in the world endowed with plenty of land & water resources. The average precipitation is 1250 mm. over 329m ha area (400 million hectare metre). The total water availability is about 2300 M^3/P/year and when the population reaches a level of 1640M (1640 Billion) in 2050 according to UN report per capita availability will be about 1400 M^3, based on this our country will be water stressed but not water scarcity. Most of the rainwater goes as runoff. Scientific methods may help in harvesting rain water in the best possible ways, they are conservation of rain water by harvesting structures, contour bunding, contour stone wall. Contour trenching, check dams in low rainfall area and construction of percolation ponds, irrigation tank and scheduling of irrigation. By adopting these technologies/methods we can improve the ground water availability in the low rainfall areas, water scarcity and more runoff area.

Water is a national resource which is an essential content in every part of life on the earth. Everything is originated from water and everything is sustained by it. “Water” said the eminent Greek Philosopher Pindar “is the best of all things”. As the twenty first century dawns, the importance of this statement is becoming evident in many parts of the world, even through Pindar lived some two and a half millennia ago(Naik et.al.2006).

Narula (2006) stated that water is finite resource. With only about 1,222 billion cubic meters presently estimated as the total annual utilizable water resource, the present per capita water availability in India is about 1,022 cubic meters. Water may be a God given resource but we must wake up to the fact that with demand rising exponentially, its price will also shoot up. Also, we must seriously look into replenishing our water resources so we can meet long-terms demands as well.

2.2 DEPLETION OF WATER RESOURCES

Sinha explained in 1997 that the underground water is most inexpensive source of water used for various purposes like drinking, bathing, irrigation as well as industrial operations. Due to indiscriminate uses and wastage by human beings, the underground water has become polluted and unsafe for human consumption. Several countries are already in the grip of severe underground water crisis. The stupendous increase in population, ill-conceived, industrialization, urbanization and many other human activities have made availability of underground water more & more difficult and expensive as well. The excessive extraction of underground water & its pollution due to leaching of pollutants to the aquifers have led towards a underground water crises in several parts of the world. The scenario is even more depressing in developing countries because of their efforts to improve their economy. Thus acquiring the status of developed industrialized countries.

Kanmony (2002) have stated that in India nearly 70% of inland water is unfit for human consumption. It is estimated that 90 to 95% of all domestic sewage and 75 percent of industrial wastes are discharged into surface water without any treatment. New technology, which has brought about Green Revolution, has also contributed to the indirect use of pesticides and chemical fertilizers which is the main cause for water pollution. Green revolution also favours the excessive utilization of ground water. It leads to ground water depletion and in turn causes excessive damage to the country's infrastructure and environment.

According to Nautiyal (2002) in one third of India’s agroclimatic regions, there is water scarcity already in terms of per capita demand and supply of water. This imbalance is bound to lead to conflicts at the local, state & the national levels. At present, thousands of Indian cities do not have sources of water and in future, it would have to be transported over larger distances as the water sources move much more away from the cities. The country’s current and future situation can be gauged by the trend in water availability. Presently, six of India’s 20 major river basins already fall into water scarce category. By the year 2025, five more river basins are feared to be water scarce. Even Brahmaputra, Barak & west following rivers will be water insufficient in the times to come. The glaciers of Himalaya are rapidly melting and it is feared that within next 50 to 80 years, most of the glaciers will disappear.

Water problems are one of the most pressing issues falling the world this century. We are faced with the critical question of how to provide a stable supply of water for drinking and food production for a projected population of 8 billion people in 2025. So, water problems become one of the biggest issues of concern for global society (Okada, 2003).

Rajvedi explained in 2003, that the fresh water sources which are finite and fragile are becoming scarce day by day. More than 1.5 billion people worldwide depend on ground water. The global water scenario is so grim that more than one third of world's population is already living in countries moderate to high water stress. According to a report of global environment outlook, the global fresh water consumption has risen six fold between 1900 and 1995 which roughly twice the rate of population increases. This problem is assuming serious proportions in Africa and West Asia. Roughly 20% of world population lacks access to safe drinking water. Excessive withdrawal of ground water, more than recharge, has become widespread in many parts of the Arabian Peninsula, China, India, Mexico former Soviet Union and the United States resulting in appreciable fall in water level. With rapid industrialization during the last century, excessive use of fresh water for different purposes is mainly responsible for present scenario. Over extraction of ground water has also affected its quality leading to saline ingress in coastal areas as in the case of Oman, Bahrain and India biological contamination in the form of faecal coliform count, chemical fertilizer and pesticide residue in Asia's rivers is 50 times higher than that of the WHO guidelines making the local population vulnerable to high risk level. The problem is not wide recognized because it is going underground. However, in many places the situation has already reached a crisis level and may be economically irreversible.

It is reported by Swanappan in 2003, that water is becoming scarce commodity and it is considered as liquid gold in the desert part of the country. The demand of water is also increasing day by day not only for agriculture but also for household purpose. It is estimated that water need for drinking and other municipal uses will increase from 3.3 MHm to 7.00 MHm in 2020/25. The rainfall is abundant in the world and in India. But it is not evenly distributed in all places. India being monsoonic country, the rain falls only for 3 to 4 months in a year with high intensity, it results in more runoff and soil erosion. If the availability of water is 1700 M^3/P/Y

there will be occasional water stress, and if it is less than 1000 M^3/P/Y it is under water scarcity condition. Though India is not under water stress, Tamil Nadu is already under water scarcity condition, but there is no need for panic since it is possible to manage this condition as in the case of Israel where the availability is about 450 M^3/P/Y by means of water harvesting, water conservation and water management. Hence, to mitigate water problem/drought etc., there is an urgent need to follow our ancestral way of water harvesting and the latest technologies adopted in Soil and Water Conservation measure on watershed basis including roof water harvesting etc.

Chand (2004) observed that in developing countries like India, inadequate sanitation adds to the microbial contamination of drinking water and food, leading to an increased number of carriers and causes. Person to person spread of diseases result because of poor hygienic practices or ignorance about them. The microbial contamination of drinking water from its abstraction till consumption is to be especially avoided because of its high degree of simultaneous infection in the community.

The United Nations population projections indicate that India will be among 34 countries of the world, which are likely to face severe water shortage by the year 2025. As per estimates, the country's annual fresh water requirement (i.e about 1,050 billion cum) by that year will be almost at par with its exploitable water resources. Thus, the preservation of safe water and protection of water quality of existing sources become priority areas.

In the year 2004, Garg & Totwat stated that rapid industrialization and urbanization have led to discharge of industrial effluents which in turn pollute the ecosystem. The disposal of effluents has become a serious techno-economic problem particularly due to rising cost of disposal and growing awareness of pollution hazards. Ground water is an important source of drinking water for much of the world's population and its quality & purity has a direct effect on human health.

It is reported by Raheem (2004) that as an area develops and population increases, the volume of wastewater increases, resulting increase in the deleterious substances leaching into local aquifers. Eventually the water will get contaminated and reach a state, where it will be either unsafe or unaesthetic for use. It then becomes

necessary to exploit a new aquifer at a deeper level, than the one initially used and contaminated.

Singh et al. (2004) stated that water is an inexhaustible gift of nature. However, its uneven distribution in space & time has often threatened human welfare, livelihood & economic development. The growing scarcity of water has been the result of rapidly growing population, rising demand for food and cash crops increasing urbanization and rising standard of living. These will increase the acuteness of the problem of water scarcity in future. In several villages and even in cities, the quality of water is degraded. Low availability & growing scarcity of water is another serious problem, the country has been falling today. The quality of water available for various uses is not up to the mark.

According to Bamniya et al. (2005) the scarcity of fresh water is common problem every where these days because of the errotic and irregular rainfall and fast depletion of underground water resources. The excessive use of water in domestic, irrigation and industrial sector is the main cause of water scarcity.

It is obvious that ground water resources, their exploitable potential, yield of wells and chemical quality of water mainly depends upon hydrogeological formations. Due to indiscriminate pumping of ground water for various purposes, depletion in their level have been taken place and consequently the potential zone have been converted to “Dark Zone” category. Water levels vary with rainfall, physiography, drainage and climate conditions. In case of Rajasthan the trend of water level during 1984-99 has been analyzed on the basis of water level records during pre-monsoon 1984 and pre-monsoon 1999. According to which, out of 32 districts, 27 districts show a depletion of water level. However, only in 5 districts a rise in water level has been observed (1990-2000). The prime cause of water table depletion is uncontrolled withdrawal of ground water to meet out ever growing demands for agriculture, domestic & industrial purpose, through huge numbers of structures in potential areas. Thus resultant is the shrinking of ground water resource due to which the wells are getting dry, deterioration in chemical quality & increase in lifting cost. Therefore, now the time has come to think and act according by way of adopting different methods to step declining water resources (Kaliwar & Sharma. 2005).

Water scarcity is now the single biggest threat to global food production. Just two decades ago, serious water problems were confined only to small pockets of the world. Today, it exists in every continent and is spreading rapidly 22 of world's countries at present have renewable water supplies of less than 1000 M^3/Year. The World Bank estimates that by the year 2025 one person in three, or 3.25 billion people in 52 countries will live in conditions of water shortage. The supply of water for human use entails not only the problem of quantity but also one of quality, since all human activities impair the natural quality of water. Beyond a certain degree of pollution, water becomes unusable. The result is a reduction in the supply of usable water and problems with the disposal of the polluted water. Under these circumstances, to overcome the demand of water is crucial in the coming years (Sivanappan, 2005).

In an article by Sharma (2006) where it has been stated that India is surrounded by water bodies on three sides yet we face water shortage every year. The quality of available water is also fast deteriorating. In 1982 it was reported that 70 percent of all available water in India was polluted. The situation is much more worse today. Over-extraction of ground water has led to salt water intrusion into coastal aquifiers. It has also resulted in problems of excessive fluoride, iron, arsenic and salinity in water affecting about 44 million people in India. Ground water is facing an equally serious threat from contamination by industrial effluent and faecal matter, as well as pesticides and fertilizers from farm run-offs. Unless priority is given quickly to creating an infrastructure to assure availability of water, there may be no water to meet the agricultural, domestic and industrial needs of a population that has tripled in 50 years to one billion. Water management is therefore a major challenge for town planners, builders and architects today, not just in terms of availability of water, but most important is its quality.

2.3 RAIN WATER COLLECTION AND HARVESTING

Kannan et al. (2000) explained that in humid regions, there is lot of scope for water harvesting as these regions generally receive more than 1000 mm of rainfall and it is confined to only four months. Rainwater harvesting is an ancestral technique for collecting and storing water. The design of water harvesting system is basically the

same for all locations. At the same time, there is no standard or best design for a water harvesting system. Each site and water use are unique and each system must be fitted to the local conditions and needs. There are many elements, which must be considered such as precipitation patterns, water requirement patterns, soil, land topography, alternative water sources, available material, equipments, labour, and acceptability of water harvesting concepts by the water user. The total water quantity and seasonal distribution varies for each situation. The water harvesting system must satisfy these need.

In the year 2000, Rao stated that it is possible to provide water to every people in India by rainwater harvesting. All rainwater which falls on the ground should be properly harvested and used for all domestic purposes, it should be possible to cultivate 1.2 hectares of land with just 100 m.m. of rainwater. People must be encouraged to desilt ponds, tanks and wells in the village and towns, so that all rainwater is collected which can be used for drinking and irrigation. People need to be educated and made aware that water is a limited natural resource and must be used carefully.

Singh (2000) studied that the traditional techniques of water harvesting in Rajasthan have not been well described. Still less analyzed to highlight the lessons they demonstrate. There is a need to document the state of art of various traditional techniques of harvesting of water of Rajasthan. It is also important to study the human dimension in relation to water harvesting technology.

Further he also emphasized that, poorly managed water harvesting systems may cause soil erosion and soil instability. Therefore, water harvesting catchments in Rajasthan require proper maintenance to keep them in good conditions.

Balaji et al. (2001) stated that rain water harvesting is the only feasible solution to recharge the depleted ground water aquifers and to restore the productivity values of lands and local water supply schemes. The present era of erratic monsoonic rainfall has forced the farming community and other gross consumers of water to make a paradigm shift of spending water like money rather evaporating money like water which is the central concept of any rain water harvesting strategy.

There is a need to arrest the depletion of ground water by adopting suitable artificial recharge methods. Every drop of rain water needs to be harvested to increase

the availability of water. Conserving the surplus water during the monsoons by water harvesting and recharge techniques has to be adopted, as per the water management agenda (Pravin, Maheshwari and Supatha, 2001).

According to Nair (2002) with a runaway population, pollution of water sources and the mercurial nature of the monsoon, India is bent upon tapping all sources to provide drinking water to the people. The technology mission for drinking water actively functioning in the 90's reported that if even ten percent of the monsoon rain is trapped for recharging the underground aquifers, it will solve the availability of drinking water problem in most of the states. The mission accordingly suggested the construction of as many as 10,000 water conservation structures all over the country to minimizes the rainwater runoff. So the increasing water needs of growing population can be met, if excess runoff rainwater is properly harnessed.

Pai (2002) expressed that technologies used in rainwater harvesting is region specific depending upon various aspects such as physiographic environmental, technical and socio-economic etc., apart from type of soil, rainfall, topography of catchments and operational control systems. Water harvesting can be undertaken at individual household or community level.

In the year 2002, Rao explained, though India is one of the wettest regions in the world with an annual average rainfall of 117 cubic meters over the plains, water scarcity continuous to haunt various parts of India with varying intensity. As it is, India's rainfall is characterized by its diversity, both by the geographical division and seasons of the year. Added to this diversity in space and time, there are large variations in each geographic region from one year to another, resulting in flood in some areas and droughts in others. Against this backdrop, water resources experts have stressed on the need to revive the traditional water harvesting techniques to end the nagging water shortage in an economically viable and ecologically sustainable fashion. Each region of the country has its own water harvesting technique, reflecting the geographical peculiarities and cultural uniqueness of the community. Indians, for hundreds of years now, have been using a variety of techniques to harvest every possible form of water – rainwater, streams, springs, rivers and floodwater.

Meanwhile, development strategists point out that growing interest in traditional water harvesting systems will give a big boost to people's empowerment

for ending rural poverty and speed up the process of development in all its manifestations. As things stand now, India can hope to end its nagging water famine by investing time, money and energy on reviving the local water harvesting techniques in lieu of building big, costly and sophisticated dams which involves massive expenditure, human displacement and destruction of forest stretches and other eco-assets.

Rain water harvesting provides a powerful and decentralized solution to the crisis as historical evidences have highlighted the effectiveness of rain water harvesting at fort city of Jaisalmer in Rajasthan to the temple town of Melkote in Karnataka. Lately, Anna Hazare's work in Ralegaon Siddhi in Maharashtra and Rajendra Singh's work with Tarun Bharat Sangh in Alwar District in Rajasthan needs special mention. Another most successful rain water harvesting programme is the one at Mylenahalli in Jassan District by BAIF, Tiptur in Karnataka (Raju and Manasi, 2003).

D'Souza (2004) explained that rainwater harvesting begins with a simple idea. Rain gutters are already collecting the water that falls on your roof. To harvest that water all that is needed is to change the direction of the flow so that instead of running on to the ground, the water flows into a storage tank. The quality of the water itself makes the investment worthwhile. Rainwater typically has very low hardness levels, which reduces the use of soap and detergents and eliminates the need for a water softener. Stored rainwater is also a good standby in times of emergencies such as power outrages or during periods of extreme drought and because it does not have to be treated, pumped or distributed through a complex network, rainwater harvesting saves energy and many state governments have already made rainwater harvesting mandatory for all new buildings.

It is regretted by Gupta & Despande (2004) that water resources of India are examined in the context of the growing population and the national ambition to become and be seen as a developed nation. The population of India is expected to stabilize around 1640 million by the year 2050. As a result, gross per capita water availability will decline from ~ 1820 m^3/year in 2001 to as low as ~1140m^3/year in 2050. Total water requirement of the country for various activities around the year 2050 has been assessed to 1450 km^3/year. This is significantly more than the current

estimate of utilizable water resource potential (1122 km3/year) through conventional development strategies. Therefore, when compared with the availability of ~500 km^3/year at present, the water availability around 2050 needs to be almost tripled. Various options have been considered in quantitative terms, as possible sources to augment the anticipated deficit.

It is argued that due to considerations of gestation period and capital requirements, rainwater harvesting and water-conservation measures must receive the highest priority followed by renovation and recycling which is further followed by intra and then inter basin transfers in the last phase.

Kukal and Bhatt (2004) reported that there is a vast potential to prevent rainwater to move down into the streams and rivers and ultimately into the sea. Efforts are continuously being made in this direction to conserve rainwater. Recently water harvesting, either in the impounding type or dug out reservoirs, is gaining importance. Generally these reservoirs are made at the outlet end of the catchments where the rainwater from whole of the catchments drains out. The harvested water is then carried through underground pipelines to irrigate the command area in down slopes. This practice is important and a must, for recharging the ground water.

Thus the process of water harvesting does not end with the simple construction of water reservoirs but the most important aspect of it is to prevent / check soil erosion in the catchments areas so as to achieve sustainable water harvesting.

Nair reported in 2004, that at a micro level, rain water harvesting is also being taken up. Some state governments have already amended buildings by-laws to make rain water harvesting mandatory for new buildings.

Salas (2004) stated that rainwater harvesting is a popular term used for a tradition of collecting rainwater, improved by modern concepts and technologies, a result of more than two decades of research work around the globe. Today, rainwater harvesting is used in wet and dry countries, in poor and modern situations, for water supply and for sanitation in homes. It is utilized in addressing agricultural productivity and food security for poor alleviation, even in places with 200 mm of rain. Rainwater harvesting is employed in flood mitigation in rain-drenched countries

and in solving infiltration problems of sealed surfaces in urban areas and industrial complexes or in avoiding polluted water and toxic ground water.

Most of all, rainwater harvesting is environmentally sound as it assists in recharging ground water, enhances wetlands, assists forest conservation, encourages ecological farming and slows down construction of new dams for water supply thus helping the ecological flow.

Water deficit can be reduced by water saving methods, rainwater harvesting and wastewater recycling. Tamilnadu State Govt. is promoting rainwater harvesting enthusiastically in each and every part of the state. In the first phase of the promotion, the government has made rainwater harvesting structure mandatory in each house. In the second phase, it is planning to implement rainwater harvesting in the tanks, ponds and other water bodies. (Velavan, 2004)

According to Devi (2005), water is the life blood of the environment, without water no living being can survive, water plays a unique role in the traditional economy and culture of the native people.

Life posses us with so many contradictions. Despite being one of the wettest countries of the world, India's growing water shortage has reached alarming proportions. More than 200 million people would live under conditions of high water stress by the year 2050, according to the UNEP (United Nations Environment Programme), which warns that water could prove to be a limiting factor for development in a number of regions in the world. About one fifth of the world's population lacks access to safe drinking water and with the present consumption patterns, two out of every three persons on the earth would live in water stressed conditions by 2025. To tackle this problem, the Ministry of Water Resources has drawn up a programme for rainwater harvesting and recharge. A Rs. 45 crore plan has been earmarked for rainwater harvesting and recharge in the Ninth Plan. The ministry has sanctioned Rs. 25 crores for the Central Ground Water Board Programme, which involves states and user agencies in rural and inaccessible areas. The Central Ground Water Authority is also issuing directives to the states and municipal bodies to undertake roof top rainwater harvesting and its recharge to ground water mandatory for every dwelling unit by amending city by laws.

Swanappan explained in 2005, that water scarcity is a regular phenomenon, but the society should overcome by appropriate remedial measures. It is stated that even in Cheerapunji which tops the rainfall in the world, drinking water is a problem before the rainy season commences. This indicates that we are not concerned about water harvesting and conservation.

Rainwater harvesting is the process to capture and store rainfall for its efficient utilization and conservation to control its runoff, evaporation, and seepage. There are different methods of rainwater harvesting which were developed to suit the geographical and meteorological conditions of the region in various parts of the country.

There is a need to recharge aquifers and conserve rainwater through water harvesting structures. In urban areas, rainwater will have to be harvested using rooftops and open spaces. Harvesting rainwater not only reduces the possibility of flooding, but also decreases the community's dependence on ground water for domestic use. Apart from bridging the demand-supply gap, recharging improves the quality of ground water, raises the water table in wells/bore-wells and prevents flooding and chocking of drains. One can also save energy to pump ground water as water table rises. These days rainwater harvesting is being taken up on a massive scale in many states in India. Substantial benefits of rainwater harvesting exist in urban areas as water demand has already outstripped supply in most of the cities (Kumar et al., 2005).

According to an estimate of the Central Ground water Board, if we continue to exploit our ground water resources indiscriminately, then in the next 20 years, 15 states of the country may face auto shortage of underground water. Government has recognized water harvesting as a thrust area with more allocation of money. Higher budgetary support should be given to rain water harvesting and watershed schemes to recharge our underground water sources. To tide over the present crisis, we have to keep in mind that we cannot make more rain, so we have to manage water better. Water harvesting will avoid wastage of the precious national resource (Gautam and Kumar, 2005).

Mittal reported in 2005, that rainwater harvesting largely depends on quantity and distribution of rainfall and will, therefore, be more successful in areas where

rainfall is sufficient. Besides, rainwater harvesting depends on several other factors including topography, soil type and depth, slope and vegetative cover in the catchment areas. For the rainwater harvesting programmes to be successful, it is essential that moderately large catchments and sufficient storage facilities are available in the vicinity of the villages. Rainwater harvesting structures (RWHS) can meet multiple needs of the society such as drinking, domestic water requirements, livestock etc.

2.4 RAIN WATER HARVESTING FROM ROOFTOP OF THE HOUSES

In the year 1996, Singh stated that in India, surface drainage system is not properly utilized, leading to discharge of huge quantity of water along with sediments to the sea. Every year a lot of money is invested to control floods and flood related measures. So, people should be encouraged to harvest roof water in tank of suitable capacity or underground covered reservoirs.

According to Bhagyalakshmi (2001) rooftop rainwater harvesting and its recharge to underground through existing wells or borewell or by constructing new wells, shafts or spreading basins and other methods to capture run-off in the catchments, recharging treated urban and industrial effluent underground by using it for irrigation or through recharge ponds are some of the methods and techniques which are recommended and are being popularized. So, the emphasis now is given on harvesting rainwater. Water recharging methods are part of sustainable development, which means to have resources adequately for the present without depriving the future generations of the same.

Availability of rain water from roof tops is so high in the urban areas and if properly diverted and used, artificial recharges will not only increase the ground water availability but also help in reducing the water scarcity problem of cities and towns. Rain water harvesting will go a long way in conserving ground water and augmenting natural infiltration of water into under ground formation. Roof top rain water harvesting structures are less expensive and very effective and if implemented in spirit by each household it will help in augmenting the ground water storage (Arunadevi and Padmakumari, 2003).

According to Bhuvaneswari (2003) for the conservation of rainwater and recharging of ground water acquifer, roof top rain water harvesting technique should be adopted by every house owner. In the roof top rain water harvesting, the rain water is collected from the roof of the house/building and stored in a ground concrete tank and can be used for all domestic purpose (drinking, cooking, gardening, laundry, cleaning and to flush toilets).

Rainwater harvesting can also be done from rooftop through drain pipes in small trenches and underground water storage tanks located at suitable place from where the water will be percolated down to ground water strata. (Verma, 2003).

According to Madley (2005) rooftop harvesting has been practiced since ages, and even today it is practiced in many places throughout the world. As we know the rainwater collected from the terrace is free from any bacteriological contamination (except small amount of dust and other silt particles which can be filtered) it can be diverted to the existing wells/borewells.

In the year 2005, Raphael stated that community roof water harvesting is basically the revival of traditional wisdom wherein conserving the available rainwater is the main method of water conservation. Termed as Homestead Watershed Approach (HWA), it involves allowing the rainwater that falls on rooftops to percolate down to the soil to recharge the homestead wells.

Methodology

This chapter furnishes methodological details of the present investigation with a view to execute and analyze rain water harvesting technique in urban houses of Udaipur city. A study design refers to the logical manner in which units of study are assessed and analyzed for the purpose of drawing conclusion. To achieve the planned objectives the present study was undertaken using survey and experimental method. This chapter is devoted to materials and methods used in the present investigation to achieve the set objectives. The various steps followed are organized along with the relevant details under the following sections:

3.1 Locale of the study

3.2 Sample selection

3.3 Development of tool

3.4 Administration of tool and data collection

3.5 Analysis of data

3.1 LOCALE OF THE STUDY:

The present study was conducted in houses of Udaipur city, because this city is one of the most important cities of the state of Rajasthan, attracting large tourist traffic. It is known as the city of lakes, fountains, palaces and gardens. Udaipur city is surrounded by hills and there are lakes all around. All most all the lakes were dry before the arrival of monsoon 2005. The average rainfall since last 12 years was very low , resulting the scarcity of water in city and depletion of underground water table . Majority of the newly constructed houses in the city have borewells as the main source of the water for daily routine household activities. The water table in certain areas of city was very low and certain borewells were dry too. With a view to study the possibility of popularizing the rainwater conservation for replenishing water in the borewells and to avoid the water crises among the public of Udaipur city which is so important from the point of view of tourism, history and development of trade and commerce, the investigator has selected Udaipur city as the locale of the study.

Moreover, the investigator is a resident of this city and conducting the research was convenient to the scholar.

3.2 SAMPLE SELECTION:

In order to find out the existing status of water resources and water management practices adopted by the families, a sample of 100 households was selected. The detailed procedure for sample selection is presented in table 3.1. At the initial stage a list of dark zones in Udaipur city was obtained from water works department. From this list any four areas each in East, West, South and North zone falling under the dark zone(where water table is very low) was selected. Further from each zone 25 households were randomly drawn to form the sample.

The rain water harvesting technique among all 100 households was popularized by the investigator with the help of selected educational aids as per their convenience either in group or individually as recommended by the scientists for the area under study.

Out of the total sample, based on willingness of the respondents 30 houses were selected purposively for commissioning of the roof top rain water harvesting system in their houses. Experiments for judging the quality and quantity of available water before and after commissioning of rooftop rain water harvesting system was also studied by the researcher.

The rooftop rain water harvesting potential was also calculated only among 30 selected household by the standard formula.

Further, to judge the effectiveness of rain water harvesting system executed in (only in terms of quantity of water) in selected areas, a sample of 30 houses without rain water harvesting system situated 50 meter away from the house with rain water harvesting system in same area was also selected. The purpose of taking the sample 50 meter away is that the ground water formation changes every meter of the aquifer/water bodies below the surface. To keep the difference in sampling a distance of 50 meter was selected at random so that the variation in observation is well taken care. The water recharging capacity/ availability/quality all changes in below the surface with the depth and distance from one source to another so, these houses were considered as controll group for the study.

Table 3.1: Procedure for sample selection

S. No.	Procedure for sampling	Sample selected
1.	A. To study the management practices and popularization of rain water harvesting technique 1. Zones 2.Total number of homemakers from each zone	100 homemakers Four zones North East West South 25 25 25 25
2.	B. To commission rain water harvesting system and conducting the experiments	30 houses
3.	C. To compare difference in the water table by rainwater harvesting system	30 houses without rainwater harvesting system
4.	D. To estimate the rooftop rainwater harvesting potential	30 houses with rainwater harvesting system

3.3 DEVELOPMENT OF TOOL:

Keeping in view the objective of this study and relevant information to be collected, an interview schedule (appendix-I) was developed. In order to cross check the collected information an observation schedule (appendix-I) was also developed.

Interview Schedule:

The interview schedule dealt with the socio-economic and demographic profiles of family including their personal background information such as family size, educational background, existing status of water in households (Sources/availability in terms of quality and quantity) and various water management practices adopted by homemakers.

Observation schedule:

An observation schedule was developed to collect certain information on existing household conditions affecting the rain water harvesting potential of

households. Observations were made and measurements were taken by the investigator at the time of interview on the aspects related to household rain water harvesting technique such as roof shape , area of roof , diameter of bore well and depth of bore well.

3.4 ADMINISTRATION OF TOOL AND METHOD OF DATA COLLECTION:

To achieve the planned objectives the proposed study was carried out in the following six steps:

Table 3.2: Plan of work

STEPS	TITLE
I	Household survey
II	Popularizing the rain water harvesting technique
III	Household and laboratory experiments for judging the quantity and quality of water before commissioning rainwater harvesting system
IV	Commissioning of rain water harvesting system in selected houses
V	Household and laboratory experiments for judging the quantity and quality of water after commissioning rainwater harvesting system
VI	Estimation of rooftop rain water harvesting potential

Step I : Household Survey

Household survey was conducted through:

a) Interview schedule

The relevant data were collected from the home makers with the help of objectively based purposeful questions in the interview schedule. Supplementary questions or open ended questions were also asked on the spot while interviewing the home makers.

b) Observation schedule

The researcher personally had gone to the selected households for observations and taking measurement of catchment area at the site of individual house.

Step II : Popularizing the rainwater harvesting technique:

Rainwater harvesting technique was propagated among all the 100 homemakers through the following measures:

- A CD on rooftop rainwater harvesting system developed by Dr. P.C. Jain was shown to the selected homemakers (Appendix - IV).
- Working model on rooftop rainwater harvesting technique was developed by investigator (Plate 9).
- A folder on rooftop rainwater harvesting technique was developed by the investigator (Appendix - V).
- **A CD on rooftop rainwater harvesting**

A CD on rooftop rainwater harvesting has been developed by Dr. P.C. Jain, who is a medical doctor by profession but actively engaged in promoting rooftop rainwater harvesting among the public of Udaipur city, since last 7 years. He has developed a CD on rooftop rainwater harvesting technique in a very simple language with lots of visuals to make it more understandable and adoptable for the public. He has been engaged in educating, promoting and commissioning the rooftop rainwater harvesting system in many households of Udaipur city. He is one of the most successful and easily approachable persons

for this noble cause. During research, the investigator has taken the full support of Dr. P.C.Jain and made use of the CD developed by him.

- **Working model on rooftop rainwater harvesting technique**

A working model on rooftop rainwater harvesting technique was developed by the investigator for propagating this technique among the selected homemakers. The developed model can be seen in (plate - 9).

- **A folder on rooftop rainwater harvesting technique**

A folder on rooftop rainwater harvesting technique was developed by the investigator on the following aspects:

  - definition of rain water harvesting,
  - information about rain water harvesting system,

- precaution about rainwater harvesting system and
- advantages of rain water harvesting

Before developing the folder, the investigator herself has done indepth study on various above mentioned aspects of rain water harvesting technique and the collected information was arranged in a systematic manner with simple language and illustrations. Finally it was approved by the technical person before distributing to the selected 100 homemakers.

Step III: Household and laboratory experiments for judging the quantity and quality of water before commissioning rainwater harvesting system:

Household and laboratory experiments were conducted to compare and evaluate the efficacy of rain water harvesting system. To study the quality of water obtained from each bore well, the following experiments were conducted and method of conducting experiments is explained later :

Experiments to test the –

I) Chemical parameters

- pH
- Total Dissolved Solid (TDS)
- Electrical Conductivity (EC)
- Hardness
- Chloride

II) Microbiological parameters

- Total Coliform
- Faecal Coliform

To assess the efficacy of rain water harvesting system, step III was divided under the following heads –

(a) Equipments

(b) Collection of water sample

(c) Procedure for conducting experiments

(d) Conducting the experiments

A). Equipments:

a) Required glassware and equipments:

I. **Sampling bottles:** To collect water samples for laboratory experiments

II. **Test tubes:** To prepare the colour standards of the water.

III. **Test tube stand:** To hold the test tube during laboratory experiments.

IV. **Beaker:** It was used to hold water sample while testing pH value and EC of water.

V. **Measuring jar:** 50 ml, 500 ml and 1000 ml measuring jar were used to measure water for hardness, chloride and microbiological quality respectively.

VI. **Pipette:** 1 ml, 2 ml, 5 ml and 10 ml capacity pipette were used to measure water sample and chemicals for testing the chemical and microbiological quality of water.

VII. **EC meter:** It is a digital systronic direct reading conductivity meter which is used to determine electrical conductivity of experimental water (plate 1).

VIII. **pH meter:** . Pen type digital pH meter is used to measure the acidity and alkalinity of water (plate 2).

IX. **Autoclave:** Autoclave is an instrument used for sterilization of bacteriological media. Moist heat is employed for sterilization at temperature 121^0C for 15 minutes. Autoclave is a large pressure cooker and enables liquid media to be heated to high temperature under high steam pressure for destruction of all living cells (plate 3).

X. **Water level indicator:** Water Level Indicator is an equipment which has sound indicator attach to 2 different wires having an electrical charge of positive and negative. At the end, these 2 wires are necked and placed separately. When the wires are drawn into the borewell and touches the water level a close circuit is formed and current start flowing resulting into a continuous sound blowing from sound indicator. The total length of wire is marked at equal interval to know the

depth of water level in ft. It was used to measure the depth of water table in borewells (plate 4).

XI. **Incubator:** The incubator is an insulated metallic chamber, maintaining a constant temperature and used for growing bacterial cultures. Temperature is regulated by thermostat provided (plate 5).

b). Required chemicals:

I. **Ammonia Buffer solution:** Ammonium hydroxide was used as buffer solution. It was used in hardness test of water.

II. **Erichrome black T indicator dye:** It was used to test hardness of water, by giving colour to the sample solution.

III. **Standard EDTA titrant:** It was used to titrant of water sample for hardness, by giving colour to the sample solution.

IV. **Silver nitrate:** It was used to test chloride of water sample.

V. **Potassium chromate:** It was used to test chloride of water sample.

VI. **Mc Broth:** Single and double strength Mc Broth was used to test the most probable number of water sample.

B). Collection of water sample:

For judging the efficiency of rainwater harvesting system the water sample was collected from borewells before and after commissioning of rainwater harvesting system for experiments.

Procedure for collecting water sample:

The water samples were collected in sampling bottles.

1. The bottles were sterilized before collecting the sample.
2. The tap from which the water was drawn was also sterilized by heating it with a blow lamp (spirit lamp) for approximately 1-2 minutes.
3. Then 120 ml water of each sample was collected in sampling bottles.

4. The bottles were covered with glass stopper.
5. After covering the bottles, they were kept in refrigerator until it was taken for analysis in the laboratory.

C). Procedure for conducting experiments:

The water samples were tested for its pH value, electrical conductivity, total dissolve solids, hardness, chloride and microbiological quality by the standardized methods given by American Public Health Association – APHA (1989), Trivedi and Goel (1986) and World Health Organization – WHO (1984).

1. pH

1. The water sample was taken in a clean beaker.
2. Placed under the glass electrode of pH meter.
3. pH meter was switched on and reading were drawn from the displayed screen of the pH meter.
4. After using the pH meter, electrode was washed thoroughly and wiped it with tissue paper.

2 .Electrical conductivity (EC).

1. The water sample was taken in a clean beaker.
2. Placed under the glass electrode of EC meter.
3. The EC meter was switch on and reading were drawn from the displayed screen of the EC meter.
4. After using the EC meter, electrode was washed thoroughly and wiped it with tissue paper.

3. Total Dissolved Solids (TDS)

1. An evaporating dish of at least 100 ml capacity was taken and ignited at 550 ± 50^0C in a muffle furnance for about an hour, cooled in a desiccator and weighed.
2. The sample was filtered through glass fire filter paper applying the suction.
3. The 100 ml of sample was evaporated in the preweighed evaporating dish on a water bath.

4. The residue was heated at 103-105^{0}C in an oven for one hour and then the final weight was taken after cooling in a desiccator.

$$\text{TDS (mg/litre)} = \frac{A-B \times 1000 \times 1000}{V}$$

Where,

A = Final weight of the dish in gram

B = Initial weight of the dish in gram

V = Volume of sample taken in ml

4. Hardness

The hardness of water was determined by titration method.

Procedure to make reagents for hardness:

Standard EDTA titrant (0.01 M):

3.723 g of disodium salt of EDTA was dissolve in distilled water to prepare 1 litre of titrant stored in plastic bottle.

Ammonia buffer solution:

114 ml concentrate NH_4OH was added to 13.5 g of NH_4Cl and made the volume upto 200 ml.

Erichrome black T indicator:

0.5 g dye was dissolve in 100 ml of 80% ethyl alcohol.

Procedure to test hardness:

1. 50 ml of water sample was taken in a flask.
2. 1 ml buffer solution and 0.1 g of Erichorme black T indicator dye was added. The colour of the solution in flask turns wine red.
3. Titrate with standard EDTA solution till the colours turns red to violet or bright blue. This indicates the end point. Recorded the volume used titrant.

Calculating the total hardness:

Total hardness was then calculated by the following formula:

$$\text{Total hardness (mg/litre.)} = \frac{\text{ml. of EDTA used}}{\text{ml. of sample used}} \times 1000$$

5. Chloride

Chloride was determined by Mohar's titration method

Procedure to make reagents for chloride:

Silver nitrate (0.02 N):

3.400 g of dried $AgNO_3$ was dissolved in distilled water to make 1 litre of solution and kept in dark bottle.

Potassium chromate (5%):

5 g of K_2CrO_4 was dissolved in 100 ml of distilled water.

Procedure to test chloride:

1. 50 ml of sample was taken in a conical flask and then 5 drops of potassium chromate indicator was added. This give yellow colour to the sample.
2. Titrate with standard nitrate solution until a brick red end point is obtained.

Calculating the chloride:

$$\text{Chloride (mg/litre)} = \frac{\text{ml of titrant used} \times 1000 \times 35.46}{\text{ml of sample}}$$

6. Microbiological examination of water:

For the microbiological examination of water sample, MPN values for total and faecal coliform were determined as per the procedure outlined in WHO Manual (1984). The collected water samples were processed as follows:

The coliform organisms are the most commonly measured indicators of water quality, although experience has shown that they are not completely satisfactory for this purpose. Total coliform are defined as Gram-negative bacteria that ferment lactose at 35 or 37°C, with the production of acid, gas, and aldehyde within 24-48 hours. They are cytochrome oxidase negative and non-spore forming.

Faecal coliform are a subgroup of total coliforms, having the same properties except that they tolerate and grow at the higher temperature of 44-44.5^{o}C, and form indole from tryptophan; organisms processing these combined properties are regarded as presumptive Escherichia coli (E. coli).

Collection of water samples:

One of the key elements in the quality control of drinking water is the microbiological examination of the water. This is affected by analyzing water samples collected from the water supply system. In the collection of such samples following requirements should be satisfied:

a) Sampling should be properly and ideally planned;

b) It should be collected, stored, and dispatched in suitable sterilized bottles;

c) The volume of water collected should be large enough to permit an accurate analysis;

d) The sampling points in the water supply should be selected in such a way that the samples obtained are as representative as possible;

e) Great care should be taken during sampling to prevent contamination of the sample being collected.

Sterilization procedure for sample bottles:

For a sample size of 200 ml, 4 or 5 drops of aqueous sodium thiosulphate solution (100 g/liter) was added to each clean sample bottle.

The stopper was inserted loosely and in order to prevent the entry of dust, a brown paper or aluminium foil cover was tied to the neck of the bottle. The bottle was then sterilized in a hot-air oven for one hour at 170^{0}C, or in an autoclave for 30 minutes at 120^{0}C. In order to prevent the stopper from getting stuck during sterilization, a strip of brown paper (75 x 10 mm) was inserted between the stopper and the neck of the bottle.

Method of water analysis

The following method was adopted for the detection of indicator bacteria in water:

Multiple tube technique (M.T.T.)

In the M.T.T, a series of tubes containing Mac Conkey Broth culture media was inoculated with a test portion of water sample.

Culture media and dilution of water:

For this purpose 40 gram of dehydrated Mc Conkey broth media was dissolved in 500 ml distilled water in order to double strength presumptive medium. The requisite volume of this medium was dispensed into culture tubes and the culture tubes were capped. They were then sterilized in an autoclave at 114^0C for 10 minutes. The sterilized medium was stored at a room temperature.

Procedure:

a) First the paper wrapping from the sample bottle was removed with the stopper in position, the bottle was shaken vigorously to achieve a homogeneous dispersion of bacteria.

b) With a sterile 10 ml pipette, 10 ml of sample was inoculated into each of five tubes containing 10 ml of presumptive broth (double strength). The tubes were incubated at 35^0C or 37^0C for 24 hours. For total coliforms and faecal coliforms at the end of 24 hours incubation period each tube was closely watched for the presence of gas. The positive tubes were tabulated and the negative tubes were reincubated for a further 24 hour period. At the end of this period the tubes were checked again for gas production at the end of either 24 or 48 hours incubation was presumed to be due to the presence of coliforms in the sample. The MPN of coliform is taken from the table (Appendix - II).

7. Analyzing water table:

1. Wire which is wrapped around equipment is unrolled.
2. Wires were placed into the borewell through a small hole, near the motor which is used for lifting the water from borewell.
3. The wire is pushed inside the borewell till the ringing sound is heard.

4. The reading on the wire are noted which shows the availability of water at particular depth. Hence the water table is analyzed (plate - 8).

D). Conducting the Experiments:

The experiments were conducted to know the quantity and quality of existing water available in households, before the onset of monsoon once in each months of April, May and June 2005.

Likewise the household experiments for judging quantity of water was also conducted on controlled group (30 households).

In order to judge the quantity of water available in borewell of selected household, the water table was judged with the help of an equipment called Water Level Indicator (Plate 4).

Step: IV Commissioning of rainwater harvesting system in selected households:

The rooftop rainwater harvesting system was installed by the professional person (plate 11) before the monsoon arrival in the year 2005 (June, 2005) and the cost of complete rainwater harvesting system and its commissioning was borne by the respondents themselves. The system was commissioned to recharge the ground water level through borewell. The detail information about rainwater harvesting system was given in (Appendix-III).

Step V: Household and laboratory experiments for judging the quantity and quality of water after commissioning rainwater harvesting system:

The efficiency of rainwater harvesting system (in terms of quantity and quality) was judged by conducting the same experiments once again as mentioned in step III in the each months of April, May and June, 2006 in 30 households selected for commissioning of rainwater harvesting system.

Likewise, after monsoon for judging quantity of water the household experiment was also be conducted in 30 households without rain water harvesting system.

Each experiment was conducted thrice to get the authentic data.

Step VI : Estimation of roof top rain water harvesting potential:

Rooftop rain water harvesting potential was calculated by using the following standard formula.

Area of terrace	:	Sq. m.
Height of rainfall	:	m
Volume of rainfall over the terrace	:	Area x Height of rainfall
(litres)	:	sq.m. x m.

Assuming that 60.0% of the total rainfall is effectively harvested

Volume of water harvested = Volume of rainfall over the terrace x 0.6

= …….litres

That means (volume of water harvested / 365)…….litres of water per day was available for the household (Kishore, 2004).

3.5 ANALYSIS OF THE DATA:

Phase I : Household survey:

After the collection of data, the information was categorized, responding to the existing source of water and various water management practices, problems faced with regard to availability of water etc. Coding was done on the above categories to determine the code character for responses. Then the coded data was decoded by transforming it from code sheet to comprehensive tables.

Phase II : Laboratory Experiment:

1. **Paired 't' test** was used to test the significance of difference between pre and post test readings of each experiment conducted to judge the quantity and quality of water before and after rain water harvesting. Formula used:

$$|t| = \frac{|\bar{d}|}{S/\sqrt{n}} \sim t_{n-1} \text{ d.f.}$$

$$\bar{d} = \frac{\sum d_i}{n} = \text{Mean difference}$$

$d_i = x_i - y_i$

n = Number of observations

S^2 = Mean sum of difference

$$S^2 = \frac{\sum \left(d_i - \bar{d}\right)^2}{(n-1)}$$

S.E = Standard Error = $\frac{S}{\sqrt{n}}$

Results and Discussion

This chapter presents the results and discussion of the study on **"Rain Water Harvesting in Houses of Udaipur City : A measure to conserve natural resource."** The results of the research conducted have been presented in three sections. The first part highlights the information collected through household survey in urban areas of Udaipur city, while the second determines the status of quantity and quality of harvested rainwater in houses and third part deals with estimation of rooftop rainwater harvesting potential of houses. The results obtained has been arranged and discussed in a systematic manner, keeping the objectives in view under the following headings:

4.1 HOUSEHOLD SURVEY

Section I : General information about respondents.

Section II: Specific information related to existing practices adopted by the homemakers to conserve the quantity and quality of water.

Section III: Popularization of rain water harvesting technique among households.

Section IV: Commissioning of rooftop rainwater harvesting system among selected houses.

4.2 EXPERIMENTS

To judge the quantity and quality of water in terms of:

a). Water table of borewells.

b). Chemical quality of water, from borewells

c). Microbiological quality of water, from borewells

4.3. ESTIMATION OF ROOFTOP RAIN WATER HARVESTING POTENTIAL OF SELECTED HOUSES

4.1 HOUSEHOLD SURVEY:

The information collected through interview and observation schedule with respect to general background and the various water management practices adopted by homemakers are systematically presented in the following tables:

Section I: General information about respondents and households

This section reveals the background details of the respondents. The respondents were studied for their type of family and qualification as they have direct relationship with the consumption of water in a family and conservation practices adopted by them.

Table 4.1 : Type of family

N = 100

S.No.	Type of family	No. of family members	Percentage
1.	Nuclear	2-4	38
		4-6	32
2.	Joint	Above 6	30
	Total	**-**	**100**

The amount of water consumed in households depends on the type and size of family. More the number of family members in joint families compels for increased water consumption as compared to nuclear families. Data in table 4.1 indicates that nearly two-third of the respondents were belonging to nuclear families and the remaining one third were having joint families. Thirty eight percent of families had 2 to 4 members in their household where as 32 & 30 percent families had 4 to 6 and above 6 family members respectively.

Table 4.2 : Educational qualification of respondents

N = 100

S.No.	Educational qualifications	Percentage
1.	Higher secondary	05
2.	Graduate	35
3.	Masters degree	45
4.	Ph.D.	15
	Total	**100**

Table 4.2 depicts that 45 percent of respondents were having masters degree whereas 35 percent of respondents were graduate. Minimum number of respondents i.e. 5 percent were having upto higher secondary qualification and 15 percent of the respondents were qualified upto doctoral level respectively, while collecting the data it was observed that as high educational level increased better were the water conservation technique adopted by the home makers.

Table 4.3: Average water consumption per day by the family

N = 100

S.No.	Water consumption in liters	Percentage
1.	Less than 500	30
2.	500 – 1000	60
3.	Above 1000	10
	Total	**100**

Table 4.3 shows that majority of respondents i.e. 60 percent on an average consume 500-1000 liters of water per day for their common household activities. Minimum number of respondents i.e.10 percent consumes more than 1000 liters of water in a day. Further, it can be concluded that the average consumption of the water per day depends on various factors, such as size of family, size of house, size of garden, number of plants and pots, various activities performed and their frequency, personal hygienic activities and habits, interest and consciousness of each family member in a household.

Section II : Specific information related to practices adopted to conserve the quantity and quality of water:

Water is one of the most important and precise component in human life. Availability of water is essentially required in desired quality and quantity. The sources of water are those from where one gets water for its daily requirements (Vasudevan et al, 2000).

Table 4.4 : Sources of water in households

N = 100

S.No.	Sources	Percentage
1.	Open well	-
2.	Hand pump	5
3.	Municipal water supply	15
4.	Personal borewell	30
5.	Both 3 & 4	45
6.	Any other	5
	Total	**100**

It is clearly seen from table 4.4 and fig. 4.1 that most of the households i.e. 45 percent had more than one source of water supply i.e. personal borewell as well as municipal water supply in their homes. Thirty percent and fifteen percent families either have only personal borewell or municipal water supply respectively to fulfill the need of water for their family. None of the families had openwell in their houses. The most common other sources mentioned by remaining 5% of home makers were private water tankers and community borewells.

Table 4.5 : Availability of sufficient amount of water for general household activities

N = 100

S.No.	Seasons	Adequate	Inadequate	Percentage
1.	Summer	30	70	100
2.	Winter	75	25	100
3.	Mansoon	100	-	100

Table 4.5 reveals that 70 percent of the respondents do not have sufficient amount of water for general household and other domestic activities form the various sources especially in summer. Further, few respondents faced water problem in winter also. In summers the average per capita consumption of water increases resulting into water crises in the family. It can also be observed that during mansoon season the water is available in sufficient amount as stated by all the selected homemakers. While interviewing the respondents it was specifically mentioned by some of them that during rains they collect the water in the buckets and store for shorter period, so the rain water can be used for cleaning purposes. During mansoon season the per capita consumption of water in domestic sector is also decreased. The water scenario of India is in bad shape due to mining operation and its associate activities, much more water than is recharged every year. This results into the deficit amount of under ground water. Hence, our country now needs to be concerned about its ground water.

Table 4.6: Strategies for managing deficit water

N = 100

S.No.	Strategies	Percentage
1.	Through water tankers	40
2.	Borrow from neighbourhood	10
3.	Use water economically	20
4.	Re use the water	10

5.	Recycle the water	-
6.	Both 1 & 3	20
	Total	**100**

It is evident from table 4.6 that majority of families (40) meet their deficit amount of water through water tankers. 20% of the homemakers have mentioned that instead of buying water they use water very economically and manage their household activities with limited amount of water available to them. Similar percentage of family members manages the shortage of water by adopting both the practices that is sometimes purchasing water and use water economically, few examples of such practices enumerated by them were 1). using tumbler for washing face and brushing teeth instead of using running water, 2). taking bath with bucket and mug in the place of using bath tubs and shower, 3). washing clothes with full load of machine with economy wash cycle and washing clothes manually instead of using washing machine 4). using the drip irrigation system for watering the garden instead of use of pipe, are some of the most common economic practices adopted by the homemakers to conserve water, whereas 10% each of families have mentioned that they reuse the waste water for some of the activities and also borrow water from neighborhood who have extra water in their house. The practice of recycling of water was not adopted by any homemaker, as it require a water treatment plant which is not economically feasible to install at individual level. Water treatment plants are commonly installed at industrial and community housing.

Table 4.7.1 : Water based common activities and their frequency of performance in a house

N = 100

S. No	Activities	Daily	Alternate days	weekly	Monthly	Total
1.	Washing of clothes					
	• Undergarments	100	-	-	-	100
	• Outfits	25	45	30	-	100
	• Towels	10	50	40	-	100
		-	-	20	80	100

	• Bed covers • Household furnishings • Any other	- - 	10 - 	30 - 	60 - 	100 -
2.	Washing clothes by • Hand washing • Machine washing	 30 -	 10 20	 - 40	 - -	100
3.	Bathing	100	-	-	-	100
4.	Toilet	100	-	-	-	100
5.	Room cooler	100	-	-	-	100
6.	Cleaning of utensils • By hand • By dish washer	 80 20	 - -	 - -	 - -	100
7.	Cleaning of house • Moping of floor • Washing of porches/chowk	 70 15	 20 60	 10 20	 - 5	 100 100
8.	Watering the garden and pots	30	55	15	-	100
9.	Washing of vehicle	-	20	25	55	100

Table 4.7.2: Responsibility of performance of household activities

N = 100

S. No.	Activities	Self	Servant	Family members	Percentage
1.	Washing of clothes • Undergarments • Outfits • Towels • Bed covers • Household furnishing	 100 60 60 50 80	 - 25 20 50 20	 - 15 20 - -	 100 100 100 100 100

2.	Washing clothes by • Hand washing • Machine washing	 70 20	 - 10	 - -	 100
3.	Cleaning of utensils • By hand • By dish washer	 50 20	 30 -	 - -	 100
4.	Cleaning of house • Mopping of floor • Washing of porches/chowk	 60 60	 40 40	 - -	 100 100
5.	Watering the garden and pots	70	20	10	100
6.	Washing of vehicle	20	30	50	100

The amount of water required by a family is greatly influenced by the number of activities and frequency of performance of a particular activity. More the number of activities with greater frequency results into increased per capita consumption of water.

The most common activities with their frequency of performance by the homemakers in a family in which water is required can be understood easily from the tables 4.7.1. Bathing, washing of under garments, cleaning of utensils and house are certain activities which are performed by all the homemakers daily, while interviewing it was specifically mentioned by the homemakers that when there is scarcity of water specially during summers, certain activities are performed alternately. Moreover, it was also mentioned that those activities which are performed by the servants such as washing of clothes and cleaning of utensils require more amount of water as compared to the activities performed by homemakers themselves or any other member of the family. Further, it was expressed by the home makers that the part time servants performing the activity runs more amount of water as they are always in hurry and performing the activity using water economically takes lot of time. Sometimes it so happens that during the period of water scarcity the work is preferred to be performed by the homemakers themselves

rather than assigning the work to servants which can be confirmed by the data presented in table 4.7.2 that the responsibility of performance of work specially when there is water crises in households lies with the homemakers .Very few families get their work done by servants and other family members except cleaning of vehicles.

Water conservation practices adopted by homemakers:

No single practice of water conservation can be adopted in all the areas of a household. Most of the household areas of activities which needs water are kitchen, bathroom/ washroom, utility area, garden and kitchen gardens. In each area activities are preformed in different ways by consuming water. Hence, the water conservation practices adopted in each area of a house has been studied separately:

1. Kitchen:

Kitchen is the most important area of Indian houses, where lots of activities are done practically from morning 6.00a.m. to 12.00p.m., sometimes the work performed in this area exceeds than this duration. The potable water is also stored in this area. Water is required in each of the activity like cooking, washing vegetables and fruits, cereals, pulses, utensils etc.

Table: 4.8 Practices adopted to conserve the quantity of water in kitchen

N = 100

S. No.	Practices	Responses	Percentage	Total
1.	Attached any device to the taps to reduce water flow	Yes	30	100
		No	70	
2	Turn tap tightly without any dripping	Yes	75	100
		No	25	
3	Tap and faucet repaired promptly, if there is any leakage	Yes	80	100
		No	20	
4	Diverting the flow of wastewater from kitchen to kitchen garden or lawn	Yes	40	100
		No	60	

5	Procedure for washing vegetables, fruits, cereals, pulses and utensils in kitchen	Under running water	45	100
		Washing in a container	55	
6	Reuse of waste water from washing vegetables, fruits, cereals, pulses and utensils in kitchen	Water the plant	45	100
		Do not reuse	45	
		Used for other purpose such as for cleaning, toilet, porches etc.	10	

It is clearly seen from table 4.8 that, most of the homemakers i.e. 70 percent do not attach any flow regulatory device to reduce the water flow, because they did not even have the knowledge that such type of taps and devices are available now a days in the market. Only 30 percent homemakers have mention that they attach small cloth bag or water flow reducer attachment to reduce the water flow in order to minimize the consumption of water. Another common practices of turning the tap tightly without allowing to drip water after use was adopted by 75 percent of homemakers, because they think that leakage in taps can waste several thousand liters of water per year. Likewise, maximum number of respondents i.e. 80 percent were prompt enough to get the taps and faucets repaired immediately, if there is any leakage in and around the faucet.

Further, it is also depicted from the table 4.8 that majority of the respondents i.e.55 percent wash the vegetables, fruits, cereals, pulses and utensils in a container, so that less water is required as compared to washing under running water specially when there is scarcity of water. This is a very good practice that helps in conserving water and they reuse waste water collected in the container for watering the plants. Forty five percent respondents who adopt the practice of washing under running water allows the water to run through drain outlet and remaining 10 percent reuse the waste water from cleaning the utensils for the other purpose such as flushing the toilets and

cleaning of porches. While interviewing the home makers it was also mentioned specifically that water used in washing clothes either by washing machine or manually is collected in buckets and tubs and reused by few homemaker for cleaning purposes.

Table 4.8 also portrays that only 40 percent of respondents divert the flow of wastewater from the kitchen towards kitchen garden or lawn and out of the rest 60 percent, 30 percent respondents do not have kitchen garden or lawn in their house, so they do not adopt this practice and 30 percent have kitchen garden or garden, but they do not reuse the wastewater from kitchen for kitchen garden or garden.

2. Bathroom:

Bathroom is an another place where lot of water is required in activities related to personal health and hygiene. The individual habits in this room very much affects the consumption of water.

Table 4.9.1: Practices adopted to conserve the quantity of water for personal hygiene in bathroom

N = 100

S. No.	Practices	Responses	Percentage	Total
1	While brushing teeth and washing face	Use tumbler	40	100
		Under running water	60	
2	While taking bath	Use bucket and tumbler	80	100
		Use bathtub	5	
		Use shower	10	
		Under running water	5	
3	Install dual cistern (with low & high flush) toilets, to reduce water usage	Yes	38	100
		No	62	

Table 4.9.2 : Practices adopted while using washing machine

N = 70

S. No.	Practices	Responses	Number of respondents	Total
1.	Use the shortest cycle possible for washing clothes in washing machine	Yes	45 (64.28)	70
		No	25 (35.71)	
2.	Setting of adjustable water level indicator to use minimum required water as per the necessity	Yes	45 (64.28)	70
		No	25 (35.71)	
3.	Reuse the drained water from the washing machine	Yes	50 (71.42)	70
		No	20 (28.57)	

Values in parenthesis are percentage

The data presented in table 4.9.1 enumerates that in 60 percent of the families, the members brush their teeth and wash their face under running water and rest of the 40 percent respondents, family members are in practice of using tumbler while brushing teeth and washing face, as they were conscious about conservation of water. A research study conducted by Krishnamurti (2003) reported that by this method i.e. using tumbler while brushing and washing face, conserves about 80 percent of the water as compared to using running water. Eight five percent respondent have the habit of taking bath using bucket and tumbler and only 5 percent use bathtub, whereas 10 percent use shower while taking bath, because they have excess amount of water for domestic and drinking purpose from more than one water source. Practice of bathing under running water (directly from tap) was mentioned by 5 percent of the respondents. Likewise, 62 percent respondents do not installed dual cistern (with low & high flush) flush tanks for toilets, to reduce water usage, and 38 percent respondents reduce water usage. The same study has also reported that by using dual cistern flush tanks for toilets, water can be conserved upto 40-50 percent in flushing the toilets

Further, it is seen from the table 4.9.2 that majority of respondents i.e. 70 percent use washing machine for washing clothes where as 30 percent of respondents do manual washing, because they do not have washing machine or although some have washing machine but they do not have sufficient amount of water to operate

washing machine specially during the period of scarcity of water (summers). Out of 70, only 45 homemakers were in the practice of using the shortest cycle possible and setting of adjustable water level indicator in washing machine, while washing clothes, to consume only minimum required amount of water for cleaning and rest 25 respondents were not aware of these features in washing machine.

Similarly, it is also evident from the table that maximum number of respondents, i.e. 71.42 percent collect the drained water from the washing machine for the purpose of reuse such as cleaning the porches and flushing the toilets. Only 28.57 percent do not reuse the drain water, because they have enough amount of water.

3. Garden and Kitchen garden:

Gardens and kitchen garden needs lot of amount of water during summer, otherwise it is very difficult to maintain them. Because of scarcity of water in many houses the garden, kitchen garden and potted plants get dried. Though there are certain techniques though which water can be conserved and gardens can be maintained with less amount of water .Few of them are explained in the description of table no 4.10.

Table 4.10: Practices adopted to conserve the quantity of water in garden and kitchen garden

N = 80

S. No.	Practices	Responses	Number of respondents	Total
1.	Frequency of watering garden and kitchen garden in summer	Twice a day	4 (5)	80
		Daily	10 (12.5)	
		Alternately	26 (32.5)	
		Once a week	40 (50)	
	Frequency of watering potted plants in summer	Twice a day	8 (10)	80
		Daily	20 (25)	
		Alternately	40 (50)	
		Once a week	12 (15)	

S. No.	Practices	Responses	Number of respondents	Total
2.	Procedure for watering the pots and lawn	Continuous flow through hose pipe	50 (62.5)	80
		Use bucket and tumbler	25 (31.25)	
		Through sprinkler specially for lawns	5 (6.25)	
3.	Water the garden during the cool part of the day preferably in evening	Yes	55 (68.75)	80
		No	25 (31.25)	
4.	Conscious to use water economically while watering the lawn	Yes	50 (62.5)	80
		No	30 (37.5)	
5.	Keep pots under shed during summer	Yes	50 (62.5)	80
		No	30 (37.5)	
6.	Use agro-net in garden to reduce moisture evaporation from garden	Yes	24 (30)	80
		No	56 (70)	

Values in parenthesis are percentage

Eighty percent respondents have either garden or kitchen garden or both in their houses. Half of the respondents water the lawn once a week and the pots are watered alternately in summer, due to the shortage of water in summer. Those homemakers who have delicate grass in the lawns such as Australian grass water their lawn daily as mentioned by 12.5 percent homemakers and only few homemakers, having enough amount of water, water the lawn and pots twice a day in summer and most of the respondents water the pots and lawn by continuous flow through hose pipe and 31.25 percent respondents use bucket and tumbler for watering the pots and lawn. Likewise, most of the respondents water the garden during the cool part of the day preferably in evening as compared to sunny part of the day i.e. late in the morning or afternoon. Very few homemakers, i.e.6.25 percent who have large garden use sprinklers to water their lawns, as they were aware of drip irrigation system which conserves water.

Further, it is also seen from the table that most of the respondents i.e. 62.5 percent were conscious to use water economically, while watering the lawn, they said that they water lawns after every five to seven days, rather than for a short period every day and avoid the sunny part of the day and do not water on windy days – it increases evaporation and there by causes loss of water and they also keep pots under shed during summer, so that they need less water and their greenness is also maintain. Few respondents i.e. 30 percent have the provision of agro net in their garden, in order to reduce evaporation of water from lawn and pots, and majority of respondents that is 70 percent do not have the provision of agro net in their garden, because half of the respondents have no knowledge about agro net.

Practices adopted to preserve the quality of water

Table 4.11 : Storage system for water in the home

N = 100

S.No.	For general household supply of water	Percentage	For potable water	Season	
				Summer	Winter
1.	Overhead water tank	15	Earthen ware	65	10
2.	Underground water tank	25	Stainless steel pot	15	70
3.	Other storage containers	5	Plastic ware	5	10
4.	Both 1 & 2	55	Both 1 & 2	15	10
	Total	**100**	**Total**	**100**	**100**

It is clearly seen from table 4.11 and fig. 4.3, 4.4 that most of the homemakers i.e. 55 percent have both overhead and underground tank for storage of water for general household supply and in summer season maximum of respondents (65%) use earthen ware for storing potable water and during winter season, maximum number of

respondents store water in stainless steel container. The plastic container was used by fewer respondents for storing purified water. The selection of container to store potable water vary from season to season.

Table 4.12 : Frequency of cleaning of water storage units

N = 100

S.No.	Frequency of cleaning potable water container	Percentage	Frequency of cleaning overhead water supply tank	Percentage	Frequency of cleaning under ground water storage tank	Percentage
1.	Twice a day	-	Monthly	25	Monthly	25
2.	Daily	80	Half yearly	60	Half yearly	60
3.	Alternately	20	Yearly	15	Yearly	15
	Total	**100**	**Total**	**100**	**Total**	**100**

Table 4.12 reveals that different homemakers adopt different frequencies for cleaning of water storage tank but one thing is very clear that most of the homemakers clean their water containers every day used for storing potable water. Majority of the homemakers that is 60 percent have mentioned that they clean their overhead water tanks twice in a year that is once just before Diwali and second time after Holi, this practice is adopted since years specially in Hindu families. 25 percent and 15 percent homemakers have mentioned that they clean the storage tank once in a month and yearly respectively. The reasons given behind not cleaning the tank frequently is that it is a very laborious task and some of them are living in apartments, where the contract has been given to the professionals once in a year. Likewise, the same practices are adopted in case of cleaning the underground water tank for storage of water from which water is further lifted to the overhead tanks.

Table 4.13 : Method to purify potable water at home

N = 100

S.No.	Method of purification	Percentage
1.	Boiling	6
2.	Filtering	26
3.	Chemical treatment	-
4.	R.O. system	8
5.	Other water purifier	60
	Total	**100**

It is ascertained from the table 4.13 that most of the homemakers i.e.60 percent use water purifier for water purification and 26 percent respondents use traditional filtration method i.e. use of a fine white cloth. Only few respondents use reverse osmosis system and boiling method for water purification. Boiling is most common among those families where there were young children. Further, it was also mentioned that whenever the purifier is out of order due to non-availability of electricity or any defect in the equipment, boiling method was adopted by the homemakers to purify water at home. It was also mentioned by few homemakers during interview that in emergency sometimes they also purchase the purified water bottles.

Table 4.14: Procedure to refill the potable water container

N=100

S.No.	Procedure	Percentage
1.	Empty the container and refill	40
2.	Fill with the left over water	10
3.	Use the left over water for some other purpose and refill	50
	Total	**100**

The data presented in table 4.14 shows that half of the respondents use the left over water for some other propose such as watering the plants, cleaning of porches

etc. and 40 percent respondents empty the container and refill. Few respondents do not empty the container and fill with the left over water in the container.

Table 4.15 : Practices adopted for drawing water from storage container for drinking and cooking purpose

N = 100

S.No.	Practices	Percentage
1.	Use long handled container	60
2.	Dip the glass inside the water	25
3.	Tap of pot	10
4.	Both 1 & 3	5
	Total	**100**

The practices adopted to draw water from storage container by homemakers interviewed has been presented in the table 4.15. It is evident from the table that 60 percent of the respondents use long handled container to draw water from the storage container for cooking and drinking purposes. 25 percent households dip the glass inside the container to draw water. This practice lead to contamination of water .Remaining 10 percent of respondents take water directly from the tap of pot, which is the most safe method to draw water without any contamination.

Table 4.16: Frequency of cleaning of water purifiers

N=100

S.No.	Frequency of cleaning	Percentage
1.	Weekly	11
2.	Fortnightly	26
3.	Monthly	31
4.	More-than a month	32
	Total	**100**

The technology of water purifier is such that if the purifier is not clean, it automatically stops discharging purified water. The frequency of cleaning of water purifier depands upon number of factors such as the source of water, season and the practice of homemakers. Few homemakers clean the purifier vary frequently to get the personal satisfaction. Table 4.16 reveals that among the home makers higher percentage of respondents i.e. 32 and 31 percent clean the purifier

after one month duration and once in a month respectively. Very few respondents were cleaning purifier weekly .While collecting the data it was found that few home makers have obtained annual maintenance contract from the dealer of water purifier. Hence, whenever the water purifier stops giving its services the salesman is contacted who attends to the complaint and does the complete maintenance of the equipment.

Table 4.17: Water quality problems faced by the homemakers

N = 100

S.No.	Parameters	Percentage
1.	Colour	-
2.	Taste	10
3.	Odour	5
4.	Hardness	60
5.	Both 2 & 4	25
6	Microbial	-
	Total	**100**

It is depicted in the table 4.17 that hardness of water was the most common problem faced by the 65 percent of homemakers and 25 percent homemaker having taste and hardness as the problem of water. None of them have reported the problem of having color in the water. The water seems to be transparent. Similarly all the respondents have mentioned that they can not judge the presence of microbes in the water. Hence, they could not spell out this problem clearly.

Table 4.18: Level of satisfaction from the source of water (both in terms of quantity and quality) in home

N = 100

S.No.	Satisfaction level	Percentage
1.	Fully satisfied	25
2.	Partially satisfied	60

3.	Not satisfied	15
	Total	**100**

Table 4.18 shows that 60 percent of respondent were partially satisfied from the source of water, 25 percent of respondents were fully satisfied and 15 percent respondents were not at all satisfied with the quality and quantity of water available to them. The most common reason for dissatisfaction with regard to quality and quantity of water were mentioned by the selected homemakers are as under:

- Municipal supply of water with low pressure, resulting into scarcity of water.
- Timings of supply of water are irregular and at odd hours.
- Those homemaker having borewells have mentioned that during summers (March –June) the water table goes extremely low and quantity of water available in borewell for household activities is scarce. Homemaker have specifically explained that they have to operate the pump for very limited period (1/2 hour, 1 hour and 1½ hour) and than give break and wait for another 5-6 hours for collection of water in borewell for next supply. This disturbs their daily routine, causes lot of stress and affect their life in summers.
- Some illegal practices adopted by citizens such as using booster in main supply of water and taking extra connections from pipeline are also the causes of dissatisfaction among the homemakers.
- The water received from borewells is very hard, affecting their daily household cleaning, cooking and personal hygiene.
- Water supplied by tankers are sometime of poor quality (hard, dirty and with unwanted smell).
- There is no restriction on the cost of water supplied by water tankers. In case of emergency they charge five times more then the actual cost of water tanker as mentioned by few homemakers.

Table 4.19 : Specifications of households for roof top rainwater harvesting

N = 30

S.No.	Specifications of households	Number of respondents	Total
1.	**Area of the plot** a. 1200 – 2200 sqft b. 2201 – 3200 sqft	20 (66.6) 5	30

	c. 3201 – 4200 sqft	(16) 5 (16)	
2.	**Topography of the house** a. Hilly b. Plane c. Uneven surface	 - 25 (83.3) 5 (16.6)	30
3.	**Roof shape** a. Flat b. Slopping	 22 (73.33) 8 (26.66)	30
4.	**Area of roof** a. 600 – 1200 sqft b. 1201 – 1800 sqft c. 1801 – 2400 sqft	 21 (70) 7 (25) 2 (5)	30
5.	**Diameter of borewell** a. 2 – 4 inches b. 4 – 6 inches	 25 (83.3) 5 (16.6)	30
6.	**Depth of borewell** a. 125 – 225 ft b. 226 – 325 ft c. 326 - 425 ft	 12 (40) 10 (35) 8 (25)	30

Values in parenthesis are percentage

The specifications of households for rooftop rainwater harvesting were observed and measured by the researchers at the time of interviewing the selected 30 households for commissioning the rooftop rainwater harvesting system. The data received is well presented in table 4.19. 66.66 percent selected homemakers were having an approximate area of the plot within the range of 1200 – 2200 sqft whereas only 16 percent of the respondents were having the larger plot size with an approximate area ranging between 2201 – 3200 sqft and 3201 – 4200 sqft respectively.

It was further seen that large number of samples i.e. 83.3 percent had constructed their houses in plain

area and 16.6 percent sample had multi level houses as their site was uneven. Flat and slopping roofs are the two most common types of roofs found in urban areas as observed in 73.33 and 26.66 percent houses respectively. Most of the houses selected as a sample for the present investigation were having an approximate roof area of the 600-1200 sqft and 25 and 5 percent of respondents were having an approx roof area ranging between 1201 – 1800 sqft and 1801 – 2400 sqft respectively. It was observed that 83.3 percent of the houses had borewell of 2-4 inches diameter which is considered to be sufficient for household purposes. Only very few families i.e. 16.6 percent who have big houses with big gardens and kitchen gardens had borewell of 4-6 inches diameter. The range of depth of borewell among the houses selected were varying between 125 – 400 ft. Among these 12 households were having the depth of borewell ranging between 125-225 ft and 10 and 8 households were having their borewells dug upto 226-325 ft to 326-425 ft respectively.

Section III : Popularization of rain water harvesting technique:

To popularized the technique of rooftop rain water harvesting in houses of Udaipur city the researcher had taken the following measure:

1) A CD on rooftop rain water harvesting technique developed by Dr. P.C. Jain (details of C.D. has been given in the chapter of Methodology) was shown to selected 100 homemakers in group as well as a CD was given to each homemaker for their ready reference on rooftop rain water harvesting in homes (appendix no. IV).
2) A folder on importance and type of rain water harvesting technique was developed by the researcher and distributed to selected homemakers (appendix no. V).
3) Homemakers were also taken to the homes where rain water harvesting systems was commissioned and an interview with the users of this technique was arranged.
4) A model on rain water harvesting technique was developed by the researcher and shown to homemaker to understand the complete procedure of this technique and ease in commissioning the system at there residences (plate no. 9).
5) Lots of articles on rain water harvesting technique published for its propagation from time to time by media was also brought to the knowledge of homemakers (appendix no. VI).

Section IV : Commissioning of rooftop rainwater harvesting system among selected houses

Table 4.20 : Status of commissioning of rooftop rain water harvesting system in houses

Status	Sample	Number of households	Duration
Popularizing of rain water harvesting technique	Houses	100	March-April 2005

Commissioning of rain water harvesting system	Houses	60	June 2005-Nov.2005
Selected for conducting experiments	Houses	30	Before monsoon 2005 (June2005)

After popularizing the technique among 100 homemakers, 60 out of them who were partially and not satisfied with the existing water facility available to them were ready to get rooftop rain water harvesting system commissioned immediately in their houses. Remaining 40 homemakers who were fully satisfied with the existing facilities of water in their house were also convenced and wanted to commission this system for better quality and quantity of water. Initially researcher planned to select only 30 houses for the purpose of study, but looking at the enthusiasm of more number of respondents, the water harvesting system was commissioned in all the 60 houses with the help of professional within a period of six months (June 2005 to Nov. 2005). From among these 60 houses 30 houses which were proposed at the time of selection of sample were considered for conducting all the necessary experiments to judge the quality and quantity of water. The rain water harvesting system in these 30 houses was commissioned before arrival of monsoon 2005 (June 2005).

Table 4.21 : Approximate cost of commissioning rain water harvesting system in houses

S.No.	Items	Cost/Unit
1.	PVC Pipe	Rs. 14.50 for 3 inch diameter pipe/ ft. Rs. 28.50 for 4 inch diameter pipe/ft.
2.	Fitter	Rs. 800-1080/filter
3.	Commissioning charges	Rs. 14 for one pipe fitting

The cost to commission the rain water harvesting system varies from house to house depending upon the catchment area of the roof. As the catchment area increases, the length of P.V.C. pipe and size of filter also increases resulting into increased cost. The researcher felt that those homemakers who were not convinced to get this system commissioned in their houses were due to unaffordability, not because of the concept of system itself.

4.2 EXPERIMENTS

To judge the quantity and quality of water in terms of :

A). Water table of borewells:

The quantity of water available in borewells was measured through the water table in the borewell. To judge the availability of water through rain water harvesting system the experiments were conducted before monsoon 2005 and after monsoon 2005 that is in the month of April, May, June (the lean period) of 2005 and 2006.

Table 4.22 : Comparative readings of water table of borewells

Sample house	Parameter	Houses where rain water harvesting system was commissioned N = 30			Houses where rain water harvesting system was not commissioned N = 30		
		Before commissioning rainwater harvesting system **A**	**After commissioning rainwater harvesting system B**	**Difference in water table (A-B)**	**Before monsoon A**	**After monsoon B**	**Difference in water table (A-B)**
01.	Depth of water table in feet	47	40	7	50	47	3
02.		54	50	4	55	50	5
03.		27	25	2	30	25	5
04.		38	25	12	40	38	2
05.		32	30	2	35	30	5
06.		35	20	15	35	35	0
07.		37	25	12	30	25	5
08.		42	40	2	45	40	5
09.		37	32	5	35	32	3
10.		29	21	8	25[2]	20[2]	5
11.		40	28	2	37	35	2
12.		37	30	7	45	42	3
13.		55	50	5	50	45	5
14.		110[1]	60[1]	50[1]	90[1]	75[1]	15[1]
15.		43	30	13	40	40	0
16.		40	25	15	35	30	5
17.		53	25	28	50	45	5
18.		35	20	15	35	30	5
19.		25	15	10	30	28	2
20.		43	25	18	40	35	5
21.		20[2]	15[2]	5	30	28	2
22.		65	28	37	60	55	5
23.		50	30	20	45	42	3
24.		42	25	18	40	38	2
25.		32	15	18	35	32	3

Sample house	Parameter	Houses where rain water harvesting system was commissioned N = 30			Houses where rain water harvesting system was not commissioned N = 30		
		Before commissioning rainwater harvesting system **A**	**After commissioning rainwater harvesting system B**	**Difference in water table (A-B)**	**Before monsoon A**	**After monsoon B**	**Difference in water table (A-B)**
26.		40	25	18	45	43	2
27.		25	15	10	30	28	2
28.		60	35	25	55	50	5
29.		55	25	20	60	55	5
30.		45	20	25	50	50	0
Overall mean value		43	29	14	41	38	3

[1]Highest water table [2]Lowest water table

It can be seen from the table 4.22 and fig. 4.4 that depth of water table before commissioning rainwater harvesting system, was ranging between 20-110 ft. among the selected houses. As this year during the monsoon 2005 there was good rains, with approximate annual rainfall of 882.4 mm in Udaipur, the recharging of borewells after commissioning rain water harvesting system in the selected households was found to be very encouraging with an increase of water table as high as 15-60 ft. The houses where the rainwater harvesting system was not commissioned, the water table in borewell was also increased to some extent due to good rains, but did not increased as per the increase in borewells where the rain water harvesting system was commissioned. So, it can be said that every household must adopt the rain water harvesting technique to increases ground water availability, so that present water demand can be met and water crises can be avoided.

Table 4.23: 't' value for water table

N=30

S. No.	Water table in borewell	Before commissioning rainwater harvesting system	After commissioning rainwater harvesting system	Standard Deviation	Standard Error	't' value

1	House where rain water harvesting system was commissioned	43 ft.	29 ft.	11.024	2.01	7.35**
2	Houses where rainwater harvesting system was not commissioned	**Before monsoon A**	**After monsoon B**	7.98	1.45	2.62*
		41 ft.	38 ft.			

*5 percent level of significance

**1 percent level of significance

The data presented in table 4.21 extrapolates the effectiveness of rain water harvesting system in rising the water table in borewell of selected houses. The t value calculated for rise in water table among those houses where rainwater harvesting system was commissioned shows a significance difference at 1 percent level of significance. Whereas the calculated t values among the house without rain water harvesting system shows the difference in rise of water table at only 5 percent level of significance. Hence, it can be concluded that rain water harvesting system is very effective measure in increasing the quantity of water in borewells as compared to those borewells without having the rain water harvesting system attached to them. Thus rain water harvesting system in homes can solve the water crises at domestic level.

B). Chemical Quality of water, from borewells:

The relationship between drinking water and personal health is well known. Diarrhea is the most common human diseases and there is a very strong connection between this disease and the quality of water consumed by affected persons. Therefore, it is of obvious importance to ensure that drinking water provided to users is of good quality (Rajput, 2001). Suitability of harvested rain water for domestic and

drinking consumption was assessed through data collected to judge the chemical quality of water during the course of present investigation and then were compared with those of BIS (1991) and WHO (1997) standards for safe drinking water.

1. pH (hydrogen ion concentration) level of water:

pH is the logarithm of the reciprocal of the hydrogen ion concentration. It ranges from 0 to 14 scales. pH value of 7 indicates neutral state whereas below this it is acidic and above 7 it is alkaline. The results of experiments conducted to test the pH level of water is shown in following table.

Table 4.24: Comparative readings for the pH level of water received from borewell

N = 30

Sample house	Chemical parameter to judge the quality of water	Before commissioning rainwater harvesting system A	After commissioning rainwater harvesting system B	Difference in pH readings (A-B)	WHO Standards for safe drinking water 1997	Safe drinking water permissible limit BIS:10500 1991
01.		7.9[1]	7.5	0.4		
02.		7.9	7.2	0.7		
03.		7.6	7.0	0.6		
04.		7.6	7.6[1]	0.0		
05.		7.6	7.5	0.1		
06.		7.3	7.1	0.2		
07.		7.4	7.2	0.2		
08.		7.4	7.0	0.4		
09.	pH Value	7.5	7.4	0.1	6.5-7.5	6.5-8.5
10.		7.4	7.0[2]	0.4		
11.		7.1[2]	7.0	0.1		
12.		7.4	7.4	0.0		

Sample house	Chemical parameter to judge the quality of water	Before commissioning rainwater harvesting system A	After commissioning rainwater harvesting system B	Difference in pH readings (A-B)	WHO Standards for safe drinking water 1997	Safe drinking water permissible limit BIS:10500 1991
13.		7.2	7.1	0.1		
14.		7.5	7.4	0.1		
15.		7.5	7.2	0.3		
16.		7.5	7.1	0.4		
17.		7.2	7.0	0.2		
18.		7.4	7.3	0.1		
19.		8.0	7.4	0.6		
20.		7.6	7.4	0.2		
21.		7.6	7.0	0.6		
22.		7.7	7.4	0.3		
23.		7.8	7.3	0.5		
24.	pH value	7.8	7.5	0.3	6.5-7.5	6.5-8.5
25.		7.6	7.0	0.6		
26.		7.5	7.0	0.5		
27.		7.6	7.1	0.5		
28.		7.4	7.2	0.2		
29.		7.5	7.2	0.3		
30.		7.6	7.5	0.1		
Over all mean value		7.53	7.23	0.30		

[2] Lowest pH [1] Highest pH

A direct relation of the pH of drinking water and human health is difficult to determine as the pH of water has not been found to affect human health within the

normal pH ranges available in the drinking water, the pH does not appear to affect human health adversely. As the pH of rainwater can vary with location and roof material and may be aggressive towards concrete, plastic storage cisterns are usually recommended (Vyas et. al., 1996).

It was seen that the pH value ranged between 7.00 to 8.00 which indicates that water quality among the selected samples was almost good as for as pH is concerned. Further it can also be seen that all the water samples of selected borewells were having the pH value within the permissible limit prescribed by BIS 1991, which is 6.5 to 8.5, where as, the limit given by WHO, 1997 ranging from 6.5 to 7.5. All the samples were having higher pH value before harvesting the rainwater indicating that the water is alkaline in nature. Likewise, it can also be said that after harvesting the rainwater all most all the water samples except two were falling under the permissible limit of pH given by WHO.

2. Electrical conductivity of water

It is a measure of current carrying capacity of the water and thus gives a clear idea of soluble salts present in water. Most of the salts in the water are present in the ionic forms capable of conductivity current, therefore, conductivity is a good and rapid measure of the total dissolve solids (Durve et al., 1991).

Table 4.25: Comparative readings for Electrical conductivity of water

N=30

Sample house	**Chemical parameter to judge the quality of water**	Before commissioning rainwater harvesting system **A**	**After commissioning rainwater harvesting system B**	**Difference in EC readings (A-B)**	**WHO Standards for safe drinking water 1997**	**Safe drinking water permissible limit BIS:10500 1991**
01.		.53[1]	.25	0.28		
02.		.40	.30	0.10		
03.		.40	.35	0.05		

Sample house	Chemical parameter to judge the quality of water	Before commissioning rainwater harvesting system A	After commissioning rainwater harvesting system B	Difference in EC readings (A-B)	WHO Standards for safe drinking water 1997	Safe drinking water permissible limit BIS:10500 1991
04.		.32	.20	0.12		
05.		.26	.09	0.17		
06.		.36	.18	0.18		
07.	EC(mS/cm)	.48	.40	0.08	No limit	No limit
08.		.48	.40	0.08		
09.		.46	.42[1]	0.04		
10.		.21	.21	0.0		
11.		.23	.21	0.02		
12.		.33	.32	0.01		
13.		.29	.17	0.12		
14.		.23	.09	0.14		
15.		.24	.20	0.04		
16.		.23	.20	0.03		
17.		.35	.29	0.06		
18.		.21	.20	0.01		
19.		.24	.17	0.07		
20.	EC(mS/cm)	.23	.21	0.02	No limit	No limit
21.		.26	.22	0.04		
22.		.24	.20	0.04		
23.		.19	.15	0.04		
24.		.25	.18	0.07		
25.		.07[2]	.07[2]	0.0		
26.		.14	.12	0.02		
27.		.18	.15	0.03		
28.		.34	.28	0.06		
29.		.27	.20	0.07		

Sample house	Chemical parameter to judge the quality of water	Before commissioning rainwater harvesting system A	After commissioning rainwater harvesting system B	Difference in EC readings (A-B)	WHO Standards for safe drinking water 1997	Safe drinking water permissible limit BIS:10500 1991
30.		.29	.25	0.04		
Over all mean value		.29	.22	0.07		

[2] Lowest EC [1]Highest EC

The tabulated data reveled that overall mean value of electrical conductivity, before commissioning rain water harvesting system was higher (0.29ms/cm) in water than after commissioning rain water harvesting system (0.22ms/cm). The value of electrical conductivity of water ranged between 0.07 – 0.53 ms/cm in before harvesting the rainwater and 0.07 - .42 ms/cm after the harvesting of rainwater.

There was no permissible limit recommended for electrical conductivity either by BIS, 1991 and WHO 1997 as the electrical conductivity of water does not affect the health of human beings.

3. Total Dissolved solids (TDS) of water:

This is important parameter in drinking water. This includes various kinds of minerals present in the water. Organic substance present in the polluted water may also contribute to the total dissolved solids. Total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of calcium, magnesium, sodium, potassium, iron and manganese. Dissolved solids give a particular taste to the water at high concentration and also reduce its palatability (Durve et al, 1991).

Table 4.26: Comparative readings for total dissolved solids of water

N = 30

Sample house	Chemical parameter to judge the quality of water	Before commissioning rainwater harvesting system A	After commissioning rainwater harvesting system B	Difference in TDS readings (A-B)	WHO Standards for safe drinking water 1997	Safe drinking water permissible limit BIS:10500 1991
01.		339.2[1]	160.0	179.2		
02.		256.0	192.0	64		
03.		256.0	224.0	32		
04.		204.8	128.0	76.8		
05.	TDS(mg/l)	166.4	57.6	108.8	1000mg/l	2000 mg/l
06.		230.4	115.2	115.2		
07.		307.2	256.0	51.2		
08.		307.2	256.0	51.2		
09.		294.4	268.8[1]	25.6		
10.		134.4	134.4	0		
11.		147.2	134.4	12.8		
12.		211.2	204.8	6.4		
13.		185.6	108.8	76.8		
14.		147.2	57.6	89.6		
15.		153.6	128.0	25.6		
16.		147.2	128.0	19.2		
17.		224.0	185.6	38.4		
18.		134.4	128.0	6.4		
19.		153.6	108.8	44.8		
20.	TDS (mg/l)	147.6	134.4	12.8	1000mg/l	2000 mg/l

Sample house	Chemical parameter to judge the quality of water	Before commissioning rainwater harvesting system A	After commissioning rainwater harvesting system B	Difference in TDS readings (A-B)	WHO Standards for safe drinking water 1997	Safe drinking water permissible limit BIS:10500 1991
21.		166.4	140.8	25.6		
22.		153.6	128.0	25.6		
23.		121.6	96.0	25.6		
24.		160.0	115.2	44.8		
25.		44.8[2]	44.8[2]	0		
26.		89.6	76.8	12.8		
27.		115.2	96.0	19.2		
28.		217.6	179.2	38.4		
29.		172.8	128.0	44.8		
30.		185.6	160.0	25.6		
Overall mean value		185.8	142.5	43.3		

[2] Lowest TDS [1] Highest TDS

Table 4.26 and fig. 4.5 indicate that the permissible limit prescribed by BIS and WHO is much higher as compared to the total dissolved solids presented in the water of selected samples of borewells. The range of total dissolved solids in water obtained was ranging between 44.8 – 339.2 mg/litre before commissioning rain water harvesting system and 44.8 – 268.8 mg/litre after commissioning rain water harvesting system. Thus it can be said that the harvested rainwater in the borewells help in reducing the total dissolve solids and improves quality of water with better palatability.

4. Hardness of water:

Total hardness in water is the sum of the concentrations of alkaline earth metal cations (e.g., ca^{++} mg^{++}). In most natural from of water nearly all the hardness is due to calcium and magnesium, fifty ppm of total hardness has been considered a boundryline between soft and hard water (Vyas et al., 1996).Table 4.27 shows the results of the experiments on hardness in water.

Table 4.27: Comparative reading for the hardness of water

N=30

Sample house	**Chemical parameter to judge the quality of water**	Before commissioning rainwater harvesting system **A**	**After commissioning rainwater harvesting system B**	**Difference in hardness reading (A-B)**	**WHO Standards for safe drinking water 1997**	**Safe drinking water permissible limit BIS:10500 1991**
01.		580	480	100		
02.		586[1]	440	146		
03.		530	420	110		
04.	Hardness(mg/l)	480	280	200	500 mg/l	600 mg/l
05.		430	260	170		
06.		530	340	190		
07.		514	440	74		
08.		590	460	130		
09.		420	380	40		
10.		450	200	250		
11.		380	300	80		
12.		320	280	40		
13.		500	260	240		
14.		260	240	20		
15.		290	220	70		
16.		520	340	180		
17.		460	420	40		
18.		286	240	46		
19.	Hardness(mg/l)	300	280	20	500mg/l	600mg/l

Sample house	Chemical parameter to judge the quality of water	Before commissioning rainwater harvesting system A	After commissioning rainwater harvesting system B	Difference in hardness reading (A-B)	WHO Standards for safe drinking water 1997	Safe drinking water permissible limit BIS:10500 1991
20.		160[2]	120[2]	40		
21.		240	220	20		
22.		340	300	40		
23.		580	520[1]	60		
24.		490	400	90		
25.		340	220	120		
26.		360	300	60		
27.		366	270	96		
28.		280	220	60		
29.		460	420	40		
30.		480	300	180		
Overall mean value		418.0	319.0	99		

[2] Lowest hardness [1] Highest hardness

The data presented in table 4.27 and fig. 4.6 clearly depicts that the overall mean value of hardness of water sample, was higher i.e. 418.0mg/litre as compared to after commissioning rain water harvesting system i.e. 319.0mg/litre. The value of hardness in water before harvesting ranged between 160-580mg/litre and after harvesting rain water, it was ranging between 120-520mg/litre which was within the permissible limits proposed by BIS.

5. Chloride of water:

Chlorides may be contributed from pollution of organic nature or through slow mineralization processes. The high concentration of chloride is considered to be the indicators of pollution, which is due to organic water of animal origin or industrial effluents (Vyas et al., 1996).

Table 4.28 : Comparative readings for chloride in water

N=30

Sample house	Chemical parameter to judge the quality of water	Before commissioning rainwater harvesting system **A**	After commissioning rainwater harvesting system **B**	Difference in chloride reading **(A-B)**	WHO Standards for safe drinking water 1997	Safe drinking water permissible limit BIS:10500 1991
01.		440.2[1]	205.9	234.3		
02.		362.1	156.2	205.9		
03.		305.3	163.3	142		
04.		333.7	159.5	174.2		
05.		205.9	85.2	120.7		
06.		234.3	184.6	49.7		
07.	Chloride(mg/l)	383.4	184.6	198.8	250mg/lit.	1000mg/lit
08.		390.5	312.4	78.1		
09.		383.4	355.0	28.4		
10.		198.8	184.6	14.2		
11.		255.6	170.4	85.2		
12.		369.2	369.2	0		
13.		397.6	156.2	241.4		
14.		213.0	85.2	127.8		
15.		284.0	184.6	99.4		
16.		241.4	156.2	85.2		
17.		241.4	227.2	14.2		
18.		177.5	156.2	21.3		
19.		241.4	198.8	42.6		
20.	Chloride(mg/l)	312.4	234.3	78.1	250mg/lit.	1000mg/lit
21.		322.3	284.0	38.3		
22.		174.6	156.2[2]	18.4		
23.		262.7	163.3	99.4		
24.		85.2	42.6	42.6		
25.		156.2[2]	99.4	56.8		
26.		170.4	170.4	0		
27.		440.2	374.8[1]	65.4		
28.		291.1	213.0	78.1		

Sample house	Chemical parameter to judge the quality of water	Before commissioning rainwater harvesting system **A**	After commissioning rainwater harvesting system **B**	Difference in chloride reading (A-B)	WHO Standards for safe drinking water 1997	Safe drinking water permissible limit BIS:10500 1991
29.		369.2	234.3	136.9		
30.		284.0	205.9	78.1		
Over all mean value		284.2	195.7	88.5		

[2] Lowest chloride [1] Highest chloride

The data presented in table 4.28 and fig. 4.7 clearly depicts that the overall mean value of chloride, before commissioning rooftop rainwater harvesting system in borewell was higher (284.2mg/litre) as compared to after commissioning rain water harvesting system (195.7mg/litre). The value of chloride in water before harvesting rain water was (85.2 – 440.2mg/litre) and after harvesting rain water, it was reduced (85.2 – 369.2 mg/litre). Hence, it can be concluded that the quality of water as far as the parameter of chloride is concerned was within the permissible limit prescribed by BIS. Whereas as per the limits given by WHO which is 250 mg/litre it can be said that the value of chloride was higher than WHO standards among 5 samples of water from borewells after harvesting rainwater.

C). Microbiological quality of water from borewells:

Faecal coliform and E. Coli, are bacteria whose presence indicates that the water may be contaminated with human and animal waste. Disease causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches or other symptoms. These pathogens may pose a special health risk on infants, young children and people with severely compromised immune systems. It is an indication of the microbiological quality of water and indicates the presence of bacteria in the water sample. Standards require potable water to be completely free from total coliform bacteria (Rajput, 2001).

Thus, it is essential that the water used for drinking purposes is periodically examined for microbiological parameters. It is a safeguard against the possible outbreak of the diseases.

Table 4.29: Comparative readings for total coliform in water

N=30

Sample house	Microbiological parameter to judge the quality of water	Before commissioning rainwater harvesting system A	After commissioning rainwater harvesting system B	Difference in total coliform readings (A-B)	WHO Standards for safe drinking water 1997	Safe drinking water permissible limit BIS:10500 1991
01.		240	109	131		
02.		1609[1]	542[1]	1067		
03.		240	130	110		
04.	Total coliform	175	94	81	10MPN/100ml	10MPN/100ml
05.	(MPN/100ml)	70	22	48		
06.		1609	918	691		
07.		240	141	99		
08.		130	109	21		
09.		4	2	2		
10.		240	94	146		
11.		542	175	367		
12.		7	2	5		
13.		23	22	1		
14.		130	109	21		
15.		2	2	0		
16.		22	9	13		
17.		348	130	218		
18.		49	2	47		
19.		345	2	343		
20.	Total coliform	17	2	15	10MPN/100ml	10MPN/100ml
21.	(MPN/100ml)	109	22	87		
22.		79	12	67		
23.		130	2	128		
24.		141	70	71		
25.		918	79	839		

Sample house	Microbiological parameter to judge the quality of water	Before commissioning rainwater harvesting system **A**	**After commissioning rainwater harvesting system B**	**Difference in total coliform readings (A-B)**	**WHO Standards for safe drinking water 1997**	**Safe drinking water permissible limit BIS:10500 1991**
26.		348	141	207		
27.		172	7	165		
28.		130	109	21		
29.		33	12	21		
30.		2[2]	2[2]	0		
Overall mean value		270.13	102.4	167.7		

[2] Lowest MPN [1]Highest MPN

The data obtained from experiments regarding the total coliform present in water has been arranged in table 4.29 and fig. 4.8 which clearly indicates that the mean reading of total coliform was as low as 2 MPN/100 ml to as high as 1609 MPN/100 ml, before commissioning rooftop rainwater harvesting system and it was as low as 2 MPN/100ml to as high as 542 MPN/100ml after commissioning of rainwater harvesting system. The overall mean value of total coliform in water before harvesting was higher i.e.270.13 MPN/100ml than after harvesting rain water i.e. 102.4 MPN/100ml. According to the drinking water guidelines of BIS and WHO there should not be more than 10 MPN/100ml total coliform in drinking water. Thus, is can be said that the quality of water was very poor with a significantly greater presence of microbes in water which was reduced to a greater extent after rainwater harvesting, but still can not be considered as safe drinking water .

Table 4.30: Comparative readings for Faecal coliform in water

N=30

Sample house	Microbiological parameter to judge the quality of water	Before commissioning rainwater harvesting system **A**	After commissioning rainwater harvesting system **B**	Difference in faecal coliform readings (A-B)	WHO Standards for safe drinking water 1997	Safe drinking water permissible limit BIS:10500 1991
01.		7	2	5		
02.		22	2	20		
03.		17	2	15		
04.		94	2	92		
05.	Faecal coliform	13	2	11	0	0
06.	(MPN/100 ml)	26	2	24	MPN/100 ml	MPN/100 ml
07.		49	2	47		
08.		49	2	47		
09.		2	2	0		
10.		2	2	0		
11.		130	2	128		
12.		2	2	0		
13.		2	2	0		
14.		5	2	3		
15.		2[2]	2[2]	0		
16.		2	2	0		
17.		9	2	7		
18.		13	2	11		
19.	Faecal coliform	49	9	40		
20.	(MPN/100 ml)	130[1]	23[1]	107	0	0
21.		9	2	7	MPN/100 ml	MPN/100ml
22.		5	2	3		
23.		5	2	3		
24.		2	2	0		
25.		2	2	0		
26.		5	2	3		

Sample house	Microbiological parameter to judge the quality of water	Before commissioning rainwater harvesting system **A**	After commissioning rainwater harvesting system **B**	Difference in faecal coliform readings (A-B)	WHO Standards for safe drinking water 1997	Safe drinking water permissible limit BIS:10500 1991
27.		2	2	0		
28.		5	2	3		
29.		2	2	0		
30.		5	2	3		
Over all mean value		22.2	2.93	19.27		

[2] Lowest MPN [1] Highest MPN

Data in the table 4.30 and fig. 4.9 reveals that overall mean value of faecal coliform present in water, before commissioning rooftop rainwater harvesting system (22.2MPN/100ml) was higher as compared to the value found in water sample, after commissioned of rainwater harvesting system (2.93 MPN/100ml). The overall mean value of faecal coliform, after harvesting rain water shows that rainwater harvesting system helped to reduce the faecal coliform in water. The faecal coliform present in water ranged between 2 – 130 MPN/100ml before harvesting rain water and it was reduced after harvesting rain water within the range between 2 – 23 MPN/100ml. The presence of faecal coliform may be due to the bird droppings on the roof, animal and human excreta, in case the borewell is situated near the septic tank or other drain outlet. According to the drinking water guidelines by WHO there should be no faecal coliform in drinking water. This shows that the harvested rainwater maintain the quality of water by bringing down faecal coliform to potable status i.e. 2 MPN/100ml faecal coliform which means closer to 0 (appendix no. II). Thus, it can be concluded that rainwater is free from pollution and purest form of water and collected systematically will surly improves the quality of water by reducing the number of faecal coliform present in borewells.

Table 4.31: 't' value for chemical and microbiological parameter to judge the quality of water

N=30

S. No.	Chemical and microbiological parameter of judge the quality of water	Before commissioning rainwater harvesting system A	After commissioning rainwater harvesting system B	Standard Deviation	Standard Error	't' value
1	pH	7.53	7.23	0.202	0.0369	8.20**
2	Ec (ms/cm)	0.29	0.22	0.062	0.011	5.99**
3	TDS (mg/l)	185.8	142.5	39.53	7.21	6.00**
4	Hardness(mg/l)	418.0	319.0	67.45	12.31	7.99**
5	Chloride (mg/l)	284.2	195.7	68.41	12.49	7.08**
6	Total coliform (MPN/100ml)	270.13	102.4	259.50	47.378	3.54**
7	Faecal coliform (MPN/100ml)	22.2	2.93	33.61	6.136	3.145**

** 1 percent level of significance

The data arranged in table 4.31 gives a comprehensive status of water quality judged before and after commissioning of rain water harvesting system in selected houses. The calculated t value very emphatically narrates that the chemical and microbial quality of water has significantly improved by commissioning rain water harvesting system. All the calculated t values for various parameters of water shows a significance difference in improving the quality of water at 1 percent level of significance.

4.3 ESTIMATION OF ROOFTOP RAINWATER HARVESTING POTENTIAL OF SELECTED HOUSES

The total amount of water that is received in the form of rainfall over an area is called the rainwater endowment of the area. Out of this, the amount that can be effectively harvested is called the water harvesting potential.

Water harvesting potential = Rainfall (mm) x collection efficiency

The collection efficiency accounts for the fact that all the rainwater falling over an area cannot be effectively harvested, because of evaporation, spillage etc. Factors like runoff coefficient and the first-flush wastage are taken into account while estimating the collection efficiency.

This part of the study reveals the rooftop rainwater harvesting potential of the selected households. The catchment area of roof was calculated by multiplying the length of the roof by its width. The most important factor in harvesting water is the amount of rainfall that is received during the year, which is extremely varied in India. Therefore, average yearly rainfall values are used to calculate the rooftop rainwater harvesting potential (Riley, 2002). The average rainfall during the year 2004-2005 was 882.4 mm in Udaipur.

Table 4.32: Average rainwater harvesting potential of selected households in an year-2005

N=30

Sample house	Area of roof (sqft)	Rooftop rainwater harvesting potential (in m^3)	Availability of harvested rainwater per day (in litres)
01.	600	29.49[2]	80[2]
02.	1600	78.66	215
03.	1000	49.16	134
04.	800	39.33	107
05.	1200	58.99	161
06.	1600	78.66	215
07.	1000	49.16	134
08.	1500	73.74	202
09.	1200	58.99	161
10.	800	39.33	107

Sample house	Area of roof (sqft)	Rooftop rainwater harvesting potential (in m^3)	Availability of harvested rainwater per day (in litres)
11.	1800	88.49	242
12.	2000	98.32[1]	269[1]
13.	1200	58.99	161
14.	1600	78.66	215
15.	700	34.41	94
16.	1000	49.16	134
17.	800	39.33	107
18.	1000	49.16	134
19.	1200	58.99	161
20.	600	29.49	80
21.	1000	49.16	134
22.	2000	98.32	269
23.	1500	73.74	202
24.	1600	78.66	215
25.	600	29.49	80
26.	800	39.33	107
27.	1000	49.16	134
28.	1200	58.99	161
29.	800	39.33	107
30.	600	29.49	80
Overall Mean value	1143	56.20	153

[1]Highest potential [1]Highest availability of harvested rainwater per day

[2]Lowest potential [2]Lowest availability of harvested rainwater per day

Table 4.32 shows that the overall mean value of roof top rainwater harvesting potential was 56.20 m^3 in selected houses of Udaipur and the overall mean value for availability of harvested rainwater was 153 litre/day. The variation in rainwater harvesting potential can be attributed mainly to the variation in area of catchment of selected houses. Higher the catchment area more will be the rainwater harvesting

potential. The rain water harvesting potential of selected houses ranged between as low as 29.49 m^3 to as high as 98.32 m^3 with minimum availability of water 80liters/day to maximum availability 269liters/day in Udaipur. These findings are in conformity with the research finding of Goins (2002) where the amount of water that can be captured depends on the size of the catchment areas and the material of the surface.

Thus, it can be concluded that the ground water availability was higher in those households having higher catchment area. Further, it can also be explained that with a greater rainwater harvesting potential the water table of the borewell will also be higher which can also be confirmed with the data presented in table no. 4.22, where the quantity of water in a borewell is more in those households whose catchment area was higher.

Summary and Conclusion

Water is a major important ecological factor and is an essential component for the survival of everybody. Increase in human population, economic growth and a desire for high standards of living will increase the demand for large source of clean water. Water is a renewable source but its availability is limited. Increasing water demands has led to crisis situations in many parts of the world and the amount of water being consumed has exceeded the annual amount of renewal, creating a non-sustainable situation.

Fresh water is an indispensable need to man and there is no substitute for 100 percent pure and clean water. The available water on earth is in a finite quantity that has not changed over millennia. This has to be juxtaposed against increasing demands from a growing population. The population of the world, currently is around 6 billion, which is expected to exceed 8 billion by the year 2050. Apart from sheer numbers, the processes of urbanization and development are also expected to vastly increase the demand for fresh water.

In areas such as Rajasthan where, the availability of water itself is scarce, its degradation through unhygienic habits of the people causes innumerable health problems ranging from diarrhea, dysentery to dreadful diseases like typhoid, cholera etc.

Rainwater is a free source of nearly pure water. It can be used to supply potable (drinking) water and non-potable water. For non-potable uses, like watering landscapes, it is ready for use as it falls from sky. For potable uses, rainwater must be treated to remove or kill disease organisms that may be present. Rainwater is one of the purest source of water available. It’s quality almost always exceeds that of ground or surface water. The potential of rain to meet water demand is tremendous. The concept of rainwater harvesting lies in tapping the rainwater where it falls. The application of an appropriate rainwater harvesting technology can make possible the utilization of rainwater as a valuable and in many cases, necessary water resource.

Rainwater harvesting has been practiced for more than 4,000 years, and in most developing countries is becoming essential owing to the temporal and spatial variability of rainfall. Rainwater harvesting is necessary in areas having significant rainfall but lacking any kind of conventional, centralized government supply system and in areas where good quality fresh surface water or groundwater is lacking. Domestic rooftop rainwater harvesting provides an innovative solution to meet water needs and can be implemented quickly and modularly.

In past 10 years, some extraordinary efforts made by community in India to harvest rainwater has already shown that it not only improves the local ecology but also improves economy. Hence, the present study was undertaken to conserve the abundant water during monsoon, so that it is available during lean season and bring consciousness among the people towards the conservation and management of water for better quality of life through improving our environmental natural resource.

The objectives of the study were:

1. To find out the existing status of water resources in households and various water management practices adopted by homemakers.
2. To popularize and commission rainwater harvesting system in households.
3. To assess the quality and quantity of existing and harvested rainwater in households.
4. To find out the rooftop rainwater harvesting potential in selected houses.

METHODOLOGY:

The present study was conducted in houses of Udaipur city. In order to find out the existing status of water resources, water management practices adopted by the families and to popularize rooftop rainwater harvesting technique, a sample of 100 households were selected. Out of the total 100 samples, based on willingness of the respondents 30 houses were selected purposively for commissioning of the rooftop rainwater harvesting system and estimation of rooftop rainwater harvesting potential.

Further, to judge the effectiveness of rainwater harvesting system commissioned in (only in terms of quantity of water) selected areas, a sample of 30 houses without rainwater harvesting system situated 50 meter away from the house

with rainwater harvesting system in same area were also selected. These houses were considered as controlled group for the study. An interview cum observation schedule was developed to collect the information regarding the existing status of water and their sources in households. Various water management practices adopted by homemakers and various other related aspects to rainwater harvesting technique were also studied.

The study was conducted in following six steps:

STEPS	TITLE
I	Household survey
II	Popularizing the rainwater harvesting technique
III	Household and laboratory experiments for judging the quality and quantity of water before commissioning rain water harvesting system
IV	Commissioning of rainwater harvesting system in selected houses
V	Household and laboratory experiments for judging the quantity and quality of water after commissioning rain water harvesting system
VI	Estimation of rooftop rainwater harvesting potential

Step I : Household survey:

An interview cum observation technique was used to collect the demographic information from the selected households to highlight: family size, educational qualifications, existing status of water in households, various water management practices adopted by the homemakers and various aspects related to the rainwater harvesting technique.

Step II : Popularizing the rainwater harvesting technique:

Rainwater harvesting technique was propagated among all the 100 homemakers through:

- A CD on rooftop rainwater harvesting system in houses (Appendix IV).
- Working model on rooftop rainwater harvesting technique developed by investigator (Plate 9).
- A folder on rooftop rainwater harvesting technique developed by investigator (Appendix V).

Step III : Household and laboratory experiments for judging the quality and quantity of water before commissioning rain water harvesting system:

Household and laboratory experiments were conducted to measure the following parameters in water:

i) Chemical parameters

a. pH
b. TDS
c. EC
d. Hardness
e. Chloride

ii) Microbiological parameters

a. Total coliform
b. Faecal coliform

The water samples were tested for its pH value, electrical conductivity, total dissolve solids, hardness, chloride and microbiological quality by the standardized methods given by American Public Health Association – APHA (1989), Trivedi and Goel (1986) and World Health Organization – WHO (1984).

iii) Water table in borewells

The data on quantity of existing & harvested water available in borewells of households was collected before and after the onset of monsoon once in each month of April, May and June 2005 and 2006.

Likewise the household experiments of judging quantity of water was also conducted on controlled group. In order to judge the quantity of water available in borewell of selected houses, the water table was judged with the help of **Water Level Indicator.**

Step-IV: Commissioning of rainwater harvesting system in selected households:

The rooftop rainwater harvesting system was installed by the professional person before the arrival of monsoon in the year 2005 (June, 2005) and the cost of complete rainwater harvesting system and its commissioning was borne by the

respondents themselves. The detail information about rainwater harvesting system was given in (Appendix III).

Step-V: Household and laboratory experiments for judging the quantity and quality of water after commissioning rain water harvesting system:

The efficiency of rainwater harvesting system (in terms of quantity and quality) was judged by conducting all the experiments once again as mentioned in step III in 30 households selected for commissioning of rainwater harvesting system.

Step – VI: Estimation of roof top rain water harvesting potential:

Rooftop rainwater harvesting potential was calculated by using the standard formula.

Area of terrace	:	Sq. m.
Height of rainfall	:	m
Volume of rainfall over the terrace	:	Area x Height of rainfall
(litres)	:	sq.m. x m.

Assuming that 60.0% of the total rainfall is effectively harvested

Volume of water harvested = Volume of rainfall over the terrace x 0.6 = …….litres

That means (volume of water harvested / 365)…….litres of water per day was available for the household (Kishore, 2004).

Major Findings:

The comprehensive and major findings of the study are presented systematically under the following points.

General information about respondents and households

- Seventy percent respondents were belonging to nuclear families with 2 to 6 members whereas thirty percent respondents were having joint families system having more than 6 family members.
- Maximum number of respondents i.e. 45 percent were holding masters degree where as only 5 percent were having qualification upto higher secondary.

- Data revealed that majority of families i.e.60 percent consume 500-1000 liters of water per day for their routine household activities. Minimum number of respondents i.e. 10 percent use water more than 1000 liters. The quantity of water consumed depends upon various factors such as size of family, size of house, size of garden, number of plants and pots, various activities performed with the frequency, personal hygienic activities and habits, interest and consciousness of each family member in a household.

Specific information related to practices adopted to conserve the quantity and quality of water:

- Out of the total selected sample, 45 percent had more than one source of water supply i.e. personal borewell as well as municipal water supply in their homes. 30 percent and 15 percent families either have only personal borewell or municipal water supply respectively to fulfill the need of water in their family.

- Majority of respondents i.e. 70 percent do not have sufficient amount of water from the various sources especially in summer for general household activities and few respondents faced water problem in winter too. These families meet their deficit amount of water through water tankers. 20 % of the homemakers have mentioned that instead of buying water they use water very economically and manage their household activities with their limited amount of water available to them.

Water conservation practices adopted by homemaker to maintain quantity and quality of water

- About 70 percent of respondents do not attach any flow regulatory device to reduce the water flow. Only 30 percent homemakers have mentioned that they attach small cloth bag or water flow reducer attachment to the tap to reduce the water flow in order to minimize the consumption of water. Likewise, maximum number of respondents i.e. 80 percent were prompt enough to get the taps and faucets repaired immediately if there is any leakage in and around the faucet.

- 55 percent of the respondents wash the vegetables, fruits, cereals, pulses and utensils in a container, and they reuse waste water collected in the container for watering the plants. 45 percent respondents who adopt the practice of washing under running water allows the water to run through drain outlet and remaining 10 percent reuse the waste water from cleaning the utensils for the other purpose such as flushing the toilets and cleaning of porches, when there is water scarcity.

- Data revealed that in 60 percent families the members brush their teeth and wash their face under running water and rest of the 40 percent respondents' family members are in practice of using tumbler while brushing teeth and washing face as they were conscious about conservation of water. 85 percent of respondents have the habit of taking bath using bucket and tumbler whereas 10 percent use shower and 5 percent use bathtub while taking bath.

- 70 percent respondents use washing machine for washing clothes, whereas 30 percent of respondents wash manually. Out of 70, only 45 homemakers were in the practice of using the shortest cycle possible and setting of adjustable water level indicator in washing machine while washing clothes to consume minimum required amount of water for cleaning and rest 25 respondents were not aware of these features in washing machine.

- Out of 100 homemakers, only 80 percent had garden or kitchen garden in their house. Out of 80 percent, half of the respondents water the lawn once a week and the pots alternately in summers due to the shortage of water in summer, at the same time they water the lawn and pots by continuous flow through pipe and 31.25 percent respondents use bucket and tumbler for watering the pots and lawn.

- About 62.5 percent were conscious to use water economically, while watering the lawn, and few respondents i.e. 30 percent also have the provision of agro net in their garden to shade the plants and for reducing the rate of evaporation of water.

- Most of the households i.e. 55 percent have both overhead and underground tank for storage of water for general household water supply and in summer

season maximum of respondents (65%) use eastern ware for storing potable water.

- Sixty percent homemakers use water purifier for purification of water and 26 percent respondents use traditional filtration method i.e. use of a fine white cloth. Only few respondents use reverse osmosis system and boiling method for water purification at home.

- Among the home makers higher percentage of respondents i.e. 32 and 31 percent clean the purifier after one month duration and once in a month respectively. Very few respondents were cleaning purifier weekly.

- Hardness of water was the most common problem faced by 65 percent of homemakers and they were partially satisfied from the source of water.

Specifications of households for rooftop rainwater harvesting

- The average plot size was found to be 1200-2400 sqft and area of roof was measured as 600 - 1200 sqft.

- Flat and slopping were the two most common types of roofs found in urban areas as observed in 73.33 and 26.66 percent houses respectively.

- About 83.3 percent of the houses had borewell of 2-4 inches diameter and few families i.e. 16.6 percent had borewell of 4-6 inches diameter.

- The range of depth of borewell among the houses selected were varying between minimum to maximum i.e.125-425 ft among the selected sample.

Popularization and commission of rainwater harvesting system

- Rooftop rainwater harvesting technique was propagated by the researcher with the help of CD , working model and folder on rain water harvesting system which were developed in easy language with simple figures. A CD and folder were distributed to all the selected samples to keep with them for future use also.

- After popularizing the technique among 100 homemakers, the rooftop rainwater harvesting system was commissioned in 30 selected houses before arrival of monsoon 2005 (June, 2005).

Water table of borewells

- The depth of water level before monsoon 2005, was ranging between 20ft to 110 ft and after commissioning rainwater harvesting system in the selected households, the water table increased up to as high as 15-60 ft. The houses where the rainwater harvesting system was not commissioned, the water table in borewell was also increased to some extent due to good rainfall this year (2005) but did not increased as much as it increased in borewells where the rainwater harvesting system was commissioned.

Chemical and Microbiological Quality of water

- The overall mean value for pH, hardness, chloride, total coliform bacteria and faecal coliform of water sample before commissioning rooftop rainwater harvesting system was higher (pH = 7.53, cl= 284.0 mg/l, TCB = 270.13 MPN/100 ml and FCs=22.2 MPN/100ml) as compared to harvested rain water sample after commissioning rooftop rainwater harvesting system (pH=7.23, cl=195.7mg/l, TCB=102.4 MPN/100ml and FCs=2.93 MPN/100ml).

- The water samples collected from the selected houses, before commissioning rooftop rainwater harvesting system were found to have higher overall mean values for TDS (185.8mg/liter), electrical conductivity (0.29 mS/cm) and hardness (418.0ml/liter) respectively as compared to harvested rainwater sample (TDS=142.5mg/liter, electrical conductivity = 0.22 mS/cm and hardness = 319.0mg/liter).

Rooftop rain water harvesting potential

- The overall mean value of rooftop rainwater harvesting potential was found to be 56.20 m^3 and the average availability of harvested water was 153 liter/day/family. Hence, the amount of water and availability of water per day

for a family depends upon the rainwater harvesting potential i.e. higher the potential more the amount of water available in borewells.

Thus, it can be concluded from the present investigation that water is the most vital resource for the existence of life on earth. It is indispensable for the existence of plant and animal eco-system and forms an essential element in the development of economic activities. The result of the study emphasizes that by commissioning of rooftop rainwater harvesting system one not only can increase the quantity of underground water but also can improve the quality of water which can be easily consumed by the families for drinking, cooking and other household activities.

Appendices

APPENDIX - I

INTERVIEW SCHDULE

Section –A : General Information

1). Name of respondent

2). Age of respondent

3). Education of respondent

4). Occupation of respondent

6). Furnish the information in the following table:

Family	Owner	Tenant
Type of family		
- Joint		
- Nuclear		
Family Size		
-Total		
-Adult		
-Children		

Section – B: Practices adopted to conserve the quantity of water

1. State the source of water in your home?
   a). Open well
   b). Handpump
   c). Municipal water supply
   d). Borewell
   e). Any other
2. Do you have enough amount of water for general household activities from the various source throughout the year?

In Summer	In Winter	In Mansoon
Yes/No	Yes/No	Yes/No

If no, how do you manage the required amount of water resource?

a). Through water tankers

b). Borrow from neighborhood

c). Use water economically

d). Reuse the water

e). Recycle the water

f). Any other

3. List the common activities performed at home in which water is required :

Activities	Daily	Alternately	Once a week	Twice a day
1). Washing of clothes • Undergarment • Outfits • Toawel • Bedcover • Household furnishing • Any other				
2).Washing clothes by • Hand washing • Machine washing				
3).Bathing				
4).Toilet				
5).Room cooler				
6).Cleaning of utensils • by hand • by dish washer				
7).Cleaning of house • Moping of floor • Washing of yard/chowk				
8).Watering the garden and pots				
9).Washing of vehicle				
10).Any other				

4. Mention, which of the following activities are performed by self/servant/family member

Activities	Self	Servant	Family members

1). Washing of clothes • Undergarment • Outfits • Towel • Bedcover • Household furnishing • Any other			
2). Washing clothes by • Hand washing • Machine washing			
3). Cleaning of utensils • By hand • By dish washer			
4). Cleaning of house • Moping of floor • Washing of yard/chowk			
5). Watering the garden and pots			
6). Washing of vehicle			
7). Any other			

5. On an average how much water approximately is consumed by your family daily?

a). Less than 1000 liters

b). 1000-1500 liters

c). 1501-2000 liters

d). 2001-2500 liters

e). 2501 and above

6. Read the following statement pertaining to special areas of house where water is commonly consumed and give the answer:

In Kitchen

1. How many taps do you have in the kitchen?

a). 1

b). 2

c). 3

d). More than 3

2. What are various sources of water in the kitchen and their specific purpose:

Source	Drinking	Cooking	Cleaning
a). Municipal Supply			
b). Bore well			
c). Overhead			
d). Any other			

3. Have you attached any device to the taps to reduce water flow to minimize the consumption of water?

Yes / No

4. Do you always take enough care to turn tape tightly, so they do not drip?

Yes / No

5. Are you prompt enough to get the tap and faucet repaired, if there is any leak in and around.

Yes / No

6. Which of the method do you adopt for washing vegetables, fruits and utensils in the kitchen?

a). Under running water

b). Washing in a container

7. What do you do with the water accumulated after cleaning vegetables, fruits, cereal, pulses and utensils?

a). Throw it to the drain outlet

b). Water the plant

c). Used for other cleaning purpose such as toilet, porches etc.

8. Do you allow turning the wastewater from the kitchen towards kitchen garden or lawn?

Yes / No

9. Apart from the above-mentioned practices, what other practices do you follow in your daily routine to conserve each drop of water in kitchen.

i).

ii).

iii).

In Bathroom

1. How many fixtures do you have in your bathroom?

a). Washbasin

b). Bathtub

c). Bathing taps

d). Shower

e). Toilet

f). Toilet seat with flush tank

g). Any other

2. While brushing your teeth, do you use

a). Tumbler

b). Use running water

3. While taking bath, do you use

a). Bucket and tumbler

b). Use running water

c). Use bathtub

4. While using washing machine, do you use the shortest cycle possible for washing clothes in machine.
   Yes/No

5. If your washing machine has an adjustable water level indicator, do you set the dial to use only as much water as is really necessary?
   Yes / No

6. Do you collect the drain water from the washing machine for the purpose of reuse?
   Yes / No

7. Have you install dual cistern (with low and high flush) toilets, to reduce water usage?
   Yes/ No

8. Do you flush toilet only when it is really necessary?
   Yes/ No

9. Do you regularly check for leaks at the base of your toilet and get them promptly repaired?
   Yes/ No

10. Mention if any other practices adopted by you for conservation of water-

i)

ii)

iii)

In garden and kitchen garden

1. How often you water your lawn and pots in summer?

	Daily	Alternately	Once a week	Twice a day
i). Lawns				
ii). Pots				

2. While watering the pots do you water them by

   a). Continuous flow through pipe

   b). Bucket and tumbler

3. Do you water the garden during the cool part of the day-preferably in the evening?

   Yes/ No

4. While watering the lawn do you use sprinkler to reduce the consumption of water?

   Yes/ No

5. While watering the lawn are you conscious to use water economically?

   Yes/ No

6. During summers do you keep pots under shed?

   Yes/ No

7. In order to reduce evaporation of water from lawn and pots do you have provision of agro-net in the garden?

   Yes/ No

Section –C: <u>Practices adopted to conserve quality of water</u>

1. Which type of storage system for water do you have in your house ?

   a). For general household supply of water

   i). Overhead tank

   ii). Underground tank

   iii). Other storage containers

   iv). Any other

b). For potable water

i). Earth ware

ii). Metal ware

iii). Plastic ware

iv). Any other

2. How often do you clean the –

	Daily	**Monthly**	**Twice a year**
a). Potable water storage containers			
b). General water supply tank			
c). Underground storage tank			

3. Which method do you adopt to purify potable water at home?

a). Boiling

b). Filtering

c). Chemical treatment

d). Water purifier

e). R.O. System

4. When the quantity of potable water in containers is reduced, do you?

a). Empty contents and refill

b). Fill on the top of the left over water

c). Use the left over water for some other purpose and refill

5. How do you draw water from the pot, for drinking and cooking purpose?

a). With the help of glass

b). Long handle lutia

c). Tap of pot

D). Any other

6. How often do you clean the water purifier?

a). Daily

b). Weekly

c). Monthly

7. Do you face any problem in water with special reference to following parameters/

a). Colour

b). Taste

c). Odour

d). Hardness

e). Any other

8. What measure do you take to prevent water pollution?

9. Are you satisfied from the source of water (both in terms of quality and quantity) in your home ?

a). Fully satisfied

b). Partially satisfied

c). Not satisfied

OBSERVATION SCHUDLE

1. Location of plot

2. Constructed area of the plot

3. Topography of the house

hilly/ valley/ plane/ uneven surface

4. Roof shape

5. Area of roof

6. Height of rainfall

7. Diameter of bore well

8. Depth of bore well

9. Water level in bore well before rain

10. Water level in bore well after rain

APPENDIX – II

Most Probable Number (MPN) of coliforms per 100 ml of sample

Implications and

No. of tubes giving positive reaction out of			MPN	No. of tubes giving positive reaction out of			MPN
5 ml of 10 ml	5 ml of 1 ml	5 ml of 0.1 ml		5 ml of 10 ml	5 ml of 1 ml	5 ml of 0.1 ml	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0	0	0	2	4	2	1	26
0	0	1	2	4	3	0	27
0	1	0	2	4	3	1	33
0	2	0	4	4	3	0	34
1	0	0	2	5	0	0	23
1	0	1	4	5	0	1	31
1	1	0	4	5	0	2	43
1	1	1	6	5	1	0	33
1	2	0	6	5	1	1	46
2	0	0	5	5	1	2	63
2	0	1	7	5	2	0	49
2	1	0	7	5	2	1	70
2	1	1	9	5	2	2	94
2	2	0	9	5	3	0	79
2	3	0	12	5	3	1	109
3	0	0	9	5	3	2	141
3	0	1	11	5	3	3	175
3	1	0	11	5	4	0	130
3	1	1	14	5	4	1	172
3	2	0	14	5	4	2	221
3	2	1	17	5	4	3	278
3	3	0	17	5	4	4	345
4	0	0	13	5	5	0	240
4	0	1	17	5	5	1	348
4	1	0	17	5	5	2	542
4	1	1	21	5	5	3	918
4	1	2	26	5	5	4	1609
4	2	0	22	5	5	5	2400

Recommendations

Implication of the study:

1. This study would help the policy planners, architects, homemakers and various housing corporations to build an appropriate dwelling place keeping in mind the slope, shape and construction materials of roof, so that it is suitable for rooftop rainwater harvesting.
2. Findings of the study would enumerate a great deal of help to the homemakers for adopting better household practices for conserving quality and quantity of water.
3. The most significant implication of this study is that its findings explicitly revealed the need for creating awareness among people on rooftop rainwater harvesting system of residential buildings.
4. The results facilitate the homemakers to improve their various water management practices at domestic level.
5. Study is useful in creating awareness about the quality and quantity of harvested rainwater.
6. The results of the study will help homemakers to understand that, compared to other conventional sources of water, water collected through rainwater harvesting system will be of better quality and quantity.
7. This research study will be a very good resource material for both faculty and students of College of Home Science to know in detail about the reasons, importance and methods to an hence the level of water table in homes.

Recommendations of the study :

The following recommendations can be taken up for further study on rainwater harvesting and its different aspects :

1. A similar study can be planned for assessing rainwater harvesting technique in the following institutions:

* Hostels	* Institutions	* Industries
* Hotels	* Schools	* Hospitals

2. Similar type of study can be conducted on both direct and indirect types of rainwater harvesting technique.
3. Water harvesting, effective water management and water quality improving technologies can be popularized in rural areas to conserve water.
4. Research can be conducted to study the role of government in conserving water in rural areas.
5. The impact of various water management practices on water conservation can also be tested through similar type of research study.
6. Rainwater harvesting in rural homes can be studied.
7. Laboratory research can be conducted to find out the water chemical and physical qualities in harvested rainwater.
8. An impact assessment study on rainwater harvesting technique adopted by homemakers to conserve natural resource can also be conducted.

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